International
Whaling
Commission

Gillnets and Cetaceans

INCORPORATING THE PROCEEDINGS OF THE SYMPOSIUM AND WORKSHOP ON THE MORTALITY OF CETACEANS IN PASSIVE FISHING NETS AND TRAPS

EDITED BY

William F. Perrin
Southwest Fisheries Science Center
National Marine Fisheries Service, NOAA
PO Box 271, La Jolla, California 92038, USA

Gregory P. Donovan
International Whaling Commission
The Red House, Station Road, Histon
Cambridge CB4 4NP, UK

and

Jay Barlow
Southwest Fisheries Science Center
National Marine Fisheries Service, NOAA
PO Box 271, La Jolla, California 92038, USA

Series Editor
Gregory P. Donovan

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The Red House, Station Road, Histon, Cambridge CB4 4NP

Preface

This volume represents the culmination of over four years work, beginning with the organisation of a Symposium and Workshop held in La Jolla in 1990. It includes the report of that Workshop, the IWC Scientific Committee's report on stocks of small cetaceans that are subjected to 'significant' directed and incidental takes submitted to the 1992 UNCED and over 50 papers either presented to the Workshop, subsequent IWC Scientific Committee meetings or requested to address important relevant issues not covered by the presented papers. The papers herein represent the most complete and current account of a problem that probably represents the most serious threat to cetaceans today. Unfortunately, despite some progress in documenting the problems, we are still a long way from arriving at solutions for many regions and fisheries around the world. I hope that publication of this book stimulates Governments to address the issues highlighted here in a prompt and determined manner. This will involve: encouraging research in the wide range of disciplines necessary, including cetacean biology, fish biology, population dynamics, management science, and fishing gear technology; and, not least, the participation of fishermen in the process.

G.P. DONOVAN
Series Editor

Cover photograph
Gray whale (*Eschrichtius robustus*) entangled in gillnet, California.
Courtesy of Steve Leatherwood.

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Eds G. P. Donovan, C. H. Lockyer and A. R. Martin.
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Introduction

The International Whaling Commission's Scientific Committee first recognised the potential threat to cetacean populations posed by incidental kills in fisheries in 1972, when it

> 'discussed and expressed concern over the large incidental kill of porpoises and dolphins in the US tuna fishery, reported to be about 250,000 per year' (IWC, 1973, p.37).

In that same year, the Committee recommended that a sub-committee on small cetaceans be established, to improve data collection on world catches and to review species and stock identification and other problems; much of the subsequent review and scientific discussion in the Committee of incidental fishery kills and their impact has taken place in this sub-committee. The founding chairman of the sub-committee was Edward Mitchell, who deserves great credit for bringing the related issues of small cetaceans and incidental kills (of cetaceans both large and small) to the fore in the Committee and the Commission.

In 1972 the Committee also recommended that member nations

> 'engaged in killing small cetaceans provide information on their controls on these operations and also include information on catch and incidental kills in future progress reports' (IWC, 1973, p.42).

The Commission formally implemented this recommendation in 1976 (IWC, 1977, p.26) and information on incidental kills and associated research began to appear in national progress reports that year (e.g. Anonymous, 1977).

The sub-committee on small cetaceans met for the first time in Montreal in 1974 and conducted a comprehensive review across species, regions, fisheries and problems (Mitchell, 1975). It emerged that cetaceans of many species were being killed incidentally in gillnets, including Dall's porpoises, pilot whales and Baird's beaked whales, all also taken in commercial directed fisheries. The major net fisheries involved were the salmon driftnet fisheries of the North Pacific and North Atlantic, shark gillnet fisheries in several regions and coastal gillnet fisheries in South America. Thousands of Dall's porpoises were being killed in the Japanese salmon driftnet fishery alone (Ohsumi, 1975). The sub-committee recommended that further statistics on these and other kills be collected.

The FAO ACMRR Working Party on Marine Mammals conducted a large international consultation in Bergen, Norway in 1976 (Anonymous, 1978). In their conclusions, they stressed the potential importance of incidental kills and the need to document the distribution of gillnet fisheries relative to that of cetaceans, the extent of the mortality and the impact of this mortality on cetacean populations. They suggested that research on behaviour, particularly with respect to feeding and echolocation, be undertaken with the goal of modifying fishing gear or practices to reduce entanglements.

The conference that formed the basis for the present volume had its beginnings in 1984, when the sub-committee on small cetaceans proposed that an expanded session of the sub-committee should be convened in 1985 to review new and expanding gillnet fisheries that have or may have an impact on small cetacean poulations, with invitations to be extended to outside experts on gillnet fisheries and gillnet fishing gear (IWC, 1985, p.137). Because of budgetary limitations, the review did not occur in 1985, but a workshop separate from the annual IWC meeting and expanded to include the large whales (specifically gray, humpback and right whales) was proposed by the Committee for late 1986 (IWC, 1986, p.37). The Committee stressed that the meeting's scope should be limited to scientific and technical matters related to cetacean entanglement in gillnets. The participation of a behaviourist, a sensory physiologist, a fisheries development officer and a gear expert were to be encouraged. Funds for the meeting were to be sought outside the Commission. Funds were not found and the meeting did not materialise in 1986.

The meeting was subsequently included in the 1988–1992 action plan of the IUCN Cetacean Specialist Group (Perrin, 1988) and an offer to host the meeting was extended to the Commission by the Southwest Fisheries Science Center in La Jolla, California (IWC, 1988, p.123). The invitation was accepted, and in 1988 a Steering Group was established consisting of W.F. Perrin (convener), R.L. Brownell Jr., L. Jones, D.P. DeMaster, J.S. Leatherwood and J. Barlow (IWC, 1989, p.62). The scope of the meeting was extended to include a symposium of contributed papers and consideration of incidental kill in traps and other passive fishing gear, and terms of reference were drawn up (Perrin and Brownell, 1989). The Commission approved the terms of reference but again postponed the meeting because of budgetary constraints. Meanwhile, additional reports of kills in gillnet, driftnet and trap fisheries surfaced: sperm whales, humpbacks, minke whales, gray whales, right whales and many species of small cetaceans in fisheries in the Mediterranean, at the Azores, off California, in the Baltic, in the Northwest Atlantic, off the Pacific coasts of Canada and Alaska, in Japanese waters and in other regions (Perrin, 1990).

In 1989, partial funding was offered by World Wildlife Fund – Sweden. Promises of support soon followed from the United Nations Environmental Programme, the New Zealand Department of Conservation, the US Marine Mammal Commission, the Australian Fisheries Service, the US National Oceanic and Atmospheric Administration, the Southwest Fisheries Science Center and World Wildlife Fund – USA; and the Conference was set for October 1990 in La Jolla. The support provided by these agencies and NGOs was also sufficient to pay over half of the publication costs of this volume.

The Report of the Workshop was presented to the Scientific Committee and the Commission in 1991. It then became publicly available and was circulated to relevant member and non-member nations of the IWC. Partly in response to the need for the meeting and its subsequent report, the Commission passed two Resolutions requesting the Scientific Committee to draw together available information on the status of those stocks of small cetaceans that are subjected to 'significant' directed and incidental takes (IWC, 1991) and to forward that information to the 1992 United Nations Conference on Environment and Development (IWC, 1992).

We have decided to include both the Report of the Workshop and the Report to UNCED in this volume because the latter places the threat posed by incidental mortality in passive fishing gear into the context of overall threats to small cetaceans throughout the world.

The production of this extensive volume has been a major task. For a number of reasons, including communication with authors and reviewers from every continent (except Antarctica) and a full publication schedule for IWC volumes, production has taken longer than we originally anticipated. For this reason we have taken the opportunity to:

(1) encourage authors to update their papers to include data and information from after the 1991 IWC meeting when the report first became publicly available;
(2) include papers that originated in part in response to recommendations made in the Report of the Workshop.

Although this resulted in a slight additional delay to the volume, we believe that this has been worthwhile in that the included papers now represent the most complete and current account of the worldwide situation of a problem that probably represents the most serious threat to cetaceans today – some of the papers include data collected as recently as October 1994.

The contributed papers published in this volume each received at least two anonymous peer reviews. Some of the symposium and workshop papers are not included here because they were not submitted for publication (for various reasons, such as publication elsewhere) or did not pass peer review. Abstracts are included for those papers not published.

Many people made the conference and this volume possible. In particular we would like to thank those scientists who gave up their time to review papers in the volume, including: A. Aguilar, D. Ainley, W. Au, D. Aurioles-Gamboa, F. Awbrey, R. Baird, N. Bartoo, H. Benke, P. Berggren, P. Boveng, R.L. Brownell, Jr., J. Calambokidis, M. Cawthorn, I. Christensen, P. Clapham, V. Cockcroft, J.M. Coe, A. Collet, E.A. Crespo, S. Dawson, A. Di Natale, T. Gerrodette, D. Goodson, P. Hammond, D. Hanan, M-P. Heide Jørgensen, J.E. Heyning, A.A. Hohn, T. Jefferson, L. Jones, T. Kasuya, P. Kleiber, S. Kraus, F. Larsen, J.S. Leatherwood, C. Lockyer, J. Maigret, A. Martin, M.K. Marx, N. Miyazaki, K.S. Norris, G. Notarbartolo-di-Sciara, M. Pawson, M.C. Pinedo, T. Polacheck, L. Popov, R. Praderi, J. Prado, A. Read, R.R. Reeves, G.J.B. Ross, C. Smeenk, T.D. Smith, B. Taylor, A.M. Teixeira, P. Tyack, O. Vidal, G. Waring, W. Watkins, H. Whitehead, B. Würsig and K. Wynne. S. Smith and C. Blair assisted with the initial editing of some of the papers at the Southwest Fisheries Science Center. Special thanks must go to: Helen Coulson who keeps track of the manuscripts and who prepares and types in many of the revised manuscripts; Stella Duff for proof reading; Julie Creek who typesets all the tables; Helen Richardson who prepares the artwork and helps with the proof reading; and the staff of Black Bear Press. Those who helped find and shepherd funds for the meeting included J.R. Twiss, G. Anderson, R. Gambell, A.T. Brough, S.J. Holt, M. Harvey, M. Sutton, M.F. Donoghue, I. Barrett, and T. Arnbom. D.P. DeMaster, J. Sisson, J. Kashiwada, J. Ortiz, B. Remington and C. Ratcliffe assisted with the organisation and logistics of the meeting. We thank all of these people and anyone we may have inadvertently missed.

The papers in this volume reveal that some progress has been made towards addressing some of the recommendations coming out of the Conference. We hope that publication here will stimulate scientists, managers and Governments to greater efforts to further address and resolve this most important issue.

W.F. Perrin, G.P. Donovan and *J. Barlow*
Cambridge, 16 November 1994

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Report of the Workshop on Mortality of Cetaceans in Passive Fishing Nets and Traps

The Workshop was held in La Jolla, California, USA from 22 to 25 October 1990. Plenary sessions were held in the La Jolla Village Inn and sub-groups met at the Southwest Fisheries Science Center. A list of participants is given in Annex A. Perrin convened and chaired the Workshop.

1. WELCOME AND INTRODUCTION

Gambell outlined the background to the Workshop and stressed the importance of its findings, which would not only provide advice to member governments of the IWC but would also form a major part of the IWC's contribution to UN deliberations on the impacts of driftnetting (IWC, 1991a).

2. TERMS OF REFERENCE AND ADOPTION OF AGENDA

The Scientific Committee adopted terms of reference for the Workshop at its annual meeting in 1988 (Perrin and Brownell, 1989). It was stressed by the Committee that the meeting's scope should be limited to scientific and other technical matters related to cetacean entanglement in gillnets and other static fishing gear. The main charges were:
(1) to identify and describe new and expanding net and trap fisheries which take cetaceans;
(2) to investigate how and why entanglement occurs;
(3) to the extent possible, to estimate mortality and assess its impact on cetacean populations; and
(4) to consider possible ways of reducing levels of net-caused mortality.

The resultant report was to include:
(1) a list and summary descriptions of gillnet and trap fisheries that take or potentially could take cetaceans, with lists of the species involved;
(2) a species-by-species summary, listing cetacean takes by population and fishery and assessing the impacts of the takes;
(3) an analysis of the causes of entanglement and assessment of technology and alternatives for reducing the incidental takes; and
(4) recommendations for (a) documentation of takes, (b) research to develop methods for reducing takes and (c) management actions.

Invited and selected unsolicited papers were presented at a two-day open symposium immediately preceding the Workshop. Abstracts of the symposium papers are available from the Secretariat. Working papers for the Workshop are listed in Annex B.

The Agenda adopted is given as Annex C.

3. ARRANGEMENTS FOR THE MEETING

Donovan served as rapporteur for the plenary sessions.

The Workshop agreed to form three sub-groups (see Annex A) assigned the tasks of: conducting a global review of fisheries; assessing impacts; and reviewing causes and solutions. The Workshop agreed to reconvene in a plenary session on the last day, to review the reports of the sub-groups and reach agreement on conclusions and recommendations. It was agreed that the sub-group reports would form the body of the Workshop report. The sub-groups met at the Southwest Fisheries Science Center the afternoon of 22 October and all day on 23 and 24 October. Compilation of the final report was co-ordinated by Donovan and Perrin and agreed by the participants by post.

The report was submitted to the full Scientific Committee at its 1991 Annual Meeting. The Committee approved the Report and its Recommendations (IWC, 1992, p.53) after which the Report became publicly available and was circulated to relevant Governments and organisations. As this is an agreed report it has been left unaltered. Developments since its adoption by the IWC in 1991 are discussed by Donovan (this volume, pp.609–614) and in many of the published papers.

4. GLOBAL REVIEW OF GILLNET AND TRAP FISHERIES

Perrin chaired the sub-group conducting a global review of passive net and trap fisheries which take marine mammals. Barlow, Northridge and Read served as rapporteurs, and Sisson assisted with preparation of this section of the workshop report.

In addition to the terms of reference given above to identify and describe new and expanding net and trap fisheries which take marine mammals, the sub-group further agreed to provide quantitative estimates of cetacean and other marine mammal mortality where available. In the discussions of the sub-group, the world's oceans were divided into 21 coastal regions and 5 major ocean basins. The discussions and conclusions are summarised below. The sub-group agreed on the most important items to include in the summaries.

Most of the information is taken from the regional review documents, although some is from responses to a questionnaire circulated by Lien to national fishery agencies before the meeting or from other personal communications to members of the group. Where necessary, additional information from the literature and from unpublished sources was added during the editing of the report, but time did not allow an exhaustive review of the very large 'grey' fishery literature. Unless otherwise noted, fish landings are in metric tonnes and their values are based on the price paid to fishermen, converted to US dollars. Effort is expressed as kilometres of net per day (KND). Common names are used throughout the Report. Latin names are given in Annex G.

4.1 Mediterranean region

The Mediterranean and Black Seas are bordered by 28 countries: Albania, Algeria, Bulgaria, Cyprus, Egypt, France (Mediterranean coast and Corsica), Gibraltar, Greece, Israel, Italy, Lebanon, Libya, Malta, Monaco, Morocco, Rumania, Spain, Syria, Tunisia, Turkey, the former USSR (now Russian Federation, Ukraine and Georgia) and the former Yugoslavia (now Slovenia, Croatia, Serbia, Bosnia Herzegovina and Montenegro). Available fishery information varies considerably among these. Passive net fisheries in this region are of four basic types: a trap net fishery for tuna in shallow coastal waters; a drift gillnet fishery for small pelagic fish; a pelagic driftnet fishery for swordfish and tuna; and a coastal set net fishery. Significant marine mammal mortality is primarily limited to the pelagic driftnet fishery. Summaries of these four fisheries are given below. Additional information on Black Sea fisheries may be available in older FAO reports not consulted at the meeting. Detailed information on the Mediterranean is given by di Natale and Notarbartolo-di-Sciara (SC/O90/G34).

4.1.1 Trap net fishery for tuna

Trap nets for bluefin tuna are found in coastal waters in several localised areas of the Mediterranean. These anchored nets are made of natural or artificial fibres. The effort is not well quantified, but there are believed to be more than 10 traps and less than 1,000 participating fishermen. The fishery is believed to be stable in size. Fishing occurs approximately 60 days per year. Catches are greater than 1,000 tonnes for bluefin tuna and greater than 50 tonnes for swordfish; the value of these catches is approximately $4m and $0.7m, respectively. Ranges of annual cetacean catches are 0–1 minke whales, 0–1 killer whales, 0–5 bottlenose dolphins and 0–1 common dolphins.

4.1.2 Drift gillnet fishery for small pelagic fish

This fishery is found in coastal waters around the Mediterranean basin. Target species include bullet tuna, little tuna, skipjack tuna, Atlantic bonito, chub mackerel and Atlantic mackerel. Typically nets are multifilament nylon or monofilament with mesh sizes of 4–9cm and lengths of 0.2–1.5km. Vessels range from 4–14m. There are about 100–1,000 vessels and 250–3,000 fishermen operating in this fishery. The fishing season is not known, but is likely to range from 10–100 days per year. Based on this, estimates of 100–1,000 nets and a mean net length of 850m, total effort is likely to be between 850–85,000KND per year. Ranges of annual cetacean catches are 1–10 Risso's dolphins, 10–50 bottlenose dolphins, 0–2 common dolphins and 0–5 striped dolphins.

4.1.3 Drift gillnet fishery for swordfish and albacore

Vessels are from Italy, Spain, Morocco, France, Greece, Turkey, Malta and Algeria. Some countries fish in localised areas and others cover the entire Mediterranean. Multifilament nylon nets for swordfish have 36–52cm mesh and are 2–40km length, with a typical length of 12–15km. Similar nets are used for albacore, with a mesh size of 16–20cm and a total length of 9–15km. Vessels are approximately 7–26m long. The number of vessels rapidly increased to over 1,020 by July 1990. After an offshore drift gillnetting ban by Italy, this number dropped to 120 vessels in August 1990. Approximately 4,000 people fished prior to the ban and approximately 300 after the ban. Based on a mean net length of 12.6km, 1,020 vessels and a fishing season of 57 days, the total effort would have been approximately 750,000KND prior to the Italian ban. The most recent annual landings were about 9,000 tonnes for swordfish and 1,500 tonnes for albacore and were worth $130m and $8m, respectively. Prior to the Italian ban, annual catches of cetaceans were 0–1 fin, 0–1 minke, sperm 20–30, Cuvier's beaked <10 and long-finned pilot whales 50–150, and Risso's 30–80, bottlenose 50–200, striped 5,000–10,000, common 1–30 and rough-toothed dolphins 0–10. These estimates were based on specimens stranded on Italian beaches showing evidence of net entanglement. Di Natale reported that R. Ktari-Chakroun obtained observations of four of a group of 10 minke whales off North Africa entangled in driftnets.

4.1.4 Coastal set gillnet fisheries

This fishery is found all around the Mediterranean over coastal shelf regions. Target species include benthic fish, lobsters and small pelagic schooling fish. Vessels are small, typically 4–16m in length. There are approximately 50,000–100,000 such vessels fishing in the Mediterranean and approximately twice that number of fishermen. There are no data on fishing effort or the economic value of the fishery. It is thought that the fishery may be increasing moderately. Likely annual ranges of marine mammal mortality are 0–2 minke whales, 0–1 sperm whales, 1–10 Risso's dolphins, 0–5 common dolphins, 50–200 bottlenose dolphins, 1–20 striped dolphins, 0–1 rough-toothed dolphins and 0–5 Mediterranean monk seals.

4.1.5 Recommendations

(1) It is **recommended** that actions similar to the ban instituted by Italy are encouraged elsewhere. International co-operation and action by the General Council for Mediterranean Fisheries (CGPM) are required to ensure that large scale driftnet fisheries do not restart from other nations, or that reflagging for the purpose of continuing the fishery does not occur.
(2) There is little information on set gillnet and small pelagic driftnet fisheries in the Mediterranean. It is therefore **recommended** that further efforts be made to investigate the nature and extent of these fisheries and their impacts on marine mammals of the region.
(3) The action of Italy in banning driftnets has had an immediate impact on several thousand fishermen. It is **recommended** that wherever possible the consequences of such actions are studied, the economic impacts on the fishing community are appraised and the subsequent development of alternative fishing methods are monitored.
(4) It is **recommended** that information on gillnet and trap fisheries be collected for the Black Sea, including information on incidental catches of small cetaceans.

4.2 Baltic region

This region is taken to include what are commonly referred to as the Baltic and Kattegat Seas. Coastal states include Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Sweden and the Russian Federation. In this region, cetaceans are commonly found only in the Kattegat and the only common species is the harbour porpoise.

Cetacean mortality presently occurs mostly in bottom set net fisheries and pound-net fisheries. Both are described below, along with a pelagic driftnet fishery in the central Baltic. Burkanov reported that information also exists on fisheries and their bycatch of seals in Latvia, Lithuania, Estonia and the western USSR. Detailed information is given by Kinze (SC/O90/G25). Estimates of total cetacean mortality do not exist.

4.2.1 Coastal set gillnet fishery
Vessels from Denmark, Sweden and Germany participate in a bottom set net fishery for cod and (secondarily) plaice. Vessels are typically 5–20m long. Gillnets are typically 6–17cm in mesh size and are set in water depths of less than 40m; mean net lengths were not available at the meeting. The number of vessels fishing by this method is 750 for Denmark and 565 for Germany; the number for Sweden is not known. The amount of fishing effort for Denmark is stable or decreasing slightly. Harbour porpoise mortality is largely limited to the Kattegat Sea and is probably less than 500 animals per year. Harbour seal mortality is limited to the Kattegat and the southern Baltic; no estimates of seal mortality are available.

4.2.2 Pound-net fishery for eels
A small-scale pound-net fishery for eels is found along the eastern coast of Denmark. These nets are in shallow waters of less than 15m depth. Little information is available on the level of effort in this fishery, but effort is believed to have been decreasing in recent years. Harbour porpoises are occasionally captured in these traps, but are usually released alive.

4.2.3 Pelagic driftnet fisheries
Pelagic drift gillnets are used in the central Baltic by fishermen from Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Sweden and the Russian Federation. No details about this fishery were presented at the meeting. Nets are likely to take harbour, ringed and gray seals. Harbour porpoise mortality is likely to be uncommon because the species is very rare in the area of the fishery. This fishery mortality may, however, be sufficient to affect harbour porpoise recovery in the Baltic.

4.2.4 Recommendations
(1) It is **recommended** that captures of marine mammals in Baltic fisheries be monitored at an international level, as it is likely that a single harbour porpoise population is being impacted by the fisheries of several nations in this area.
(2) In this connection it is **recommended** that further research be carried out to improve understanding of harbour porpoise stock identities in the Baltic and North Seas.

4.3 Eastern North Atlantic region
Thirteen coastal states are included in the eastern North Atlantic region, including Belgium, Denmark (west coast), the Faroe Islands, France (north coast), Germany (North Sea coast), Iceland, Ireland, Netherlands, Norway, Portugal, Spain (Atlantic coast), United Kingdom and the Russian Federation (western Arctic). There is a long tradition of fishing in this entire area and much large- and small-scale fishing occurs there. In Norwegian coastal waters, set gillnets are used for migrating cod and drift gillnets for salmon. Although gillnets are used in Iceland, no information was available during the meeting. Detailed information is given by Northridge (SC/O90/G35) and Sequeira *et al.* (SC/O90/G47).

4.3.1 Portuguese gillnet fisheries
Around 3,300 Portuguese vessels are licensed to use gillnets for hake, other gadoids and demersal species along the Portuguese continental shelf. The mean length of nets and type of netting material varies considerably among vessels. Incidental catches of some tens of cetaceans, mainly common dolphins, harbour porpoises, striped dolphins and possibly bottlenose dolphins, are recorded.

4.3.2 Portuguese trap fisheries
Over 1,300 vessels are licensed to fish for octopus, crustaceans and some fish with basket traps and pots. There are no data on the numbers of fishermen involved, nor on the value of the catch or total landings. There are records of three minke whales having drowned in such fisheries.

4.3.3 Coastal set net fisheries in other western European countries
Set nets are used throughout European waters by a large proportion of inshore boats. Statistics on the activities and dimensions of this fleet are largely unavailable. There are over 5,500 fishing vessels of less than 16m registered in French Atlantic ports. There are more than 5,000 vessels working in British coastal waters, more than 3,000 in Norwegian waters and around 750 working in Danish North Sea coastal waters. Numbers in Spain, Iceland, Ireland, Belgium, the Netherlands and Germany are not available. The total number of coastal vessels (<20m) in western European waters is likely to be between 15–20,000 and perhaps more. An unknown but significant proportion of these are using gillnets for at least part of the year. Mesh sizes vary depending on the target species and net lengths are highly variable, from a few tens of metres for some small boats to several tens of kilometres. In some areas, notably the North Sea and English Channel, there are large amounts of netting set by fleets of vessels more or less dedicated to net fishing. In the southwest of England some of these vessels may set nets of 80km or more and increasingly large vessels have been used in recent years.

In Norway, coastal set net fisheries regularly take harp seals. Around 10,000 were caught annually for the period 1978–1981, but by the winter of 1987/88 this had reached 60,000. Harbour porpoises are taken in set gillnets throughout their range, but apparently most frequently in the North Sea. Common dolphins are also taken, notably in the English Channel. These fisheries are complex and few reliable statistics are available on effort.

4.3.4 Irish salmon driftnet fisheries
More than 700 salmon licenses were issued in Ireland in 1988, but the actual number of vessels using driftnets for salmon is unknown, as there is also a large illegal driftnet fishery. Cetaceans reported taken include common dolphins and harbour porpoises. No further details were available at the meeting.

4.3.5 Norwegian salmon driftnet fishery
In 1988 there were 582 vessels (5–12m) licensed to fish for salmon in Norwegian coastal waters. The total fishing period was about 12 weeks in 1988. During this period, 96 harbour porpoises were recorded caught in salmon nets. The fishery is now banned.

4.3.6 Spanish driftnet fishery

Approximately 40 vessels from Spain have fished for tuna and billfish in the area around the Straits of Gibraltar since 1988, under a Moroccan/EEC fishing agreement. Most of these fish in the Atlantic area, although an unknown number occasionally also fish in Mediterranean waters (Aguilar, 1990). Information on bycatches was not available to the meeting.

4.3.7 Other driftnet fisheries in northwest Europe

Small driftnet fisheries exist in a number of other locations, but information was not available to the meeting. These include driftnet fisheries for salmon and for bass in the UK, for herring in England and Wales and for mackerel in southern Norway.

4.3.8 Recommendations

(1) There is little information on the nature and extent of numerous coastal gillnet fisheries in this area. It is **recommended** that the collection of statistics on gillnet fisheries should be improved in all countries of the region and that the European Community and the International Council for the Exploration of the Sea (ICES) also give increased attention to the collection of statistics on gillnet fishing activities.

(2) There are inadequate data to assess the impact of incidental catches of cetaceans in this area. It is **recommended** that the collection of data be improved and co-ordinated. Countries that do not yet have adequate systems for recording incidental catches are urged to implement them. Again, ICES and the European Community should play important roles in facilitating these activities. Several fisheries should receive a high priority. These include the Irish salmon driftnet fishery, the Danish set net fishery in the North Sea, the English and French set net fisheries in the western English Channel, the French albacore driftnet fishery and Portuguese coastal gillnet fisheries.

4.4 Western North Atlantic region

The western North Atlantic region includes Bermuda, Canada (Atlantic provinces), Greenland (Denmark), St. Pierre and Miquelon (France) and the USA (Atlantic and Gulf states). Ten distinct fisheries have been shown to result in at least some cetacean mortality. These are summarised below. Of particular concern with regard to cetacean mortality are the several fisheries which each take hundreds to thousands of harbour porpoises per year from Greenland to the Gulf of Maine, the large-mesh drift gillnet for swordfish along the US coast and the gillnet and trap fisheries which entangle right and humpback whales. Detailed information is given by Read (SC/O90/G6), Earle (SC/O90/G42), Drew (SC/O90/G38) and Payne (SC/O90/G41).

4.4.1 US east coast swordfish drift gillnet fishery

This fishery is found along the continental shelf break from north of Cape Hatteras to Block Island. The target species are swordfish and other large pelagic fish. The 1–1.5 mile (1.6–2.4km) nets have an 18–24" (46–61cm) mesh and are set 2–6m below the surface. Approximately 10–15 vessels participate in this fishery and fishing effort has been increasing rapidly. An observer programme has determined that the incidental catches include (in order of importance) common dolphins, bottlenose dolphins, Risso's dolphins, beaked whales, pilot whales, Atlantic spotted dolphins and striped dolphins.

4.4.2 Greenland and eastern Canada surface gillnet fishery for salmon

This fishery is primarily in the inshore waters of western Greenland, Labrador, Newfoundland and the Gulf of St. Lawrence. The target species is *Salmo salar*. Nets are either anchored or (in Greenland only) drifting. A mesh size of approximately 5" (13cm) is used in Canada and 13–15cm in Greenland. There are approximately 549 fishermen in Newfoundland and Labrador and approximately 2,196 nets in Newfoundland. Mean net length is approximately 100m in Newfoundland. The level of effort may be decreasing. Total salmon landings in 1987 were 963 tonnes in Greenland, 481 tonnes in Labrador, 794 tonnes in Newfoundland and 306 tonnes in the Gulf of St. Lawrence. Incidentally caught cetaceans include harbour porpoises (probably several thousands per year), long-finned pilot whales, humpback whales and minke whales.

4.4.3 Bay of Fundy and Gulf of Maine herring weirs

Herring weirs are large fish traps designed to catch schools of pelagic fishes moving parallel to the shoreline. Weirs are found primarily in the Bay of Fundy and northern Gulf of Maine, although a few are scattered along southern New England shores. The target species are Atlantic herring and mackerel. There are more than 250 active weirs at present, but this number is slowly decreasing. Harbour porpoises and humpback, minke and right whales have been reported trapped inside weirs. Large whales are almost always removed alive, but some harbour porpoises are either shot or die during seining. Approximately 70 porpoises become trapped each year and, on average, 27 die as a result of the entrapment.

4.4.4 Atlantic Canada cod traps

Cod traps are found scattered along the shores of southern Labrador, Newfoundland and the Gulf of St. Lawrence. There are also a few cod traps in operation along the coast of western Greenland. Atlantic cod are captured as they move into inshore waters during the summer. The traps are essentially rectangular boxes of net, with a leader extending from the mouth to the shoreline. There were approximately 3,121 cod traps operating in Newfoundland alone during 1979. Harbour porpoises and white, long-finned pilot, humpback, right and minke whales all become entangled in cod traps, more often with the leader than with the trap itself. Mortality rates of large whales in this gear are fairly low, at least in Newfoundland waters, largely due to the efforts of the entrapment assistance programme run by Memorial University. In 1989, there were reports of 22 humpbacks and six minke whales entangled with Newfoundland cod traps, although a much larger number of collisions go unreported.

4.4.5 Atlantic Canada and Gulf of Maine demersal gillnets

This fishery operates throughout the inshore waters of southern Labrador, Newfoundland, the Gulf of St. Lawrence, the Bay of Fundy and Gulf of Maine. The target species are primarily Atlantic cod, pollock and hake. Gill nets are constructed of 14–23cm monofilament mesh, are between three and four metres deep and vary in length from 450 to 2,000m. Each vessel sets between four and six nets each day. The nets are anchored on the bottom in depths of 30 to 100m. The fishery operates year-round in the southern Gulf of Maine, but is highly seasonal in more northerly waters. In 1989, there were 325 vessels operating in US waters. The number of active vessels in Canadian waters is not known, but is in the thousands. Effort data are being collected by the National Marine Fisheries Service (NMFS) in US waters; preliminary data suggest that gillnet vessels made over 14,000 day trips in 1989. Assuming 5 net sets per day trip of 1km each, total fishing effort would be approximately 70,000KND. Fishing effort is increasing, at least in US waters. There are no data on fishing effort in Canada.

A large number of cetacean species are entangled in these demersal gillnets, including harbour porpoises, white-sided and white-beaked dolphins and long-finned pilot, white, humpback, minke, fin and right whales. Many large whales survive entanglement, although they may carry off portions of gear. Entanglement is almost always fatal for smaller cetaceans. Harbour porpoises are the most frequently killed cetacean in these nets and annual mortality estimates are: Bay of Fundy – approximately 100; Gulf of Maine – 600 to 1,000; Gulf of St. Lawrence – approximately 1,500. There is no estimate from Newfoundland, although large numbers of porpoises are known to be taken in that area. The demersal fishery in the Gulf of Maine has been classified as Category I under 1988 amendments to the US Marine Mammal Protection Act. Observers placed on gillnet vessels in 1989 and 1990 witnessed 15 harbour porpoises killed in 247 fishing days, believed to represent between 1 and 3% of total effort. Sampling effort for this observer programme was not proportional to fishing effort or corrected for seasonal movements of porpoises.

4.4.6 Florida shark driftnet fishery

This is a small and poorly documented fishery operating along the northeastern coast of Florida. Nets are constructed from 8 – 12" (20–30cm) mesh and allowed to drift within 10 miles offshore. The primary target species is blacktip shark, although a variety of pelagic species are taken. There is no information on incidental catches of cetaceans in this fishery, although it is likely that bottlenose dolphins are taken. The fishery operates within the winter range of the endangered northern right whale population.

4.4.7 US east coast shad gillnets

These gillnets are set in estuarine and coastal waters to intercept anadromous movements of shad. Most nets employ 13–15cm mesh and vary from approximately 100–1,000m in length, depending on local regulations. Several thousand nets are used each spring, but the fishery is in gradual decline. Bottlenose dolphins and harbour porpoises are occasionally taken and there are two records of humpback whale mortality in these nets.

4.4.8 US east coast trap and pound net fisheries

A variety of pound, fyke and trap nets are used in coastal areas from Massachusetts to North Carolina. The nets are anchored near shore and are usually constructed of fine mesh, designed to capture a variety of coastal species including striped bass, tautog, bluefish and mackerel. The only reported cetacean entanglement was of a minke whale killed in a Rhode Island fish trap during 1976.

4.4.9 Atlantic Canada and US east coast bait gillnets

A large number of gillnets are used to take small pelagic fish in the waters of eastern Canada and the northeastern USA. Target species include Atlantic herring, mackerel and menhaden. The nets are usually constructed of fine mesh (2–3", 5–8cm) and are no more than 100–200m in length. These nets are either allowed to drift or are anchored, but all fish at the surface. The fish are used variously for direct consumption, roe, or bait for lobster or crab traps. Harbour porpoises, white-sided dolphins, short-finned pilot whales, humpback whales and fin whales are occasionally entangled in these nets. The only fishery that takes significant numbers of cetaceans is a small driftnet fishery for mackerel in Cape Cod Bay. Most porpoises and dolphins entangled in this fishery, however, are released alive.

4.4.10 US east coast mixed species demersal gillnets

A large number of fisheries utilise demersal gillnets along the US coast from Rhode Island to Louisiana. Coastal gillnets have been banned in South Carolina, Georgia and Texas waters for fisheries conservation reasons. These fisheries use a variety of mesh sizes, from 9–35cm, depending on the target species. Most nets are fairly short, less than 1km in length, although individual fishermen may set several at a time. Harbour porpoises and bottlenose dolphins are occasionally taken, although incidental catches have not been systematically examined.

4.4.11 Recommendations

(1) It is **recommended** that estimation of incidental catches of harbour porpoise made by groundfish gillnets in (i) Newfoundland and Labrador and (ii) the Gulf of St. Lawrence be undertaken. Such estimates will require an on-board observation programme, if accurate data on catch rates are to be obtained. An observer programme should be formulated as soon as possible, even with very low sampling intensity, to provide rough estimates of the magnitude of mortality. In addition, attempts should be made to improve the reporting of fishing effort.

(2) It is **recommended** that estimates be made of the magnitude of incidental mortality of harbour porpoises in the Greenland salmon driftnet fishery. As noted for (1) above, this will require accurate information on both catch rates and total effort.

(3) It is **recommended** that efforts to estimate incidental catch of harbour porpoise and fishing effort for the Gulf of Maine/Bay of Fundy groundfish gillnet fishery be continued. These efforts should ensure that future sampling intensity is statistically adequate and should explore the effects of variation in gear type and mode of operation on mortality rates. In addition, the level of incidental mortality should be assessed and data collected in previously unstudied areas, such as southwestern Nova Scotia.

(4) It is **recommended** that onboard observations of the swordfish driftnet fishery be continued at a level which is proportional to fishing effort. Consideration should be given to increasing sampling intensity because of (i) the large number of cetaceans killed and (ii) the relatively small size of the fishery in relation to other driftnet fisheries. It should be possible to sample a large proportion of all sets made, increasing the reliability of estimates of total mortality. Data on fishing effort should be obtained from ICCAT (International Convention for the Conservation of Atlantic Tuna).

(5) It is **recommended** that the magnitude of incidental mortality of cetaceans be assessed for several US east coast gillnet fisheries, including the Florida east coast shark driftnet fishery and the North Carolina sink net

fishery. A small observer programme would suffice to determine whether or not substantial incidental catches are incurred by these fisheries.

(6) The threat of gear damage is an excellent incentive to persuade fishermen to cooperate in programmes that release entangled large whales. It is **strongly recommended** that projects such as Memorial University's entrapment assistance programme be encouraged and supported.

4.5 Mexico, Central America and Caribbean region

This region is defined to include Anguilla, Antigua & Barbuda, Bahamas, Barbados, Belize, British Virgin Islands, Cayman Islands, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, El Salvador, French Guiana, Grenada, Guadaloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Mexico, Montserrat, Netherlands Antilles, Nicaragua, Panama, Puerto Rico (US), St. Christopher & Nevis, St. Lucia, St. Vincent & The Grenadines, Surinam, Trinidad & Tobago, Turks & Caicos Islands, Virgin Islands (US) and Venezuela. Very little information is available on fisheries and their incidental catches in this large area. Most passive gear fisheries are based on small-scale coastal gillnets. These fisheries are divided into Pacific, Gulf/Caribbean and Amazon/Orinoco regions and are summarised below. Also included is limited information on large-scale driftnet fisheries operating in the Caribbean. Detailed information is given by Vidal *et al.* (SC/O90/G7).

4.5.1 Pacific small-scale gillnet fisheries

Small-scale and subsistence fisheries occur along the entire west coasts of Mexico, Central America and Colombia. The fisheries take a large number of fish species, including elasmobranchs, usually within a very short distance from shore. Gillnets range in length from 30–700m and from 8–30cm mesh sizes. Vessels are typically 4–12m in length. The number of vessels is available only for a few of the countries. Based on data from those countries, we know that the minimum number of boats is 7,550–8,550 and the minimum number of fishermen using gillnets is 5,500–12,000. The actual number is likely to be much greater and increasing. Cetacean species taken in these fisheries include the vaquita (at least 30–40 per year), common dolphins, bottlenose dolphins and gray whales. No estimates are available for the take of the latter three.

4.5.2 Gulf of Mexico and Caribbean small-scale gillnet fisheries

Small-scale and subsistence fisheries occur along the entire Gulf of Mexico and the Caribbean. The fisheries take a large number of fish, turtles and elasmobranch species. Gillnets range in length from 30–2,000m and from 4–40cm in mesh size. Vessels are typically 4–15m in length. Based on data from a few countries, we know that the minimum number of boats is 732 and the minimum number of fishermen using gillnets is 1,600. Fishing effort in these fisheries is generally increasing. Based on the few countries which report catch statistics, the minimum catch is 420 tonnes per year. Cetacean species taken include pygmy sperm whales, tucuxi, Risso's dolphin, bottlenose dolphins, Atlantic spotted dolphins, killer whales, clymene dolphins, spinner dolphins, rorquals and humpback whales. The annual take of cetaceans has not been estimated for any species or fishery.

4.5.3 Small-scale gillnet fisheries in the Amazon and Orinoco rivers

In the Colombian Amazon and in the Orinoco River basin, gillnets are used in artisanal fisheries. Target species include mainly pimelodid catfishes and characids but also other species. Vessels are typically 3–10m. Cetaceans killed include the boto (in the Amazon).

4.5.4 Drift gillnet fisheries for pelagic fish in the Caribbean

Gillnets are used to catch pelagic fishes in the vicinity of Trinidad & Tobago, Barbados, Grenada and along parts of the coast of Mexico. Target species include *Scomberomorus* spp., flying fish, large pelagic fishes (possibly including tuna) and possibly flying squid. Detailed information is only available for Trinidad. Driftnets with lengths of 100–150m and mesh sizes of 10–11cm are set from 10m vessels. There are 100–150 such vessels in Trinidad. The total catch of *Scomberomorus* in Trinidad is approximately 2,000 tonnes (including some other gear types). Marine mammal mortality has included killer whales and unidentified dolphins.

4.5.6 Recommendations

(1) It is **urgently recommended** that the incidental mortality of the vaquita be urgently addressed by (i) fully enforcing the ban on the totoaba gillnet fishery, (ii) reconsidering the issuance of experimental totoaba gillnet fishing permits and (iii) monitoring and evaluating the incidental mortality of the vaquita in the shark gillnet fishery.

(2) It is **recommended** that new and expanding driftnet fisheries in this area be identified and the occurrence and magnitude of cetacean bycatch determined. This should be accomplished through national and regional international programmes.

(3) It is **recommended** that education programmes be designed and implemented to increase the awareness of fishermen and the general public to the problems faced by cetacean populations interacting with gillnet fisheries.

(4) The tucuxi is especially vulnerable to population depletion because of its restricted coastal and riverine habitats and the possible existence of isolated and locally adapted populations. It is **recommended** that incidental mortality of this species receives particular attention in the Caribbean.

4.6 Brazil region

For discussion in this report, Brazil is divided into five regions: the north coast (2°33′S to 4°52′S); the northeast coast (4°52′S to 18°20′S); the southeast coast (18°20′S to 23°16′S); the south coast (23°16′S to 33°45′S); and the Amazon. Detailed information is given by Pinedo (SC/O90/G3), Cannella and Ximenez (SC/O90/G26) and da Silva and Best (SC/O90/G27).

4.6.1 Net fishery for red porgy and Brazilian shrimp

No details about this northern region fishery were available at the meeting, but Lodi *et al.* (1990) noted the take of tucuxi in this fishery.

4.6.2 Gillnet fishery for croakers, weakfish and marine catfish

This fishery is found in the north, northeast and southeast. At least 83 fishing villages operate gillnets year round (Lodi *et al.*, 1990). No additional information was available about the fishery, but recorded marine mammal takes include approximately 90 tucuxi, 29 franciscana, 3 rough-toothed dolphins, 2 common dolphins, 1 false killer whale and 1 Atlantic spotted dolphin.

4.6.3 Lobster trap fisheries in northeast region
Baited traps are used to catch lobsters in northeast Brazil. No marine mammal mortality has been reported, but in other parts of the world, large whales have been entangled in crustacean trap lines.

4.6.4 Artisanal gillnet fisheries in northeast region
Gillnets are used (along with other gear) to catch a variety of coastal fishes in northeast Brazil. Nets are typically set from small (4–8m) sail-rigged open boats called *jangadas* or *saveiros*. Data are not available on effort for these fisheries. Tucuxi are occasionally caught in gillnets (Barros and Teixeira, 1994). These dolphins are used as bait and for human consumption (Capistrano *et al.*, 1990; Taveres de Almeida, pers. comm. to Ximenez; Nerees do Reis, pers. comm. to Ximenez).

4.6.5 Longline fishery in northeast region
Longlines are used to catch tuna, marine catfish, half beaks, ballyhoo, tarpon and other species in coastal areas of northwest Brazil. There are approximately 30,000 small boats. Other small vessels carry iced fish between the fishing vessels on the open sea and the home ports. At least 275 tonnes of fish product are landed in Maranhão state alone. No information is available regarding marine mammal mortality.

4.6.6 Gillnet fisheries in southeast region
Gillnets and trap fisheries are used to catch a variety of fish species in southeastern Brazil. Gillnets are 146–2,000m long with mesh sizes of 3–20cm (Capistrano *et al.*, 1990). No additional information is available about the fishery operation. Reported cetacean bycatch in gillnets has included 17 tucuxi, 7 franciscana and one unidentified dolphin (Capistrano *et al.*, 1990). Three dolphins have also been reported taken in trap fisheries (Monteiro Filho, 1990). Tucuxi have been reported to be used for bait and human consumption (Lodi, pers. comm.).

4.6.7 Gillnet fisheries in southern region
Gillnets are used to catch a variety of fish species in southern Brazil. Nets are fished up to 30 n.miles offshore. Approximately 1,600 vessels are licensed to fish in the Rio Grande area. Each vessel fishes up to 3km of net each day for a total of 300 days per year. If all vessels are fishing, total effort is approximately 1,500,000KND. Records of marine mammal mortality include 867 franciscana, 1 tucuxi, 3 rough-toothed, 4 bottlenose, 5 Atlantic spotted and 2 common dolphins, and 1 false killer and 1 minke whale.

4.6.8 Recommendation
All the gillnet fisheries of Brazil require systematic monitoring in order to assess the level of incidental catches of small cetaceans, especially those from the north, northeast and southwest and it is **recommended** that this be initiated as soon as possible. Mortality of the tucuxi and the franciscana urgently requires monitoring.

4.7 Southwest Atlantic region
The Southwest Atlantic region consists of Argentina, the Falkland Islands/Islas Malvinas and Uruguay. Gillnet fisheries include shark fisheries in both Uruguay and Argentina, a croaker fishery in Argentina and a mixed-species trammel net fishery in Argentina. These are summarised below. Detailed accounts are given by Crespo (SC/O90/G2) and Praderi (SC/O90/G1).

4.7.1 Gillnet fishery for sharks in Uruguay
Bottom-set gillnets are used to catch soupfin sharks, other shark species and bony fish along the coast of Uruguay. Twenty vessels (each approximately 8m long) fish out of five fishing villages along the Uruguay coast. Approximately 80 fishermen are employed in this fishery. Gillnets are approximately 1,200m long and have mesh sizes of 10cm, 20–22cm and 32–34cm. Based on an estimated 72km of net being used in 1989 and a fishing season of 60 days, total effort was approximately 4,356KND. Effort is currently estimated to be decreasing. The total annual value of the catch is approximately $200,000. Marine mammals killed incidentally include franciscanas (more than 100 per year) and, to a much lesser extent, bottlenose dolphins and Burmeister's porpoises.

4.7.2 Gillnet fishery for croaker species in Argentina
Gillnets are set on the bottom to catch several species of croaker (Sciaenidae) in the Samborombon Bay and Bahía Blanca regions of Argentina. Vessel sizes in these regions are 8–10m and 13–15m, respectively, and the number of vessels fishing gillnets 7–8 and 15–16, respectively. Gillnets in Samborombon Bay are typically 200m long and have mesh sizes of 10–30cm. For Bahía Blanca three types of nets are used with mesh sizes ranging from 2cm to 10cm. Given 8 vessels fishing 200m of net over a 60-day fishing season, total annual effort in Samborombon Bay is approximately 100KND. There are no effort data for the Bahía Blanca area. Effort is stable or increasing slightly. Cetacean mortality at Samborombon Bay includes approximately 50 franciscanas per year. No information on cetacean mortality is available for Bahía Blanca.

4.7.3 Gillnet fishery for sharks in Argentina
Set gillnets are used to catch soupfin and other shark species in the Necochea and Claromecó areas of Argentina. There were 21 vessels fishing in 1989 and 17 in 1988. Vessels are 8–45m in length and typically fish 1–4km of 19–21cm mesh gillnet. Approximately 150 fishermen are employed in this fishery. Total effort is approximately 6,700KND and is increasing. The catch is approximately 500 tonnes per year and is worth approximately $2 million. The annual cetacean catch includes franciscanas (approximately 70–80), Burmeister's porpoises (approximately 20) and common and dusky dolphins.

4.7.4 Other coastal gillnet fisheries
Gillnets are used to catch a variety of fish species, including robalo, silverside and hake, in the region of southern Patagonia and Tierra del Fuego. Nets include single-panel gillnets and 3-walled trammel nets with mesh sizes of 3, 12 and 30cm. Nets are set from shore with and without vessels. Little is known about the level of fishing effort, but it is believed to be increasing. Incidental cetacean catch has not been quantified, but includes Commerson's dolphins, spectacled porpoises, Peale's dolphins and Burmeister's porpoises.

4.7.5 Recommendations
(1) It is **recommended** that age and reproductive parameters of the franciscana continue to be monitored and that they be compared with those found

by Kasuya and Brownell during the 1970s (Kasuya and Brownell, 1979) and between populations within the area.

(2) It is **recommended** that Punta del Diablo be used as a location to estimate the size of the franciscana population off Uruguay. In Argentina, incidental mortality and abundance should be assessed at San Clemente del Tuyu, Nocochea, Claromecó and Bahía Blanca.

(3) It is **recommended** that samples be collected and analysed to examine genetic variability and stock structure in the franciscana.

(4) It is **recommended** that the purse-seine fishery in Buenos Aires Province be assessed for its impact on dusky and common dolphins.

(5) It is **recommended** that mortality rates and population sizes of cetaceans impacted by trawl fisheries in northern Patagonia be assessed.

(6) In southern Patagonia and Tierra del Fuego, the fisheries require further documentation, in terms of gears used and the amount of effort expended. It is **recommended** that such research begin. Mortality to cetaceans and population sizes of those species affected also need to be assessed in this region. A co-operative research programme should be established between Argentina and Chile for the Tierra del Fuego region.

4.8 Western Africa region

The western Africa region includes 22 coastal states, including Angola, Benin, Cameroon, Cape Verde, Congo, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Liberia, Mauritania, Morocco (Atlantic coast), Nigeria, Sao Tome & Principe, Senegal, Sierra Leone, Togo, Western Sahara and Zaire. Most of the gillnet fishing in this area is conducted from small vessels. Little information is available on catch, effort or bycatch. Summaries are provided for four such fisheries. More detailed information is given by Maigret (SC/O90/G5).

4.8.1 Drift gillnet fishery for tuna

A drift gillnet fishery for tuna and billfish is found off the Ivory Coast and the Moroccan coast. In Morocco, vessels are primarily small boats which previously fished with seines or hook and line. In the Ivory Coast and Ghana, small vessels called *pirogues* (10–15m long) fish with approximately 450m of 40–60cm mesh gillnet. There are approximately 30 vessels in the Ivory Coast. No information is available on the level of effort in Morocco, other than the fact that the number of vessels is rapidly increasing. The annual catch of tuna by all gear types is approximately 3,000 tonnes per year in Morocco. The gillnet catch in the Ivory Coast is approximately 200 tonnes and is sold in local markets. Approximately 100 'dolphins' are estimated to be caught per year in the Ivory Coast fishery. No information was available for Morocco.

4.8.2 Western Africa lobster set nets

Spiny lobsters (*Panulirus regius*) are taken in set nets from the Western Sahara to the Congo. Bottom entangling nets are set with small boats (8–12m). The fishery appears to be stable. Lobsters are sold domestically and are exported to Spain and France. No information is available on marine mammal mortality in most areas, but in the north approximately 10 dolphins and harbour porpoises are believed to be caught each year. Monk seals are also found in the area and may be caught.

4.8.3 Western Africa set gillnet fisheries

Bottom-set gillnets are used for a variety of fish species from Mauritania to Angola. Nets are set from small boats, with or without engines. A variety of sizes and types of gillnets are used, all of relatively short length. No quantitative estimates of effort are available, but this type of fishing is generally increasing in all countries. No information is available on marine mammal mortality, but these nets may occasionally capture Atlantic hump-backed dolphins and (in lagoons) manatees.

4.8.4 Small-scale drift gillnet fishery for small pelagic fishes

This fishery occurs along the coasts of Nigeria, Benin and Gabon. Small pelagic species (e.g., *Sardinella*) are taken with short (65–70m), small-mesh (5–6cm) gillnets which are deployed from small boats (only 10% of which may have outboard engines in Nigeria). There is no information on the effort or the catch. The catch is sold in local markets. There has been some documentation of the catch of unidentified 'dolphins'.

4.8.5 Recommendations

(1) There is very little or no expertise on marine mammals in the West African nations. It is **recommended** that a training programme for African scientists be implemented in order to facilitate the formation of a local network to study the problems of incidental catches in West African waters.

(2) More information on gillnet fisheries in this area is required than was available to the Workshop and it is **recommended** that this be collected and reviewed.

(3) The identity, size and status of cetacean populations in the eastern tropical Atlantic is unknown. It is **recommended** that these be investigated.

4.9 Southern Africa and southern Indian Ocean region

The southern Africa and southern Indian Ocean region includes the coastal waters of British Indian Ocean Territory, Comoros, Kerguelen (France), Malagasy Republic, Mauritius, Mozambique, Namibia, Reunion (France), Seychelles, South Africa and St. Helena (and dependencies Ascension Island and Tristan da Cunha, UK). Most of the coastal gillnet fishing in this area is artisanal and subsistence-type fishing. Data are completely lacking on most of the fisheries. Some information is summarised below for three fisheries. A small gillnet fishery for tunas is known to exist in the Seychelles, but no information is available on bycatches (Indo-Pacific Tuna Development and Management Programme, 1987). More detailed information is presented by Cockcroft (SC/O90/G20).

4.9.1 Shark gillnetting in Natal, South Africa

Gillnets are used to catch sharks (and presumably protect bathers) along beaches in Natal, South Africa. Nets are set along popular beaches within 500m of shore. Nets are constructed of multifilament nylon with stretched-mesh size of 34cm. There are 416 such nets which are left in a fixed position for most of the year apart from mid-winter when some may deliberately be lifted to avoid major entanglements of predators associated with the sardine run. Each net is 110m long. Total effort is 16,702KND per year and is stable. Shark catch and bycatch in the nets is carefully monitored. The cetacean species most commonly caught include bottlenose, Indo-Pacific hump-backed and common dolphins. Bottlenose and hump-backed dolphin populations appear to be declining in this area.

4.9.2 Shrimp set netting in Mozambique
Very small mesh (1cm) gillnets are used to catch shrimp in an artisanal fishery in Mozambique and probably some areas of Madagascar. Almost nothing is known about this fishing method. Shore-based dugouts less than 8m long are used. Incidental cetacean catch is not known, but is probably marginal due to the small size of the nets and the small mesh size.

4.9.3 Artisanal gillnet fisheries in the Malagasy Republic, Mauritius, Mozambique, Reunion and Seychelles
Gillnets are used to take a variety of benthic and neritic fish species in coastal areas throughout the southwestern Indian Ocean and southeastern Atlantic. Nets may be set or drift types and may be fished at either the surface or the bottom. Mesh sizes vary between 5–15cm. Vessels range in size from dugouts to 10m sail or motorised boats. There are a minimum of 15,404 such vessels and more probably 20,000. There are more than 20,000 fishermen using these methods and possibly 40–50,000. Total effort is likely to be greater than 450,000KND days per year. Effort is probably increasing with population size. Such fisheries probably also exist in the other nations in the region, with the possible exception of the Comoros. There is no information available on cetacean bycatches.

4.9.4 Recommendations
(1) Where aid agencies have provided gillnets as part of development assistance programmes, it is **recommended** that the donors be encouraged to obtain information on the impacts of these gears on non-target species.
(2) In order to encourage fishermen to report incidental catches, it is **recommended** that regulations concerning marine mammals be devised which encourage rather than discourage reporting.
(3) It is **recommended** that the UN and other aid agencies be made aware of the potential effects of the development of gillnet fisheries.
(4) It is recommended that Regional fishery bodies be encouraged to place observers on board high seas driftnet vessels to collect information on incidental catches.
(5) In view of the mortality and depletion of Indo-Pacific hump-backed and bottlenose dolphins by incidental capture in shark nets, it is **urgently recommended** that an immediate reassessment of existing deployment of these nets be carried out.

4.10 East Africa, northwestern Indian Ocean and Red Sea region
This region includes Bahrain, Djibouti, Egypt (Red Sea coast), Ethiopia, Iran, Iraq, Israel (Red Sea coast), Kenya, Kuwait, Oman, Pakistan, Qatar, Saudi Arabia, Somalia, Sudan, Tanzania, United Arab Emirates and Yemen. Information from the region presented to the meeting was limited to a review of the fisheries of Pakistan by Niazi (SC/O90/G30). There are several important marine fisheries in the waters of Pakistan that are known to take cetaceans, although the magnitude of this problem has received little study to date. It is known that many fishermen attempt to avoid entangling dolphins and attempt to release them alive whenever possible. Of particular concern in Pakistan is a proposed refitting of 1,800 trawlers with gillnet gear. Such an expansion of existing gillnet fisheries could have a serious impact on coastal cetacean populations.

A shark gillnet fishery in the Gulf of Oman is known to take at least common dolphins and humpbacked whales (Papastavrou, 1990), but no further information was available to the meeting. A gillnet fishery for large pelagic species, mainly tuna, is described below; the information comes from Dudley (1989).

Information from the literature on gillnet fisheries of Iran, Kenya, Somalia, Tanzania and Zanzibar is also summarised below.

4.10.1 Large pelagic gillnet fishery in Pakistan
This fishery is conducted in offshore waters along the Sind and Baluchistan coasts and as far away as Oman, in depths of 25–100m. A variety of sharks, tuna and seerfish are taken by drift gillnets that are as long as 10km (Indo-Pacific Tuna Development and Management Programme, 1987). The mesh size of these nets varies between 15 and 25cm. Approximately 500 vessels are active in the fishery, each setting two nets. Assuming a 200-day fishing season, these 500 vessels each setting two 3km nets each day would have a combined effort of 600,000KND per year. Indo-Pacific hump-backed, bottlenose, spinner and spotted dolphins are among the cetacean species taken in unknown numbers by this growing fishery.

4.10.2 Bottom set gillnet fishery in Pakistan
These nets are used in coastal waters in Sind and Baluchistan in depths of 10–30m. A variety of groupers, grunts, croakers and other demersal species are taken in these set nets using mesh sizes of 10–12cm. A total of 2,500 vessels each set one to three nets of between 500 and 1,200m in length. Total fishing effort would be approximately 500,000KND based on each vessel setting 1km of net each day during a 200-day fishing season. This fishery is also growing and is known to take Indo-Pacific hump-backed dolphins, bottlenose dolphins, spotted dolphins and finless porpoises.

4.10.3 Artisanal fisheries in Pakistan
This category includes a large number of small-scale fisheries that employ a variety of gear, including fine mesh gillnets and stake nets. These fisheries operate year round and take most coastal shallow water fish species. More than 20,000 artisanal vessels are in operation in Pakistan around the year. Only the finless porpoise is known to be taken by these small scale fisheries.

4.10.4 Fishery for large pelagic species in Oman
The primary target species are *Scomberomorus commerson* (about 27,581 tonnes landed in 1988), *Thunnus tonggol* (15,669 tonnes in 1988) and other small tunas. Both set nets (some configured as traps) and driftnets of 1–2,000m are used. The fleet consists of a variety of vessels ranging from small fibreglass boats of less than 10m to large dhows. No information is available on effort or bycatches.

4.10.5 Driftnet fishery for tuna in Iran
Iran operates a gillnet fishery for tunas in the Indian Ocean, with total catches in 1986 of 5,071 tonnes (Indo-Pacific Tuna Development and Management Programme,

1987; Indian Ocean Fishery Commission, 1990). There are about 2,500 multipurpose artisanal vessels engaged in the fishery; most are wooden and range from 5 to 100 GRT. Some are fibreglass and range from 12 to 27ft (3.7–8.2m). The nets range in length from 0.5 to 7–8km; mesh size is 14–16cm. There is no information on incidental catches.

4.10.6 Artisanal gillnet fishery in Kenya
In 1987, 404 vessels (most less than 10m) operated bottom and surface gillnets, targeting sharks, rays, tunas and over 100 other species including needlefish, jacks, parrotfish, kingfish and rabbitfish; 2,288 tonnes of all species were landed in that year (de Sousa, 1988). Nets are 90m by 26 meshes; three are usually fished together by one boat. There is no information on incidental catches of cetaceans.

4.10.7 Artisanal driftnet fishery for sharks and large pelagics in Somalia
'Mesh nets' are employed in Somalian fisheries (Van Zelinge, 1988). Reported data on vessels and catches have not been broken down by gear type. No data are available on incidental catches.

4.10.8 Artisanal gillnet fisheries in mainland Tanzania
In 1986, a reported 8,842 'gillnets' and 3,590 'shark gillnets' were in use in mainland Tanzania (Nhwani, 1988). The reported data are not broken down by gear type. There is no information on incidental catches.

4.10.9 Gillnet fisheries for large pelagic fish and sharks in Zanzibar
Two vessels engaged in driftnetting for large pelagic fish in 1986 (Jiddawi and Pandu, 1988). The fleet in that year fished 5,622 gillnets for sharks and large pelagics. For the period 1974–76, 91,375 tonnes were landed from gillnets. Again, there is no information available on incidental catches of cetaceans.

4.10.10 Recommendations
(1) Further research effort into cetaceans in the region is required. In particular, the population status of the finless porpoise and factors controlling it need urgent attention; it is **recommended** that this begin as soon as possible. The causes of the decline in this species should be identified and steps taken to reverse the decline.
(2) Gillnet fisheries continue to be developed in Pakistan and elsewhere throughout the region. It is **recommended** that these fisheries not be further developed until evaluation of their effects on non-target species has been conducted.
(3) It is **strongly recommended** that distant water large mesh driftnet fleets operating in the Indian Ocean either be closely monitored or stopped.

4.11 Northeastern Indian Ocean region
This region includes Bangladesh, Myanmar, India, Maldives and Sri Lanka. Within this region, with the exception of the Maldives (Anderson, 1990), gillnets are the most common passive fishing gear. Literally millions of fishermen use this method. The vast majority of the effort is in small-scale artisanal or subsistence fisheries. For purposes of summary, all of these fisheries are considered collectively below. Details are given by Mohan (SC/O90/G22), Dayaratne and de Silva (1990) and Leatherwood and Reeves (1989).

4.11.1 Small scale artisanal gillnet fisheries of India, Bangladesh and Sri Lanka
Target species in these fisheries include many marine fish and elasmobranchs and freshwater catfish. Almost all coastal areas are fished. Nets include both drift and set type gillnets. Most vessels are small (5–15m). Of approximately 289,000 vessels, only about 8% are motorised. Approximately 2,500,000 fishermen are found in this region, most of whom fish with gillnets at least some of the time. There are estimated to be 216,000 gillnets in India. Although data are not available for the rest of the countries, the total number of nets is likely to be close to 350,000. Mean net length is approximately 400m and mesh sizes range between 2–30cm. Assuming each net is fished 150 days per year, the total effort is approximately 21,000,000KND per year in this region. Marine mammal mortality includes spinner, spotted, striped, common, bottlenose, Indo-Pacific hump-backed, Risso's and Ganges river dolphins and false killer, dwarf sperm and pygmy sperm whales. Total mortality has been estimated by statistical sampling in Sri Lanka and by fishery reporting systems in India. Total mortality of all cetacean species in Sri Lanka alone may exceed 40,000 per year, with a minimum additional catch of 2,000 dolphins in other areas of this region. Dolphin catches in portions of Sri Lanka have evolved from being a bycatch to being a directed catch for human consumption and for bait for the long-line fisheries.

4.11.2 Recommendations
(1) The fisheries of the region are generally poorly documented and it is **recommended** that a comprehensive survey be made of the fisheries of Bangladesh, Burma, Sri Lanka and India which are known or suspected to kill marine mammals.
(2) It is **recommended** that the nations in the region consider the establishment of marine mammal protection agencies.
(3) It is **recommended** that education programmes be initiated for fishermen, fishery officials and others to highlight the problems faced by cetacean populations interacting with gillnet fisheries. Cetacean awareness programmes should be instigated at the village level. Fishery co-operatives and local schools and colleges should be involved in the work, and where dolphins are being caught, a local college or school should be identified to protect the dolphins through public contact programmes.
(4) Because of the vulnerability and general depletion of river dolphins in Asia, it is **recommended** that particular efforts be made to collect information on the gillnet fisheries of the Ganges and Brahmaputra rivers and their involvement in entanglement of the Ganges susu.

4.12 Southeast Asia region
This region includes the coastal areas of Brunei Darussaalam, Kampuchea, Malaysia, Philippines, Singapore, Thailand and Vietnam. Most passive net fisheries in all of these countries are small-scale, artisanal type enterprises. Little information is available for some regions; no information is available for most. Malaysia, Thailand and the Philippines operate gillnet fisheries for

tunas, with reported catches in 1986 of 9,751 and 25,154 tonnes in Malaysia and Thailand, respectively, and 25,186 tonnes in the Philippines in 1985 (Indo-Pacific Tuna Development and Management Programme, 1987), but little information on vessels, gear, effort or bycatches was available to the meeting. The limited information available to the meeting on some areas in the Philippines and on Thailand is summarised below. More detailed accounts are given by Dolar (SC/O90/G29) and Sudara (SC/O90/G32).

4.12.1 Artisanal fishery for pelagic fish in Thailand
Gillnets are used to catch skipjack, Spanish mackerel and longtail tuna in the Gulf of Thailand and in the Andaman Sea. According to Bhatia *et al.* (1989), driftnetting accounted for about 1/3 of the catch of 95,679 tonnes in the Gulf of Thailand in 1987. There are approximately 10,000 small (6–8m) vessels in this fishery. Nets are typically less than 1km, but some are up to 5km long. Nets are either anchored or are allowed to drift. Marine mammals taken in these nets include dwarf spinner dolphins, Indo-Pacific hump-backed dolphins, Irrawaddy dolphins and dugongs.

4.12.2 Artisanal fisheries in the Philippines
Gillnets are used to catch a wide variety of small fish throughout the coastal waters of the Philippines. Boats are small, typically 3–6m in length. There are approximately 3–15,000 such vessels fishing with small (approx. 300m) gillnets. If fishing is practised 220 days per year, total effort would be in the range of 200,000–1,000,000KND per year. Cetacean mortality includes spinner, spotted and Fraser's dolphins. Based on a small sample observed in the Negros and Bohol Islands, estimated kill rates are 0.66 dolphins/km/year. Based on the above estimate of the number and length of nets, extrapolated cetacean mortality may be in the range of 600–2,000 dolphins per year.

4.12.3 Recommendations
(1) It is **recommended** that studies of cetacean populations and cetacean mortality in fishing operations should be initiated in Southeast Asia as a priority issue.
(2) It is **recommended** that national and international organisations develop educational programmes for fishermen, scientists, officials and the general public about cetaceans and their interactions with fisheries.

4.13 Australasia and Melanesia region
This region includes coastal waters of Australia, East Timor, Indonesia, New Caledonia, Papua New Guinea, Solomon Islands and Vanuatu. At this meeting, information on fisheries and marine mammal takes included only Australia. Four important net fisheries of Australia, the Taiwanese fishery operating in the Arafura and Timor Sea and the Indonesian tuna gillnet fishery are summarised below. Detailed information on the Australian fisheries was presented by Anderson.

4.13.1 Northern drift gillnet fishery for sharks
Surface driftnets are used to catch sharks, tuna and gray mackerel, 2–12km offshore along the Arafura Sea. Nets are 2.5km long and have a mesh size of 4–6" (10–15cm). There are 45 permits to fish this area, but only 10–12 vessels (approximately 30 fishermen) are actively fishing. Vessels are 10–17m long. Each vessel makes 5–10 trips of 7–21 days duration. Assuming 5–19 days of actual fishing, 7.5 trips per year and 12 vessels, the total effort is approximately 1–4,000KND per year. Bycatches of bottlenose dolphins, *Stenella* spp. and Indo-Pacific hump-backed dolphins are most likely. Cetacean catch rates are likely to range from 4–6 dolphins/100KND. Given this and the above effort estimate, total catches may be between 40–240 dolphins per year.

4.13.2 Southern set gillnet fishery for sharks
Bottom-set gillnets are used to catch gummy, whiskey and dusky sharks in Western Australia, South Australia, Tasmania, Victoria and southern New South Whales. Vessels are typically 10–20m long. The number of vessels is 172 in South Australia and 20 in Tasmania and is not known for the other areas. The total number of fishermen is approximately 500. Nets are approximately 2.5km long. Effort is generally increasing. Landings are worth approximately $20m. Reported dolphin takes are approximately 1–7 per year for the West Australia coast and are probably much lower for other areas. Species taken have not been reported, but they were probably bottlenose or common dolphins.

4.13.3 Inshore set gillnet fishery for barramundi
Set gillnets are used to catch barramundi and threadfin in estuaries and tidal areas of northeast, north and northwest Australia. Vessels include 17m net boats and 3.5m net tenders. There are approximately 23 of the mother vessels in the Northern Territories and 9 in West Australia. The number in Queensland is not known. Maximum net length is 1km and mesh sizes are typically 15–18cm. Total catches are in excess of 850 tonnes and are worth a minimum of $12m. Marine mammal catches probably occur, but data are not available.

4.13.4 Haul-net fishery in Tasmania
Haul-type nets are used to catch baitfish, arridis and mullet in inshore waters of Tasmania. Sometimes these nets are set to fish passively. Nets are set from small dinghies. There may be approximately 7,100 such nets. Nothing is known about levels of fishing effort. Marine mammal mortality included 6 common dolphins in 1980 and 9 in 1989.

4.13.5 Taiwanese driftnet fishery for sharks, billfishes and tunas
This fishery formerly operated in the 200-mile zone of Australia but was ejected from Australian waters in 1986 because of an unacceptably high dolphin bycatch (Harwood and Hembree, 1987; Anon., 1988). The fishery has continued in other waters to the north off Indonesia and Papua New Guinea (Liu, 1989), but there was no information available to the meeting on recent bycatches. Information is also lacking on bycatches outside Australian waters before 1986.

4.13.6 Indonesian tuna gillnet fishery
Approximately 200 gillnetters of 3–6 GRT with 40 HP engines operated out of Sumatra in 1987 (Uktolseja, 1989). The principal target species are skipjack and yellowfin tuna. Catches of tunas in 1988 totalled 902 tonnes; smaller amounts of sharks and billfish were also landed. Nets consist of 20 units each 60m long and 14m deep (total 1,200m), with mesh size of 4–5" (10–13cm). Vessels typically have a crew of 3–4. No information is available on cetacean bycatches.

4.13.7 Recommendations
(1) Improved documentation of the nature and extent of bycatch, including marine mammals, in southern and

western Australian shark set net fisheries and in the northern Australian driftnet fishery is required, as is an assessment of the cetacean populations involved. It is **recommended** that programmes to accomplish this be initiated.

(2) It is **recommended** that an assessment be made of the level of bycatch, including marine mammals, in commercial and other net fisheries for barramundi and threadfin bream in northern Queensland, Northern Territory and Western Australia.

(3) It is **recommended** that assessments should be made of the status of populations of small cetaceans, particularly Indo-Pacific hump-backed dolphins and Irrawaddy river dolphins, in inshore waters of the area where barramundi fisheries operate in northern Australia and in areas which shark fishing operations occur.

(4) It is **recommended** that other small scale and recreational gillnet fisheries in Australia which have a potential for impact on inshore cetacean populations be better documented.

(5) Throughout Melanesia, improved documentation of the level and distribution of net and trap fisheries and any cetacean catch or bycatch should be obtained and reporting procedures to maintain the flow of information should be developed. It is **recommended** that these begin as soon as possible. An initial assessment of the identity, distribution and abundance of cetacean populations in the Melanesian region should be made.

(6) Co-operation should be sought between nations of the area, to implement measures designed to increase the awareness of an need to reduce or eliminate incidental catches of cetaceans and other marine mammals and turtles. It is **recommended** that such efforts be initiated through existing regional cooperative bodies.

4.14 South Pacific region

For purposes of this workshop, the South Pacific is defined to include 13 island groups or territories which are loosely combined as follows: Norfolk Island, New Zealand, Fiji Islands, Tonga (including Niue and Tokelau), Western and American Samoa, the Cook Islands, French Polynesia (including Wallis and Uvea) and Pitcairn Island.

The area is predominantly characterised by islands with either fringing reefs or lagoons surrounded by low coral atolls. Two islands, Pitcairn and Norfolk, lack fringing reefs or coastal shelves; passive net or trap fisheries are not conducted there. New Zealand has a large coastal shelf and supports highly-developed fisheries, including set and driftnet fisheries.

Available fisheries information varies considerably throughout the South Pacific depending largely on the level of fisheries conducted. Passive net fisheries are primarily of three types: drift gillnets, deep and shallow set nets and reef-top and reef-passage set gillnets. Information is presented below for all areas for which it was available. Detailed descriptions of the fisheries were presented to the group by Cawthorn.

4.14.1 Set net fisheries in Fiji, Tonga, Samoa, Cooks and French Polynesia

Throughout these islands, set nets in lagoons and atop reefs are used in artisanal subsistence fisheries to collect migrating mullet and sedentary reef fishes for bait and human consumption. The nets are generally of monofilament or multifilament nylon with a stretched-mesh measurement of from 5–12.5cm. Nets are slung in 25–50m lengths and set either at the surface, submerged in reef passages or staked on the reef tops. In some areas, such as Tonga and Fiji Islands, gillnets are set from the beaches inside lagoons and staked to form fish fences to catch mullet and other small school fish on the change of tide. No data are available on the quantities of mullet or reef fishes taken by these methods. We are not aware of cetacean mortalities in any local fisheries in these islands. For islands other than the Marquesas, where drive fisheries for small cetaceans have been conducted historically (for meat and for teeth for use as currency and adornment), there is no history of fisheries targeting small cetaceans. A long-lived fishery for humpback whales in Tonga ceased in 1978. The Fijian practice of trading in sperm whale teeth did not relate to a local fishery.

4.14.2 Gillnet fisheries in New Zealand

There are commercial set and drift gillnet fisheries (366 boats, 455 permit holders in the 1989–90 fishing year) and amateur gillnet fisheries operating in both North and South islands. Species taken include mullet, reef and coastal demersal, flatfish, sharks, elephant fish, groupers, semipelagic species, kingfish and ling. Nets are braided synthetic or monofilament with variable mesh sizes which are regulated to target species. Nets are set inside harbours, on mud flats and on the coastal shelf to waters 200m deep. Commercial landings totalled 39,894 tonnes in 1989. Amateur catch is unreported. Between 1984 and 1987, the set net catch declined by about 60%; this was a result of the introduction of the ITQ (Individual Transferable Quota) management system and the resultant exclusion of many part time fishermen. Currently, 56% of the set net fishers registered are in the north of North Island.

The combination of commercial and amateur inshore gillnet fishing has had a significant impact on the population(s) of Hector's dolphins in the Banks Peninsula region of the south island. Results of recent studies of population status and catch rates led to the establishment of a sanctuary in this area and to increased attention to this species throughout New Zealand. A deep set net fishery for grouper at Kaikoura takes a substantial number of dusky dolphins annually. Ten to 25 pinnipeds are killed annually in bait nets set around the South island. To date, no cetacean mortalities have been documented in this fishery. In apparently isolated incidents, a right whale stranded following entanglement in a rock lobster pot-buoy line and reports of minke and sperm whales entangled with netting and/or line have been received. Recently, a trawler, fishing for jack mackerel with mid-water trawl in the western approach to Cook Strait reported taking 35 common dolphins.

4.14.3 Recommendations

(1) It is **recommended** that national and local island authorities be encouraged to monitor marine mammal fishery interactions systematically in all net fisheries.

(2) Fishing fleets of the area require better documentation. It is **recommended** that an improved flow of information on marine mammal fishery interactions be achieved, possibly through the South Pacific Regional Environment Programme, which could co-ordinate such data collection.

(3) It is **recommended** that the South Pacific Forum be encouraged to ensure that large scale driftnet fisheries do not operate in this area in view of the impact that such fisheries have had on local tuna stocks as well as their impact on cetaceans and other non-target species.

4.15 Micronesia and Central Pacific region

This region includes Guam, Federated States of Micronesia, Hawaiian Islands (US), Kiribati, Republic of the Marshall Islands, Nauru, Commonwealth of the Northern Mariana Islands (CNMI) and the Republic of Palau. Bottom-set gillnets are widely used in this area to catch a variety of lagoon, reef and nearshore fishes. Fishing operations are typically artisanal/subsistence or small-scale commercial. These fisheries are summarised below. Fisheries of the Hawaiian Islands are considered separately. Detailed information is given by Nitta (SC/O90/G33).

4.15.1 Artisanal and small-scale fisheries

Subsistence or small-scale commercial gillnet fisheries are found on Nauru, Kiribati, Guam, the Northern Mariana Islands, the Republic of Palau, the Federated States of Micronesia and the Republic of the Marshall Islands. Nets are typically bottom-set gillnets which are used to fish for reef fish, nearshore fish and lagoon fish. Common fish types include bigeye scad, mackerel, mullet, wrasses, goatfish and jacks. Nets are set by hand or from small skiffs, canoes or outboard-powered boats. Information on fishing effort is limited to Yap in CNMI where 3,483 gillnet trips were reported for 1987. The gillnet landings on Yap were 35 tonnes that year. The 1988 commercial (including but not exclusively gillnet-caught) landings of bigeye scad and reef fish on Guam were 61 tonnes (worth $215,219) and on CNMI were 4.5 tonnes (worth $19,364). The 1987 commercial landings of reef and lagoon fish for Tarawa (in Kiribati) was 3,628 tonnes (again including but not exclusively gillnet landings). No information was available at the meeting on landings or fishing effort in the other island nations. Some of the outer island villages and councils in the Federated States of Micronesia and the Republic of the Marshall Islands have banned the use of set gillnets in their jurisdictions. No incidents of incidental cetacean mortality in gillnets were reported at the meeting. It was noted, however, that small cetaceans had been taken in the past for subsistence purposes in Kiribati and the Marshall Islands.

4.15.2 Surround-net and gillnet fisheries in Hawaii

Inshore set gillnets are used to catch a variety of fish on reef flats, in bays and in nearshore areas around all of the main Hawaiian Islands. Species include bigeye and mackerel scad, squirrelfish, aholehole, goatfish, rudderfish, wrasse, parrotfish, surgeonfish and tangs. Surround nets are used to catch akule and opelu. Of 2,952 applications for commercial fishing licenses in Hawaii, 498 listed nets as their primary gear and 169 specified gillnets. The actual number of fishermen using gillnets is probably greater than 169. Vessels are typically 10–30ft (3–9m). Commercial landings in 1988 for reef fish, akule and opelu were 120 tonnes, 146 tonnes and 124 tonnes, respectively. Values of these landings were $441,220, $592,964 and $438,845, respectively. Marine mammals reported taken in these fisheries include spinner dolphins and one monk seal. Humpback whales may also be entangled, but there are no confirmed reports of this.

4.15.3 Recommendations

(1) It is **recommended** that fisheries data collection programmes be developed and implemented in those areas where they are currently lacking.

(2) It is **recommended** that the appropriate US agency be urged to assist the Freely Associated States of the Federated States of Micronesia and the republic of the Marshall Islands in developing counterpart legislation similar to the US Marine Mammal Protection Act and Endangered Species Act. Similar assistance should be provided to Palau.

4.16 Japan coastal region

There are many trap net fisheries in Japanese coastal waters. These can be divided into large- and small-scale trap nets for miscellaneous coastal fishes throughout Japan and a large-scale trap net fishery for salmon in Hokkaido and northern Japan. Summaries of information on these fisheries are presented below. The Japanese large-scale driftnet fisheries originated in Japanese coastal waters, but Japan now prohibits the use of large driftnets within its 200 mile zone because of conflicts with other types of gear which were already used before the introduction of this technique (United Nations, 1990). Detailed information on trap net fisheries is given by Tobayama *et al.* (SC/O90/G36).

4.16.1 Japan coastal small-scale trap net fishery

Small-scale trap fisheries for a large variety of fish species are found along much of the Japanese coast. Typically the water depth at the pocket is less than 27m. There were 14,591 such fish traps in 1988 (this number has varied between 14,324 and 16,123 over the past 11 years). The total landings were 191,523 tonnes in 1988 and were worth $424 million. Some of the 14 cetacean species listed in SC/O90/G36 could have been taken, but there are no statistics specifically for bycatch in this fishery.

4.16.2 Northern Japan coastal large-scale trap net fishery for salmon

Salmon are taken in large-scale trap fisheries in Hokkaido. In these traps, water depth at the pocket exceeds 27m. The number of nets has been stable, varying between 674 and 778 over the past 11 years. Most of the traps are 1–2km long and are fished from summer to autumn. The catch was 92,497 tonnes in 1988 and was worth $481 million. Some of the 14 cetacean species listed in SC/O90/G36 could have been taken, but there are no statistics specifically for bycatch in this fishery.

4.16.3 Japan coastal large-scale trap net fishery

Large-scale trap fisheries for a variety of fish species exist along the Japanese coast. This fishery is limited to water depths at the pocket of greater than 27m (with some exceptions in Okinawa and the inland sea). The number of nets has been stable, with fluctuations between 791 and 909 over the past 11 years. Most traps are fished year-round. Total catches were 363,766 tonnes in 1988 and were worth $500 million.

4.16.4 Recommendation

It is **recommended** that collection of statistics on the incidental capture of marine mammals in trap and gillnet fisheries in Japan be improved.

4.17 Korean coastal region
No information was made available to the meeting. A fishery yearbook for 1987 reported that 39,921 tonnes of fish were landed from 'large gillnets', 58,539 tonnes from 'small gillnets', 21,421 tonnes from 'large set nets' and 32,508 tonnes from 'small set nets' (Ministry of Agriculture, Forestry and Fisheries, 1988). There is no information available on incidental catches of cetaceans, but it must be assumed that some does occur and it is **recommended** that the national government begin efforts to collect such information.

4.18 China, Taiwan Insular region
Chen (1990) noted that bottlenose dolphins are taken in gillnets in China, Taiwan but did not specify if these are incidental or directed takes. In 1989, a variety of local (as opposed to far-seas) coastal and offshore fisheries using drift and set nets landed over 55,135 metric tonnes of fish and crustaceans caught in China, Taiwanese or adjacent waters, of nearly 100 species (Taiwan Fisheries Bureau, 1990). Information on bycatches is badly needed and it is **recommended** that the national government establish a programme to collect the information.

4.19 Mainland China region
There are a huge number of coastal and freshwater fisheries in Chinese waters that have the potential to impact cetacean populations. Until recently, and with the exception of the baiji, incidental captures of cetaceans have received little study. Since 1983, however, a total of 74 finless porpoise specimens have been recovered by researchers from passive fishing gear in Jiangsu province. [The highly endangered baiji continues to be threatened by incidental mortality in rolling hook longlines – a type of gear not discussed at this meeting]. The carcasses of other small cetaceans killed in coastal fisheries may be used locally for livestock feed. Chinese fisheries are reviewed by Zhou in SC/O90/G21.

4.19.1 Drift gillnets
These nets are widely used in Chinese coastal waters to take a great variety of target species. Mesh sizes vary from 4–16cm, depending on the target species. Unknown numbers of finless porpoises are taken by these nets in coastal waters and in the Yangtze River. Other species are probably also taken, although there are few records of entanglement. Rough estimates indicate that there may be as many as 10,000 drift gillnet vessels active in Chinese coastal waters.

4.19.2 Set gillnets
At least eighteen varieties of set gillnets are used in Chinese waters, with mesh sizes varying from 5.6–32cm. Although the nets are extensively used in shallow inshore waters, there are no data on cetacean entanglements. Approximately 7,000 set gillnet vessels operate along the Chinese coast.

4.19.3 Stow nets
These fixed traps are important components of the coastal fisheries of the East China Sea, Yellow Sea and Bohai Sea. Fish, shrimp and crabs are transported by nearshore currents into these nets. The nets are divided into six major categories, depending on their structural configuration. Finless porpoises are known to be taken by Chinese stow nets. As many as 20,000 vessels are used in the Chinese stow net fishery.

4.19.4 Fish traps
Three major types of traps (other than stow nets) are used in both fresh and salt water to take a variety of species. Finless porpoises and false killer whales are taken alive by traps in coastal waters and occasionally transported to zoos and aquaria. Baiji are sometimes captured by stake net traps set in the lower Yangtze.

4.19.5 Recommendations
(1) A general system to monitor the levels of marine mammal mortality in gillnet, stow net, trap and longline fisheries off the Chinese coast is urgently needed and it is **strongly recommended** that such a system be established as soon as possible.
(2) The population status of the finless porpoise should be studied urgently. Although data are lacking for the Indo-Pacific hump-backed dolphin, it is believed that this coastal species may also be threatened by incidental catches in fishing gear. It is **recommended** that studies of the two species be initiated.
(3) It is **recommended** that urgent measures be taken to strictly enforce the ban on longline snag fisheries ('rolling hooks') in the Yangtse.

4.20 Eastern North Pacific and Russian Far East region
This region includes the west coast of the USA and Canada and the east coast of the Russian Federation. Several of the more important gillnet and trap fisheries are summarised below. Not included in the summaries is the discontinued joint-venture driftnet fishery for flying squid in Canada. More detailed information is available in Barlow *et al.* (SC/O90/G29) and Burkanov (SC/O90/G10).

4.20.1 California drift gillnet fishery for swordfish and sharks
Nylon mono- and 3-filament nets are used to catch shark and swordfish in the offshore waters of California. Nets are 500–1,000 fathoms long (910–1,820m) and have a 18–24" (45–60cm) mesh. Vessels are approximately 30–75ft (9–23m) in length and carry a crew of 2–6 fishermen. There are 185 permits to participate in this fishery, but only 150 are active. The total effort consisted of approximately 8–10,000 net pulls per year, with a slight decrease in recent years. Nets are suspended 2–5m below the surface and are only allowed to soak at night. Assuming an average length of 750 fathoms (1,370m), total effort is about 10,000KND. Cetaceans taken have included gray, minke, Hubb's and Cuvier's beaked whales, common dolphins, northern right whale dolphins, short-finned pilot whales, Pacific white-sided dolphins, Risso's dolphins and killer whales. Annual mortality rates have been estimated only for California sea lions (150–5,100), harbour seals (0–150) and rorquals (73).

4.20.2 California set gillnet fishery for halibut and angel sharks
Bottom-set gillnets are used to catch halibut in central and southern California and angel sharks in southern California. Vessels range from 15–40ft (4.5–12m) in length and have crews of 1–3 fishermen. Currently there are 200 permits, but only 189 are actively fishing. Nets are made of nylon mono- or multi-filament with a mesh size of approximately 8" (20cm). Nets are 150–200 fathoms (275–365m) long. In 1986/87, about 30,000 sets were made for a

total fishing effort of 8–11,000KND. Effort is decreasing in central California and may be stable or decreasing in southern California, largely due to the impact of gillnet regulations. Annual marine mammal mortality has been estimated for harbour porpoises (50–300), gray whales (<10), California sea lions (2,000–4,000) and harbour seals (1,000–2,000).

4.20.3 Washington bottom-set gillnet fishery for salmon
A small fishery exists for chinook salmon in northern Washington State. This fishery is unique in that it uses bottom-set gillnets rather than the more typically floating gillnets for salmon. The fishery is run by native Americans. Vessels are typically small (16–24ft/5–7.5m). Mono- and multi-filament nylon nets are used, with mesh sizes of 7.75–8.5" (19.5–21.5cm). There are 6–10 vessels fishing a total of about 1,300–2,600 net-days each year. Total effort is thus about 240–480KND. Annual marine mammal catches include harbour porpoises (20–100) and minke whales (0–1).

4.20.4 Alaska and British Columbia driftnet fisheries for salmon
There are many separate areas where drift gillnets are allowed in Alaska and Canada. Although the fisheries may be regulated separately, the methods used are similar and all are combined for this summary. Nylon multifilament nets are used with lengths of 135–550m and mesh sizes of 4.5–8.5" (11.5–21.5cm). Vessels are typically 7–12m in length. The number of vessels is limited by the number of permits. Currently there are 3,230 license holders in Canada and 3,487 in the USA. Fishing effort is fairly stable, but catch varies with the strength of the salmon runs. Landings in 1988 were approximately 100,000 tonnes and were worth approximately $647m. Marine mammal mortality in nets includes mostly harbour porpoises, Dall's porpoises, white whales and harbour seals. Mortality rates have not been estimated for most of this region.

4.20.5 Alaska set gillnet fisheries for salmon
Again, there are many separate areas where set gillnets are allowed for salmon fishing. All such areas are considered together in this review. Set gillnets are used to catch all five Pacific salmon species. Nets are 15–150 fathoms (27–275m) in length and are usually set to float at the surface, perpendicular to the shore. Nets are typically set with small (4–8m) vessels. There are 4,172 permit-holders allowed to fish with set gillnets in Alaska. The total value of landings was in excess of $140m in 1988.

4.20.6 Salmon trap fisheries in the Kamchatka region
In eastern Russia, salmon are caught almost exclusively in trap nets. Gillnet fishing is not allowed, but is carried out illegally by vessels from several countries. Approximately 100 traps (100m x 800m dimension) are in the Kamchatka region. Each is operated by approximately 10–12 fishermen. The traps are typically operated 70–75 days each year. Fishing effort varies with the strength of the salmon run. About 40–60,000 tonnes of salmon are landed each year and total landings are worth 24–36 million rubles. The only historical records of cetacean mortality include one narwhal and one gray whale (which was released). Seals (*Phoca larga*) commonly are found inside and outside the trap and are frequently shot. One stranded North Pacific right whale was found entangled in net fragments.

4.20.7 Bottom long-line fisheries in Kamchatka and Okhotsk Sea
Longlines are used to catch cod in eastern Russia. Vessels are large (500 tonnes) and fish one 51km line per vessel. There are 10 vessels in the fleet, each of which fish 120 days per year. Fishing effort is currently up. There are no known records of marine mammal mortality in this fishery.

4.20.8 Crab trap fisheries in the Kamchatka region
Crab traps are fished by large (300–900 tonne) vessels in eastern Russia. There are 50–80 vessels, each with 18–30 fishermen. Each vessel fishes approximately 450 traps during a 120–180 day fishing season. The fishery is stable. Marine mammal mortality has involved gray whales (only one known case) and seals (*Phoca larga* and probably *Phoca hispida*).

4.20.9 Recommendations
(1) It is **recommended** that baseline data be gathered on levels of marine mammal mortality for all fisheries in the region based on direct observations and other appropriate methodology. Fisheries which are found to have a significant level of marine mammal mortality should be continuously monitored.
(2) The population size of those species most likely to be affected by fishing mortality should be estimated. For most species it is **recommended** that this include determining stock boundaries, abundance and seasonal distribution. When possible, trends in abundance should also be measured.

4.21 Southeastern Pacific region
The mortality of cetaceans is known to be high in some areas within this region, which includes Ecuador (including Galapagos Islands), Peru and Chile (including Easter Island). Information from Ecuador is scarce, but the coastal artisanal and industrial fisheries of Peru and Chile are thoroughly described by Reyes and Oporto (SC/O90/G11). In central Peru small cetaceans are used for human consumption; in Chile, the meat from dolphins and porpoises is often used for bait.

4.21.1 Swordfish driftnet fishery
This fishery operates in Chilean waters from 15 to 200 n.miles from shore. The target species is swordfish, captured in driftnets up to 2.2km in length and 29–45m deep. The mesh size employed in this fishery varies from 45–56cm. Approximately 800 vessels are active in this fishery, which is currently stable or increasing in size. Landings in 1989 reached 5,824 tonnes, with a value of between $12 and $25m. An unknown number of sperm whales, killer whales and southern right whale dolphins are taken in these driftnets. It is interesting to note the similarities between this fishery and the former Italian swordfish driftnet fishery in gear type, operation and the incidental catch of sperm whales.

4.21.2 Chilean bottom set net fishery
Ratfish and sciaenids are taken in demersal set gillnets in southern Chilean coastal waters. The nets are made of 15cm mesh and vary in length, depending on the location, from 200–800m and are from 4–6m deep. The nets are set in water depths of 15–80m and allowed to soak for 10–12 hours. In 1989, 57 Burmeister's porpoises and 51 Chilean dolphins were landed; catches of Peale's dolphins are also occasionally recorded. Approximately 90 small vessels are active in the fishery, but this number is expected to triple in the next few years.

4.21.3 Chilean salmon cage fishery

Peale's dolphins, together with sea lions and fur seals, are occasionally captured in anti-predator nets set around salmon aquaculture operations in Chilean waters. These anti-predator nets are made of 47cm mesh. The numbers of dolphins killed is unknown, but there are about 3,400 active salmon cages operating in this expanding industry.

4.21.4 Ecuadorian gillnet fisheries

This category encompasses a variety of disparate fisheries that operate in both coastal and offshore areas. Cotton and monofilament nets are used, with mesh sizes of 5–20cm and lengths of 70–200m, depending on the target species. The nets are set for a variety of fishes, from sharks and billfish to jacks and catfishes. Bottlenose and pantropical spotted dolphins are taken in these fisheries in relatively small numbers.

4.21.5 Peruvian gillnet fisheries

A diverse group of artisanal gillnet fisheries exists in Peruvian waters. These fisheries target a variety of species, ranging from bonito and blue sharks to demersal rays. The mesh size varies with target species from 3–44cm. The nets are constructed from multifilament and are from 70–270m in length and from 2–27m deep and may be operated as both bottom set and surface driftnets. Approximately 2,600 artisanal vessels are active in this growing fishery. The minimum count at one port in central Peru was 868 Burmeister's porpoises, 5,115 dusky dolphins, 476 common dolphins, 132 bottlenose dolphins and smaller numbers of 11 other odontocete species landed between 1985 and 1989. In addition, at least one humpback whale was entangled but released alive.

Gillnet fisheries in Peru blur the traditional distinction between directed and incidental take, because all small cetaceans are used for human consumption. Thus, captures of dolphins and porpoises are welcomed by fishermen as additional sources of income. In several cases, such as the offshore driftnet fishery, dusky dolphins and other odontocetes have themselves become the target species. It is likely that the utilisation of cetacean bycatches in this manner developed after the crash of the industrial anchoveta fishery in 1972.

4.21.6 Recommendations

(1) It is **recommended** that national fisheries agencies in the region should collect and report fishery statistics separately for gillnets and for other types of gear.
(2) It is **recommended** that information be obtained on cetacean entanglement in the swordfish and set net fisheries of Chile.
(3) It is **recommended** that all three nations collect more comprehensive statistics on cetacean catches and in number rather than weight.
(4) Alternative fishing methods should be sought to reduce marine mammal mortality without affecting fishery yields. It is **recommended** that technological programmes to this end be established.
(5) The crab fishery in Chilean and Argentine waters needs further study and an alternative to wildlife meat as crab bait needs to be found; it is **recommended** that a regional effort to do this be initiated.
(6) It is **recommended** that regional cooperative educational programmes be developed to highlight the problem of cetacean mortality in fishing operations.
(7) It is **recommended** that the impacts of marine farming on cetacean populations in Chile receive urgent attention.

4.22 North Pacific Basin (large-scale pelagic driftnet fisheries)

Driftnet fisheries are conducted in the North Pacific basin by Japan, South Korea and China, Taiwan. Detailed information is given by Jones *et al.* (SC/O90/G43), Nagao (SC/O90/G55) Northridge (SC/O90/G35), Watanabe (SC/O90/G52) and Yatsu (SC/O90/G8),

4.22.1 Japanese salmon drift gillnet fishery

Surface driftnets are set for Pacific salmonids (pink, sockeye, chum, coho and chinook) by mothership and landbased fleets in the western North Pacific and the Bering Sea. Nets are nylon monofilament of 11–13cm stretched mesh. Regulations require vessels to set no more than 15km of net, which is usually deployed in three sections. Vessels in each fishery are mostly less than 30m in length. The mothership fleet included 43 catcherboats in 1989 and operated from June 1 to early July. Vessels averaged 30 fishing days. Effort was approximately 19,350KND. Landings totalled about 1,150 tonnes of salmon. The landbased fleet operates from late May through June and totalled 108 vessels in 1989. Vessels also average 30 fishing days. Effort was approximately 48,600KND. Total landings were about 2,040 tonnes. There is a definite downward trend in this fishery. The predominate cetacean bycatch is of Dall's porpoises. US observers were placed in the mothership fleet inside the US EEZ from 1981 to 1987. Annual point estimates of the take ranged from 741 to 4,187 Dall's porpoises, the latter number occurring in 1982. A few harbour porpoises were also taken. Northern fur seals are incidentally taken.

4.22.2 Drift squid gillnet fishery

Japan, the Republic of Korea (ROK) and China, Taiwan operate fleets in the North Pacific targeting on neon flying squid (*Ommastrephes bartrami*). In 1989, a joint Japan-Canada-USA programme placed observers on 32 vessels. This programme has been expanded to 74 vessels in 1990. Joint programmes were arranged between the USA and China, Taiwan and the USA and ROK in 1989 as well, placing observers at sea in 1990. Information on the Japanese fishery is more complete and will be discussed separately.

The Japanese squid driftnet fleet includes 457 vessels and approximately 8,000 fishermen in 1990. The area of operation is the North Central Pacific, from 20°N-46°N (mostly north of 38°) and 170°E-145°W. The season is June-December, peaking in July-August. Vessels are 25–60m in length. The gear is nylon monofilament surface gillnet, usually 11–12cm stretch mesh. Data collected in 1989 indicated that an average of approximately 50km/vessel/day was set. There were 33,646 days fished in 1989, with 1,719,311km of net fished. The value of the 157,773 tonnes of squid landed in 1988 was $300m. The number of vessels in the fishery appears to be stable. Data from the 1989 pilot observer programme yielded the following catch-rates (per 50km of net): northern right-whale dolphin = 0.32; Pacific white-sided dolphin = 0.18; Dall's porpoise = 0.10; common dolphin = 0.01; others/unknown = 0.04. The catch rate for all cetaceans was 0.64 per 50km of net. Scientists from Canada, Japan and the USA will be analysing the data to estimate the catch for the entire fishery in the near future. Statistically reliable catch rates will be obtained from the 1990 observer programme.

China, Taiwanese and ROK squid driftnet fleets operate in the North Pacific between early March and late December. Fishing peaks in July-August. The area of operation is similar to that of the Japanese fleet, although both nations fish west of 170° East. Vessels range in size from 29–70m. There are approximately 150 Korean and 27 China, Taiwanese vessels with about 3,500 to 4,600 crew total. Vessels deploy surface gillnets of 7.5–13cm stretch mesh. Nets are usually 10–11m deep and up to 60 km or more in length. They are set out in 3 to 6 discrete sections. There is a trend towards fewer vessels, although the amount of gear deployed per vessel has increased. Effort data will be available after observers return from sea. The cetacean bycatch is undocumented, although the species taken will likely be similar to those of the Japanese fleet. Cetacean incidental take rates may differ from those in the Japanese fleets because smaller mesh sizes are used and different areas are fished.

4.22.3 Japanese large mesh drift gillnet fishery

Japanese vessels targeting on albacore and skipjack tuna, swordfish and marlin use nylon multifilament 170–210mm stretch mesh. The area of operation is north of 10°N, south of the squid fishing area, from approximately 145°W to Japan. This includes both coastal and high seas vessels, totalling 459 in 1988 (there will be less than 200 vessels in the high seas in the 1990/91 season). Coastal vessels set approximately 12km of net and high seas vessels set approximately 20–50km. The fishery is valued at $70m, with 25,000 to 40,000 tonnes landed including 7,000–15,000 tonnes of albacore. There appears to be a stable or downward trend in fishing effort. Cetacean catch rates on high seas vessels will be obtained during the 1990 joint observer programme. Reports from a research cruise indicate the species taken includes Northern right whale, common, Pacific white-sided, striped, bottlenose, Risso's and spotted dolphins, pygmy killer whales, pygmy sperm whales and ziphiids.

4.22.4 China, Taiwanese large mesh drift gillnet fishery

China, Taiwanese vessels of 29–70m length operate in the North Pacific targeting on albacore and skipjack tuna, swordfish and marlin. Little is known of these fleets, although USA and China, Taiwanese observers will monitor fishing activities on about 20 of 123 vessels in the 1990 season. Fishing is mostly between May and November, north of 20°N and south of the squid fishing area. There are probably 2,000–3,000 fishermen of several different nations, including China, Taiwan, the Philippines, Thailand and South Africa. Limited information indicates nets are nylon multifilament, 18–21cm stretch mesh and from 6.5 to 21m deep. Normal net depth is 10–11m. Cetacean bycatch is unknown but probably includes many of the same species seen in the squid driftnet fishery. Several warmer-water species may be taken as well.

4.22.5 Recommendations

(1) Japan, Canada, Korea, the USA and China, Taiwan are to be commended for the establishment of an international programme to collect data on incidental catches in the North Pacific. It is **recommended** that, should these fisheries continue, the observer programme continue to collect statistically adequate data.

(2) It is **recommended** that the data collected on mammals taken in the squid driftnet and large mesh driftnet fisheries be analysed as soon as possible.

4.23 South Pacific Basin (large-scale pelagic driftnet fisheries)

This area has experienced extensive driftnet activity in recent years. Vessels from Japan, ROK and China, Taiwan have been active, although recent conservation measures have greatly affected the composition of the fishery. Northridge (SC/O90/G35) provides a review of this fishing activity. Additional information is provided by Hagler (1990), Coffey and Grace (1990), Murray (1990), Watanabe (1990) and Sharples *et al.* (1989).

4.23.1 Large-mesh driftnet fishery

Albacore and other large pelagic species are captured in driftnets between 20 and 55 km long, 10–15m deep and with mesh sizes of 16–20cm. The fishery operates in the Tasman Sea and in the waters east of New Zealand. Large-mesh driftnetting in this area was started in 1983 by Japanese vessels. By the 1988–89 season the fishery included 64 Japanese vessels, between 60 and 130 China, Taiwanese vessels and a single Korean fishery survey vessel. In 1988, catches by the Japanese fleet alone had reached 4,801 tonnes. These driftnets are known to have taken a variety of cetaceans, including common, striped and Risso's dolphins, short-finned pilot whales and southern bottlenose whales. Estimates of entanglement rates for common dolphins have varied between 56 and 70 individuals per 1,000km.

Concern over conservation of both tuna and non-target species gave rise to the Tarawa Declaration, adopted by the South Pacific Forum in 1989. The Declaration resolved to prevent and discourage the practice of driftnetting in the region. The Japanese fleet has since withdrawn from the area and China, Taiwan has indicated that it will also cease driftnetting activity in the South Pacific. There are currently no Korean vessels active in the region.

4.24 Indian Ocean Basin (large-scale pelagic driftnet fisheries)

The only large scale driftnet fishery that exists in this region is the China, Taiwanese high seas large-mesh driftnet fishery. Information was provided by Northridge (SC/O90/G35) and Cockcroft (SC/O90/G20).

4.24.1 Large-mesh driftnet fishery

There is little published information on this China, Taiwanese fishery. Albacore is the primary target species, but a variety of large pelagic fish are also captured. The gear used is similar to that used in other high seas driftnet fisheries: mesh sizes of 20–22cm, total net lengths of 37–47km and net depth of 2–24m. There are no data on actual fishing effort, but most fishing activity is concentrated in either the Arabian Sea or southern Indian Ocean. The fishery was started in 1985 and by 1989 included 139 vessels, with evidence of continued expansion. Catch estimates for 1989 were 19,523 tonnes. No data on cetacean entanglements are available, although incidental catches are likely to be substantial. Additional information is given in Indian Ocean Fishery Commission (1990).

4.25 North Atlantic Basin (large-scale pelagic driftnet fisheries)

The only documented large-scale driftnet fishery in the North Atlantic is the new and rapidly growing French albacore fishery (SC/O90/G35,G53). The fishery has also been entered recently by Ireland on an experimental basis. There is circumstantial evidence that a China, Taiwanese driftnet fleet may also be operating in the North Atlantic (SC/O90/G35).

4.25.1 French albacore driftnet fishery
This fishery began as an experimental fishery in 1986. The primary target species is albacore, but bluefin tuna and swordfish are also taken. The area fished includes the offshore Bay of Biscay and waters extending from near the Azores to south of Ireland. The net mesh size ranges from 8–12cm; individual net panels are 50m long and 20–36m deep, with a hanging ratio of 0.6. Total net length ranges from 2,500 to 7,000m and varies with vessel size; a 20km net was reported observed by Greenpeace. The 37 vessels in the fleet in 1989 were all less than 25m long. The fishery has grown rapidly since its inception and is still expanding. The fishing season is approximately 3.5 months long, yielding a rough estimate of several hundred thousand KND per year. The catch in 1988 was 750 tonnes. Cetaceans known to be taken incidentally include striped, common and bottlenose dolphins. Other species are probably also taken. The incidental catches have been estimated at 131 dolphins in 1989 and 420–460 in 1990, at a rate of 0.03 to 0.08 per km of net (Antoine, 1990). There is no information on the bycatches in an Irish experimental fishery in the same region.

4.25.2 China, Taiwanese tuna/squid driftnet fishery
China, Taiwanese driftnet vessels have been seen in Port of Spain Harbour, Trinidad with driftnets stacked on their rear decks. The China, Taiwanese Government has stated that the nets are for flying squid rather than for tuna. Possible areas of fishing include off the mouth of the Amazon, in the region of the Azores and off West Africa. Nothing is known of landings or incidental catches.

4.26 South Atlantic Basin (large-scale pelagic driftnet fisheries)
An unacknowledged China, Taiwanese driftnet fishery for tuna exists in the South Atlantic (SC/O90/G4, G20, G35).

4.26.1 China, Taiwanese albacore driftnet fishery
A fleet of perhaps several hundred China, Taiwanese driftnet vessels is known to fish in the vicinity of the South Atlantic islands of Tristan da Cunha and Gough and farther to the east. One vessel that went aground in South African waters carried 145km of driftnetting. There is no information available on landings. Increased discharges and transshipments of frozen tuna in Cape Town indicate that the fishery has been rapidly expanding. Based on reports for one month on the fishing grounds and a total of 500 vessel months, 7,500–10,000 dolphins and 1,000–1,500 small whales may be killed annually; the species make-up of this bycatch is unknown.

5. IMPACTS ON SPECIES AND POPULATIONS

DeMaster chaired the sub-group established to evaluate the impact of passive nets and trap fisheries on species and populations of cetaceans. Hohn and Heyning served as rapporteurs and compiled the initial versions of this section of the report, with the assistance of Brownell, Perrin and Forney.

The terms of reference given by the IWC Scientific Committee were to estimate the mortality of cetaceans in passive nets and trap fisheries and assess the impact of that mortality on cetacean populations. The agenda included examination of what might constitute sustainable kill levels; identifying fisheries with kills clearly not sustainable, possibly not sustainable and sustainable; summarising the age and sex composition of the kill, summarising information on population trends, providing preliminary estimates of net replacement rates for populations under sustainable exploitation, and discussing problems of stock identity and their implications. It was agreed to accomplish this by constructing a table that listed, by species and stock or geographic region: (1) the annual level of kill in passive nets and traps; (2) the approximate annual level of mortality from other sources, including directed fisheries, incidental mortality in non-passive gear and accidental mortality such as boat collisions; (3) population size; and (4) the impact of the kill in passive nets and traps. Other relevant information is given below as notes to the table.

The impact of mortality in passive nets and traps on populations was calculated from estimated kills and population size, where possible. In addition, the impact was categorised as to the severity of the mortality to the population. For those few populations for which the level of mortality, population size and replacement rates were known or could be reasonably estimated, this task was relatively easy. For most populations, however, this evaluation was made on the basis of very scanty information, reflecting knowledge of the fisheries and very rough estimates of possible or probable levels of mortality in passive fishing nets and traps.

5.1 Definitions
The various broad levels of impact used in the table are defined below.

(1) *Not sustainable.* Kill and population data indicate that the mortality rate exceeds the expected replacement rate of the population.
(2) *Possibly not sustainable.* Kill and population data indicate that the mortality rate is close to the expected replacement rate of the population, giving reason to believe that the population may decline.
(3) *Potential.* Adequate data on kill, population size or both are lacking. The available data suggest that the kills may not be sustainable. More data need to be collected. For cases where adequate data were not available but information from similar situations/areas/ species was available and indicated that the kill was not sustainable, it was considered likely that the population in question probably cannot sustain the kill.
(4) *Minimal.* Data suggest some impact on the population although mortality rates do not exceed the level that should cause an immediate decline in the population.
(5) *Not significant.* Mortality in passive gear is known to occur, but data suggest that the levels are low relative to population size.
(6) *Unknown.* Used when sufficient data for even the crudest evaluation were unavailable.

The members of the sub-group were assigned species/ regional reviews and asked to complete a form that was drafted to help members compile the information in a consistent manner. These data were tabulated and re-examined by the sub-group for consistency, as possible.

Table 1

A summary of information on the number of cetaceans killed annually by passive gear and impacts of these mortalities on the populations. Stocks are not listed if the workshop received no data or was not aware of any data confirming kills in such fisheries. Population estimates were obtained from the literature or from workshop participants. Species are presented by known stock or geographic regions where data were available. Stocks/areas with unsustainable catches are highlighted in bold text. *This Table must be used in conjunction with the extensive annotations given in the text of Section 5.*

Terms, abbreviations and symbols used in the table:

No. killed p.a. - refers to annual kills in passive gear and traps only; '>' or '<' beside the number indicates that the figure represents a minimum or maximum, respectively. A minimum estimate might be available because the sampling effort was low relative to likely fishing effort, e.g., only a small number of fishing ports were observed. A maximum may be given if the mean mortality is less than a whole number and the estimate is rounded up, generally done when fewer than one animal was recorded killed per year or if the number places a likely upper bound on the kill.

Additional killed p.a. - refers to annual kills caused by other forms of non-natural mortality, such as kills in non-passive gear, directed kills and accidental kills such as boat collisions. '>' or '<' has the same meaning as above.

Population size - abundance was unknown for most populations. For some populations/regions, an abundance estimate was not available but the population was suspected to be small '(small?)'. When the population size given is thought to be a minimum or maximum, the estimate is preceded by '>' or '<', respectively.

Impact of passive kill - when data were available, the percentage of the population killed annually in passive nets and traps is given. In addition, five qualitative levels of impact are used: not sustainable; maybe not sustainable; potential; minimal; and not significant. A '*' beside the designation 'potential' indicates that although the population size is unknown, it is thought to be low relative to the magnitude of kill in passive gear.

Species and stock/area	*No. killed p.a.*	*Additional killed p.a.*	*Population size*	*Impact of passive kill (% of popn)*
		Family Balaenidae		
Eubalaena australis, southern right whale				
S. Africa	< 1	unknown	1200	<0.2: minimal
New Zealand	< 1	unknown	unknown	unknown
Eubalaena glacialis, northern right whale				
Western N. Atlantic	< 1	some	> 350	< 0.3: maybe not sustainable
N. Pacific	< 1	0	50	< 2: maybe not sustainable
Caperea marginata, pygmy right whale				
Coast of S. Africa	< 1	none	unknown	unknown
		Family Eschrichtiidae		
Eschrichtius robustus, gray whale				
N. Pacific - eastern stock	low tens	> 179	21,000	< 0.5: not significant
		Family Balaenopteridae		
Balaenoptera spp., unidentified rorqual				
Caribbean	some	unknown	unknown	unknown
B. acutorostrata, minke whale				
Mediterranean	< 4	unknown	rare	minimal
Western N. Atlantic	10-20	some	unknown	unknown
Eastern N. Atlantic	some	some	unknown	unknown
Southern Hemisphere	some	300	750,000	not significant
Western N. Pacific	< 10	0	unknown	unknown
Eastern N. Pacific	low tens	some	unknown	unknown
B. edeni, Bryde's whale				
Coastal Brazil	< 1	unknown	unknown	unknown
B. physalus, fin whale				
Mediterranean	< 1	some	< 1,000	0.1: minimal
Eastern Canadian coast	< 1	unknown	low 1,000's	< 0.1: not significant
Northern Indian Ocean	< 1	some	unknown	unknown
Megaptera novaeangliae, humpback whale				
Western N. Atlantic	5-20	< 3	5,500	< 0.4: minimal
Indian Ocean	some	0	small?	unknown
Western N. Pacific	some	0	small?	potential
Hawaii - Alaska	< 2	0	> 1,000	< 0.2: minimal
Mexico - California	some	0	250	potential
Coastal Peru	< 1	0	low 100s?	minimal
		Family Platanistidae		
Platanista gangetica, Ganges susu	some	some	unknown	unknown
		Family Iniidae		
***Lipotes vexillifer*, baiji**	**some**	**some**	**300**	**not sustainable**
Pontoporia blainvillei, franciscana				
Southern Brazil	90	unknown	unknown	potential
Uruguay and northern Argentina	> 230	some	unknown	unknown
Inia geoffrensis, boto	some	some	unknown	unknown

Table 1 continued

Species and stock/area	*No. killed p.a.*	*Additional killed p.a.*	*Population size*	*Impact of passive kill (% of popn)*
		Family Monodontidae		
Delphinapterus leucas, white whale				
Bristol Bay	< 30	19	1,000-1,500	< 2-3: maybe not sustainable
Cook Inlet	some	10	300-450	unknown
		Family Phocoenidae		
Australophocaena dioptrica, spectacled porpoise	unknown	unknown	unknown	unknown
Neophocaena phocaenoides, finless porpoise				
Thailand/Pakistan/India	some	some	unknown	unknown
Yangtze River	10-20	unknown	1,500	0.7-1.3: minimal
Yellow Sea	50	unknown	unknown	unknown
Coastal Japan	some	some	2,500	unknown
Phocoena phocoena, harbour porpoise				
Baltic	some	0	unknown	potential
Kattegat and Belt Seas	200	none	8,000	2.5: maybe not sustainable
North Sea area, incl. Faroe Is.	100-700	some	82,000	0.1-0.9: sustainable
Northern Norway, Barents Sea	100	several	11,000	0.9: sustainable
France, Portugal	some	unknown	unknown	unknown
Western Greenland	800	unknown	unknown	potential
Newfoundland to western Greenland	3,000-4,000	unknown	unknown	potential
Gulf of St. Lawrence and Nova Scotia	600-2,000	unknown	unknown	potential
NE coast USA, Bay of Fundy, SW Nova Scotia	**300-800**	**unknown**	**> 8,000**	**4-10: not sustainable.**
West Africa	> 30	unknown	small?	potential
Coastal Japan	some	0	unknown	potential
Central N. Pacific/Bering Sea/Alaska	0-2	some	unknown	unknown
Prince William Sound/Copper River Delta	low tens	some	unknown	unknown
British Columbia	some	unknown	unknown	potential
Northern Washington State	20-100	0	< 1,000	> 3-15: maybe not sustainable
Central California	50-300	unknown	3,000	1.7-13: maybe not sustainable
***P. sinus*, vaquita**	**30-40**	**7**	**few hundred**	**not sustainable**
P. spinipinnis, Burmeister's porpoise				
Coastal Uruguay	some	some	unknown	unknown
Coastal Argentina	> 12	some	unknown	unknown
Eastern S. Pacific - Peru and Chile	> 450	unknown	unknown	potential
Phocoenoides dalli, Dall's porpoise				
Sea of Japan/Okhotsk Sea	some	unknown	> 47,000	unknown
Truei-type	some	30,000	> 58,000	unknown
Western N. Pacific	741-4,187	unknown	unknown	unknown
Central N. Pacific	> 7,000	unknown	741,000	> 0.9: sustainable
Bering Sea	245-908	unknown	212,000	0.1-0.4: not significant
Eastern N. Pacific	some	some	unknown	unknown
		Family Delphinidae		
Cephalorhynchus eutropia, Chilean dolphin	some	some	unknown	unknown
C. heavisidii, Heaviside's dolphin	some	some	unknown	potential
C. hectori, Hector's dolphin	27-95	0	3,400	0.8-2.8: maybe not sustainable
C. commersonii, Commerson's dolphin				
Coast of southern Argentina	some	some	unknown	unknown
Chile	some	some	unknown	unknown
Delphinus delphis, common dolphin				
Mediterranean	400	some	unknown	unknown
Eastern N. Atlantic	some	unknown	unknown	unknown
Western N. Atlantic	211-422	< 20	31,000	0.7-1.4: sustainable
Brazil region	some	unknown	unknown	unknown
Coastal Argentina	> 8	50-100	unknown	unknown
Coastal West Africa	some	some	unknown	unknown
Eastern S. Atlantic basin	some	unknown	unknown	unknown
Southwestern Indian Ocean basin	> 1,000	some	unknown	unknown
Indian Ocean, coast of S. Africa	33	unknown	15,000	0.23: not significant
Northern Indian Ocean	some	unknown	unknown	potential
Tasman Sea	thousands	unknown	unknown	unknown
Coastal Japan	some	unknown	unknown	unknown
Central N. Pacific	500	unknown	unknown	unknown
Coastal California and Baja California	> 50	unknown	unknown	potential
Coastal Peru (Pucusana and Cerro Azul)	> 50	> 100	unknown	potential
Feresa attenuata, pygmy killer whale				
Coastal Sri Lanka	> 170	unknown	unknown	unknown
Central N. Pacific	some	unknown	unknown	unknown
Coastal Peru	some	unknown	unknown	unknown

Table 1 continued

Species and stock/area	*No. killed p.a.*	*Additional killed p.a.*	*Population size*	*Impact of passive kill (% of popn)*
Globicephala sp., species unidentified				
Western N. Atlantic	54-108	40-50	11,000	0.5-1.0:maybe not sustainable
Globicephala melas, long-finned pilot whale				
Mediterranean	50-100	some	unknown	potential
Atlantic coast of France	some	unknown	unknown	unknown
G. macrorhynchus, short-finned pilot whale				
Caribbean	some	some	unknown	unknown
Northern Indian Ocean	> 100	some	unknown	unknown
Japanese southern form	10	300-700	24,000	< 0.1: not significant
Japanese northern form	some	50	4,200	minimal
Coastal California	some	some	< 100	unknown
Coastal Peru	< 10	unknown	unknown	minimal
Grampus griseus, Risso's dolphin				
Mediterranean	30-100	some	> 3,000	1.7-3.3: maybe not sustainable
Eastern N. Atlantic	some	unknown	unknown	unknown
Western N. Atlantic, coast of USA	76-152	< 5	12,000	0.6-1.2: sustainable
Caribbean (off Columbia)	1	unknown	unknown	minimal
Coastal Sri Lanka	> 1,300	some	unknown	potential
Coastal Japan	some	some	105,000	not significant
Central N. Pacific	some	unknown	unknown	unknown
Pacific coast of USA	some	some	unknown	not significant
Coastal Peru	1	unknown	unknown	minimal
Lagenodelphis hosei, Fraser's dolphin				
Coastal Sri Lanka	> 10	unknown	unknown	potential
Philippines	some	unknown	unknown	unknown
Coastal Japan	some	some	unknown	unknown
Lagenorhynchus acutus, Atlantic white-sided dolphin				
Western N. Atlantic, coast of USA	< 5	< 5	36,000	not significant
L. albirostris, white-beaked dolphin				
Western N. Atlantic	some	unknown	unknown	unknown
L. australis, Peale's dolphin				
Coastal S. America	low tens	some	unknown	unknown
L. obliquidens, Pacific white-sided dolphin				
Coastal Japan	some	some	> 85,000	not significant
Offshore N. Pacific	11,000	0	unknown	potential
Eastern N. Pacific	some	> 100	> 50,000	unknown
L. obscurus, dusky dolphin				
Coastal Argentina	some	some	unknown	unknown
Coastal S. Africa	some	some	unknown	unknown
New Zealand	20-50	unknown	unknown	not significant
Coastal Peru	> 1800	some	unknown	potential
Lissodelphis borealis, northern right whale dolphin				
Central N. Pacific	19,000	unknown	unknown	potential
Pacific coast of N. America	some	unknown	> 45,000	unknown
L. peronii, southern right whale dolphin				
Pacific coast of S. America	> 5	some	unknown	unknown
Orcaella brevirostris, Irrawaddy dolphin	some	some	unknown	unknown
Orcinus orca, killer whale				
Mediterranean	< 1	unknown	rare	minimal
N. Atlantic	some	60-80	unknown	potential
Coastal Argentina	some	0	unknown	unknown
Coastal Sri Lanka	< 1	0	unknown	unknown
Indonesia	some	unknown	unknown	unknown
Central N. Pacific/Bering Sea	< 2	some	unknown	unknown
Eastern N. Pacific	< 1	some	unknown	unknown
Peponocephala electra, melon-headed whale				
Northern Indian Ocean	< 10	some	unknown	unknown
Pseudorca crassidens, false killer whale				
Brazil region	some	unknown	unknown	unknown
Coastal Sri Lanka	> 125	unknown	unknown	unknown
Australasia	> 11	some	unknown	unknown
Coastal China	some	unknown	unknown	unknown
Coastal Japan	some	0-500	16,000	unknown
Coastal Peru	1	unknown	unknown	unknown
Sotalia fluviatilis, tucuxi	>90	some	unknown	unknown

Table 1 continued

Species and stock/area	*No. killed p.a.*	*Additional killed p.a.*	*Population size*	*Impact of passive kill (% of popn)*
Sousa chinensis, Indo-Pacific hump-backed dolphin				
Indian Ocean coast of S. Africa	**7.5**	**unknown**	**< 200**[1]	**4%: not sustainable**
Coastal Sri Lanka	100	some	unknown	potential
Other N. Indian Ocean	some	unknown	unknown	unknown
Australasia	> 100	unknown	unknown	potential
Sousa teuszii, Atlantic hump-backed dolphin				
West coast of Africa	some	unknown	small?	unknown
Stenella attenuata, pantropical spotted dolphin				
Northern Indian Ocean	> 1,500	some	unknown	potential
Australasia	> 130	unknown	unknown	unknown
Philippines	some	unknown	unknown	unknown
Western N. Pacific	some	< 1,000	800,000	unknown
Coastal Peru and Ecuador	some	some	36,000	not significant
S. clymene, clymene dolphin				
Caribbean	1	unknown	unknown	unknown
S. coeruleoalba, striped dolphin				
Mediterranean	**5,000-10,000**	**some**	**> 100,000**	**5: not sustainable**
Eastern N. Atlantic	some	unknown	unknown	unknown
Western N. Atlantic	22-44	unknown	20,000	0.1-0.2: sustainable
Coastal Sri Lanka	> 700	unknown	unknown	potential
Coastal Japan and western N. Pacific	some	2,000-5,000	380,000	potential
S. frontalis, Atlantic spotted dolphin				
Western N. Atlantic	13-26	unknown	unknown	0.1-0.2: not significant
Caribbean	1	unknown	unknown	unknown
Brazil region	some	unknown	unknown	unknown
S. longirostris, spinner dolphin				
Caribbean (off Venezuela)	1	unknown	unknown	unknown
Coastal Sri Lanka	> 4,000	some	unknown	potential
Thailand (dwarf form)	some	some	unknown	unknown
Other northern Indian Ocean	some	unknown	unknown	unknown
Australasia	> 1,000	unknown	unknown	unknown
Philippines	some	unknown	unknown	unknown
Hawaii	some	unknown	unknown	unknown
Steno bredanensis, rough-toothed dolphin				
Mediterranean	some	unknown	rare	unknown
Brazil region	some	unknown	unknown	unknown
Coastal Sri Lanka	> 50	unknown	unknown	unknown
Coastal Japan	some	0-500	unknown	unknown
Tursiops truncatus, bottlenose dolphin				
Mediterranean	110-455	some	> 10,000	1-< 5: maybe not sustainable
Western N. Atlantic (offshore)	81-162	<10	8,000	1-2: maybe not sustainable
Western N. Atlantic (coastal)	15	unknown	1,000	1.5: maybe not sustainable
Gulf of Mexico	some	30	40,000	unknown
Caribbean	some	unknown	unknown	unknown
Brazil and Uruguay	some	unknown	unknown	unknown
Coastal West Africa	< 10	unknown	unknown	unknown
Indian Ocean coast of S. Africa, s. of Natal	**20-23**	**0**	**250**[1]	**8: not sustainable**
Indian Ocean coast of S. Africa, n. of Natal	**11-14**	**0**	**< 1,000**	**>3.7: not sustainable**
Coastal Sri Lanka	> 500	some	unknown	potential
Northern Indian Ocean	some	some	unknown	potential
Australasia	> 1700	unknown	unknown	potential
Western N. Pacific and coastal Japan	some	500-2000	> 35,000	unknown
Coastal California and Gulf of California	some	unknown	unknown	unknown
Pacific coast of S. America	> 30	some	unknown	potential
		Family Ziphiidae		
Ziphiids, species unidentified	some	unknown	unknown	unknown
Berardius arnuxii, Arnoux's beaked whale	some	unknown	unknown	unknown
B. bairdii, Baird's beaked whale	some	57	4,000	unknown
Hyperoodon ampullatus, northern bottlenose whale	some	unknown	unknown	unknown
H. planifrons, southern bottlenose whale	some	unknown	unknown	unknown
Mesoplodon sp., species unidentified				
Western N. Atlantic	120-240	unknown	unknown	potential
Coastal Sri Lanka	> 80	unknown	unknown	unknown

[1] This estimate makes no allowance for the proportion of schools missed, and so may be an underestimate.

Table 1 continued

Species and stock/area	*No. killed p.a.*	*Additional killed p.a.*	*Population size*	*Impact of passive kill (% of popn)*
M. carlhubbsi, Hubbs' beaked whale				
Eastern N. Pacific	low tens	unknown	unknown	unknown
M. densirostris, Blainville's beaked whale				
Coastal Sri Lanka	some	unknown	unknown	unknown
M. peruvianus, pygmy beaked whale	some	unknown	unknown	unknown
Ziphius cavirostris, Cuvier's beaked whale				
Mediterranean	<10	unknown	unknown	unknown
Coastal Sri Lanka	< 1	unknown	unknown	unknown
Western N. Pacific	some	unknown	unknown	unknown
Eastern N. Pacific	low tens	unknown	unknown	unknown
		Family Physeteridae		
Physeter macrocephalus, sperm whale				
Mediterranean	20-30	some	< 1	potential
Coastal Sri Lanka	< 5	12-50	unknown	unknown
Eastern N. Pacific	< 2	0	unknown	unknown
Kogia sp., species unidentified				
Central N. Pacific	some	unknown	unknown	unknown
Kogia breviceps, pygmy sperm whale				
Caribbean coast of Colombia	< 1	unknown	unknown	unknown
Coastal Brazil	some	unknown	unknown	unknown
Coastal Sri Lanka	> 80	unknown	unknown	unknown
N. Pacific	some	unknown	unknown	unknown
K. simus, dwarf sperm whale				
Coastal Brazil	some	unknown	unknown	unknown
Coastal Sri Lanka	> 230	unknown	unknown	potential
Coastal Peru (Pucusana)	1	unknown	unknown	unknown

5.2 Populations experiencing levels of mortality that are not sustainable

For seven of the 54 species/populations/regions for which abundance estimates and data on incidental mortality in passive gear were available, the level of mortality in passive gear and traps was determined to be not sustainable.

Two of these species, the baiji and the vaquita, have such low abundance that even relatively low levels of mortality in passive gear and nets are devastating. Two more populations, the Indo-Pacific hump-backed dolphin off the Natal Coast of South Africa and the bottlenose dolphin off the South Natal coast of South Africa have suffered relatively high levels of mortality in anti-shark nets.

The sixth 'population' currently suffering unsustainable levels of incidental mortality in passive gear is that of the harbour porpoise in the western North Atlantic. The population is relatively large, but the level of incidental mortality in gillnets has also been very high and has occurred for many years. The population has been affected in both summer and winter in different parts of its range by various fisheries.

The seventh population identified as experiencing levels of mortality in passive gear and traps that are not sustainable is the striped dolphin in the Mediterranean. The now-banned swordfish driftnet fishery[1] was primarily responsible for the highest levels of incidental mortality of striped dolphins. This fishery operated for only a few years, but the estimated levels of annual kill were extremely high, over 5,000 animals.

[1] Editor's note: The fishery has since been legally re-instituted.

5.3 Explanation of Table 1 summarising impacts on species and populations

The data used in Table 1 were compiled from published sources, documents available at the symposium and workshop, and unpublished information, such as recent survey results, provided by participants during the workshop. Table 1 comprises an overall survey of what is known and unknown about the impact of passive gear on populations of cetaceans. It must be stressed that the estimates of impact are not definitive; they are based for the most part on fragmentary information and are meant only to point out dangerous or potentially dangerous situations that may require urgent management action or investigation. They also, of course, highlight the fact that most impacts are 'unknown'. For roughly 60% of the known cases of interactions between marine mammals and fisheries, not even tentative conclusions could be drawn, because no data were available on population size or on the size of the incidental catch. Stocks/regions were not included in Table 1 if no known kill in passive nets or traps occurred or if the participants in the workshop were unaware of such a kill. Species or populations, e.g., the Indus susu, subjected to other forms of non-natural mortality than in passive gear or nets were not included, even if such effects were non-sustainable.

Because of the limitations of the table, the levels of mortality and impact on the populations may be underestimated. In situations in which the observed mortality represented only a small portion of the likely mortality, e.g., when only one or a few fish markets were observed, and a reliable estimate of effort was not available, the observed mortality was listed without an attempt to extrapolate in the absence of accurate and precise data on effort or representativeness of a set of data for a region. In many of these cases, the numbers of animals killed is likely to be significantly higher than reported. This situation occurred, for example, for the northeast Indian Ocean and the Pacific coast of South America.

5.4 Annotations to Table 1

The first section of the annotations contains general notes that pertain to a region or fishery that may affect more than one species or stock. Those in the second are relevant to specific species/stocks in a geographic region and are listed in the same order as in Table 1.

5.4.1 Regional or fishery-specific general notes

MEDITERRANEAN

Notarbartolo di Sciara reported that data for estimates of incidental catch and population size for populations of cetaceans in the Mediterranean have not been systematically collected. Minimum estimates were derived from extensive contacts with the fishing communities and from 20 months of dedicated cruises in the past five years. Extrapolations to the entire Mediterranean were made on the basis of these results. He noted, however, that these estimates have not yet been published or peer-reviewed. A marked increase in incidental catch rates was observed throughout the past 20 years. The estimates given are for the past five years (1986–1990). No reliable information exists for earlier years.

WEST AFRICA

Only a small portion of the coast has been surveyed for incidental mortality of cetaceans in passive gear. The numbers of animals killed is likely to be significantly higher than reported. Mid-water trawls and tuna purse-seines catch common dolphins, bottlenose dolphins and oceanic dolphins of the genus *Stenella* in offshore waters. This catch is thought to be large.

SRI LANKA AND THE COASTAL NORTHEAST INDIAN OCEAN

Very large catches of cetaceans have been reported in the waters around Sri Lanka. Leatherwood supplied estimates of catches updated from Leatherwood and Reeves (1989); details of the revised methodology are given in Annex D. As noted in that Annex, it must be emphasised that all these estimates are biased downward to an unknown extent by cetaceans which are killed but not landed or landed but not tallied and most are further biased downward by the use of the number of registered vessels rather than the number of vessels actually fishing.

Because of the disparity in knowledge of levels of mortality between Sri Lanka and the other countries, for the table the data for Sri Lanka have been listed separately from those of the other countries along the coasts of the northern Indian Ocean.

CENTRAL NORTH PACIFIC HIGH SEAS DRIFTNET FISHERIES FOR SALMON AND SQUID AND LARGE-MESH DRIFTNET FISHERY

Estimates of annual mortality in the central North Pacific squid driftnet fishery were made on the basis of 1989 catch rates and 3 x 10^4 km of netting set (SC/O90/G35).

COASTAL PERU AND CHILE

Direct and incidental mortality of several species of dolphins and porpoises occurs in set nets. In addition, there is a direct catch by means of harpoons. The data on levels of kill are available from only a few fishing ports. The kill levels reported in the table are from animals counted in the fish markets in those restricted ports. No attempt has been made to extrapolate over the entire coastline, as fishing effort and cetacean densities are unknown. However, cetaceans are known to be killed in these fisheries throughout the coastal waters. The actual numbers of animals killed are almost certainly significantly higher than those reported.

5.4.2 Species/population/region-specific notes

FAMILY BALAENIDAE

Eubalaena australis (southern right whale)

Levels of kill in passive gear for *South Africa* and *New Zealand* were reported by Cockcroft and Cawthorn, respectively. The population estimate is from IWC (1986).

Eubalaena glacialis (northern right whale)

In the *western North Atlantic,* five animals are known to have been killed in collisions with ships. Of 118 right whales photo-identified, 57% showed scars typical of entanglement (Kraus, 1990). The population estimate is from IWC (1986).

In the *North Pacific*, some gillnet mortality in known to occur (SC/O90/G31). The size of the population is not known precisely, but it is very small (IWC, 1986).

Caperea marginata (pygmy right whale)

Mortality in passive gear has been reported along the *coast of South Africa* by Ross *et al.* (1975).

FAMILY ESCHRICHTIIDAE

Eschrichtius robustus (gray whale)

For the *North Pacific (eastern stock),* the majority of animals entangled off southern California are sexually immature, and 67% entangle on the northern migration (Heyning and Lewis, 1990). Of stranded animals examined along the west coast of North America, 8.7–25.8% died due to entanglement. In addition, collisions with ships kill an unknown number of animals annually (SC/O90/G2). The 1990 IWC catch limit is 179. The population estimate is from IWC (1993).

FAMILY BALAENOPTERIDAE

Balaenoptera sp. (unidentified balaenopterid)

Vidal reported a kill of a unidentified balaenopterid whale in the *Caribbean* off the coast of Venezuela.

B. acutorostrata (minke whale)

The incidence of kill in passive gear in the *Mediterranean* was reported in SC/O90/G31. Levels of kill and estimates of relative abundance were reported by Notarbartolo di Sciara.

In the *western North Atlantic* region, which includes coastal US and coastal Canadian waters, although the minke whales probably constitute a single stock, the actual stock structure is unknown. A minimum of 320 minke whales have been estimated to occur in US waters (Winn, 1982), although this estimate is thought to be very low. Few whales, probably less than 1 per year, are killed in coastal US waters (Kraus *et al.*, 1990; SC/O90/G6), while 10–20 are known killed in Canadian waters (SC/O90/G6).

For the *Southern Hemisphere*, Cockcroft reported the estimated level of kill in passive gear and traps off South Africa. Directed kills occurred in past years under IWC regulations. More recently, a small directed kill of about

300 animals occurred under scientific permits issued by Japan (e.g. IWC, 1990a). The current 'best' abundance estimate is about 760,000 (IWC, 1991b).

For the *western North Pacific*, mortality figures include animals from the West Pacific/Okhotsk Sea stock and East China Sea/Sea of Japan stock. Data for these two stocks have been combined due to lack of information on incidental takes (SC/O90/G36). The last commercial catch occurred in 1987.

For the *eastern North Pacific*, the limited observer data do not always identify baleen whales to species (Heyning and Lewis, 1990). Heyning reported that some animals are killed by collisions with ships.

B. edeni (Bryde's whale)
Information from *coastal Brazil* is reported in SC/O90/G26.

B. physalus (fin whale)
The incidence of mortality in the *Mediterranean* was reported in SC/O90/G34. Levels of kill in gillnets and estimate of relative abundance were reported by Notarbartolo di Sciara.

For *eastern Canada*, levels of mortality and population estimates are given by several authors (Mitchell, 1974; Winn, 1982; Mizroch *et al.*, 1984; Lien *et al.*, 1985; SC/O90/G6).

Information on the *northern Indian Ocean* is reported in Leatherwood and Reeves (1989).

Megaptera novaeangliae (humpback whale)
In the *western North Atlantic*, the animals found off coastal Canada, the USA and Greenland and that winter in the Caribbean constitute a single stock, which is reflected in the abundance estimate (Katona and Beard, 1990). Mortality in passive gear has occurred at a level of 5–17 per year during the past 12 years in Canadian waters (Lien *et al.*, 1985; 1988b; SC/O90/G6). Kraus *et al.* (1990) reported mortality of less than five per year in coastal US waters. Few are known killed in the Caribbean (SC/O90/G7). A catch limit of three humpbacks per year is currently in force for subsistence whalers of St Vincent & The Grenadines. In recent years, usually only 1–2 have been killed annually. During a 5-week period beginning in November 1987, 14 humpback whales died in Cape Cod Bay and Nantucket Sound after eating Atlantic mackerel containing a dinoflagellate neurotoxin (Geraci *et al.*, 1989). Other animals may have died and remained at sea.

Leatherwood and Reeves (1989) provide information for the *Indian Ocean*.

The *western North Pacific* 'population' is the smallest of the North Pacific groupings. To date, 164 individuals have been identified through photo-identification (Kaufman *et al.*, 1989; K. Mori, pers. comm. to T. Kasuya, 1990).

In the *eastern North Pacific* (Hawaii/Alaska and Mexico/California) all of the entanglements documented have occurred in southeast Alaska, British Columbia and California. Two animals were caught in the offshore driftnet fishery off Southern California (Heyning and Lewis, 1990). Additional information is provided by several authors (e.g. Baker and Herman, 1987; Baker *et al.*, 1990; Calambokidis *et al.*, 1990; Straley and Baker, 1990).

Majluf and Reyes (1989) provide information from *coastal Peru*.

FAMILY PLATANISTIDAE
Platanista gangetica (Ganges susu)
Both direct (harpoon) and incidental kills occur along the Brahmaputra River. Incidental catches occur during the dry season. Incidental mortality increased with the introduction of synthetic nets and the number of nets has been increasing (Mohan, 1989).

FAMILY INIIDAE
Lipotes vexillifer (baiji)
Most are entangled by bottom snaglines ('rolling-hook'). Some are caught in traps (Zhou, 1982; 1986; Lin *et al.*, 1985; Zhou and Li, 1989; SC/O90/G21).

Pontoporia blainvillei (franciscana)
In addition to the kill in passive gear, bottom trawls catch and kill *Pontoporia* at Samboraubon Bay, Argentina, although the catch is considered negligible. In Brazil and Argentina, most of the animals killed are juveniles (SC/O90/G3). Sex and age structure of the kill is available. Other information is given by several authors (e.g. Brownell, 1975; Kasuya and Brownell, 1979; Pinedo, 1982; Pérez Macri and Crespo, 1989; Praderi *et al.*, 1989; Corcuera *et al.*, 1994; SC/O90/G1).

Inia geoffrensis (boto)
Of a sample of 35 dolphins, approximately 70% died in lampara seine nets and 30% in gillnets. Two of the 35 were harpooned, possibly because of their interference with fishing operations (Best and da Silva, 1989; Perrin and Brownell, 1989)

FAMILY MONODONTIDAE
Delphinapterus leucas (white whale)
For *Bristol Bay*, the estimate of incidental catch is based on a small sample of years. There is an aboriginal harvest (Hazard, 1988). Hazard (1988) also provides data for *Cook Inlet*.

FAMILY PHOCOENIDAE
Australophocaena dioptrica (spectacled porpoise)
This species is the second most frequently killed cetacean in passive gear in Tierra del Fuego (Goodall *et al.*, 1990; 1994) although the number killed is unknown. A direct fishery exists for use as crab bait. Several others papers provide information (e.g. Goodall and Cameron, 1980; Goodall *et al.*, 1988a; Lichter and Goodall, 1988)

Neophocaena phocaenoides (finless porpoise)
Data for *Thailand/Pakistan/India* are reported in SC/O90/G12, G22 and G30.

Levels of mortality in passive gear in the *Yangtze River* and *Yellow Sea* were given in SC/O90/G21. Unpublished estimates of abundance were reported by Zhou.

For *coastal Japan*, the population estimate is the preliminary sighting estimate for the population in the Inland Sea only. Mortality in passive gear occurs in other areas around Japan as well. Finless porpoises migrate into the Inland Sea for calving in Spring. Their distribution suggests that Japanese trap net operations may have a significant effect on their survival (Kasuya and Kureha, 1979).

Phocoena phocoena (harbour porpoise)
The *Baltic* region includes information from Sweden's east coast, Finland, Russian Federation, Luithuania, Latvia, Estonia, Poland and Germany's Baltic coast (Kremer and Schulze, 1990; SC/O90/G25).

Several papers include information for the *Kattegat and Belt Seas* (e.g. Danielsen *et al.*, 1989; Lindstedt and Lindstedt, 1989; Lindstedt, 1990; SC/O90/G57).

For the *North Sea* area (including the Faroe Islands), estimates of levels of incidental mortality in passive gear from three separate papers are widely disparate, ranging from 100 animals per year (Bjørge and Øien, 1990) to 700 animals per year for the Skagerrak (Kinze, 1994). Clausen and Andersen (1988) reported that up to 3,000 animals are killed per year, but the numbers are unsubstantiated. The estimate of abundance from the North Sea area has a CV of 0.24 (Bjørge and Øien, 1990).

Levels of mortality for *Northern Norway/Barents Sea* were given in Bjørge and Øien (1990). The estimate of abundance from northern Norway has a CV of 0.44 (Danielsen *et al.*, 1989)

Duguy and Hussenot (1982) report mortality in nets along the coast of *France*.

In *Western Greenland* and the area from *Newfoundland to western Greenland*, both incidental and directed catches are large (Gaskin, 1984; Lien *et al.*, 1988b; Kinze, 1994). Insufficient data exist to allow determination of the impact of this long-term fishery on the population, but, given the high levels of mortality, there is reason to be concerned.

For the *Gulf of St. Lawrence and Nova Scotia* region, a sample of fishermen reported taking over 600 porpoises in 1988, but total mortality is unknown (Fontaine *et al.*, 1994). Most of this mortality occurred in groundfish gillnets and some of the carcasses are kept for human consumption. This fishery has existed for some time (Laurin, 1976).

The population grouping of the *northeast coast of the USA, the Bay of Fundy and southwestern Nova Scotia* may also include southwestern Nova Scotia. Estimates of fishery mortality range from 280 (Polacheck, 1989) to almost 1,000 (Kraus *et al.*, 1983; 1990). The estimates are not based on systematic sampling of the entire range of the groundfish gillnet fishery. Other takes are known to occur, but their magnitude is unknown. The estimate excludes an occasional and probably small kill in gillnet fisheries to the south of the Gulf of Maine. Best available estimates of abundance range between to 8,000 and 15,300 (Kraus *et al.*, 1983), with the lower number thought to be biased downward (SC/O90/G44). An even lower estimate of 3,500 (Winn, 1982) may be unreliable. Current research is attempting to refine estimates of both abundance and mortality (Read and Gaskin, 1988), but there are already indications that the population is in decline (Read and Gaskin, 1990).

Information on *West Africa* is given in Gaskin (1984) and SC/O90/G5.

For *coastal Japan*, some data are given in SC/O90/G36. Kasuya reported that the impact of passive gear is potentially significant because of the large number of trap nets off Hokkaido (950 large-scale and 4,000 small-scale trap nets along less than 3,000km of coastline).

In the *central North Pacific/Bering Sea* area, the high seas driftnet fishery for salmon kills 0–2 harbour porpoises annually (SC/O90/G35).

Observations of fisheries in the *coastal waters of Alaska* suggest that the Prince William Sound/Copper River Delta area probably has the highest level of mortality of harbour porpoise in Alaskan waters (K. Wynne, pers. comm.; SC/O90/G28).

Along the *Pacific coast of the USA and Canada*, the stock structure of *Phocoena* is unknown. For the USA, limited evidence exists to support the hypothesis that separate populations exist in Washington, Oregon and California (Calambokidis, 1986). Mortality estimates have been further stratified to reflect regions where known levels of mortality occur. The potentially large impacts given for northern Washington (Gearin *et al.*, 1994) and central California represent gillnet mortality in very specific areas (Brownell, 1964; Hanan *et al.*, 1987) and assume that the porpoises in those subareas comprise separate populations within the overall populations within the states. Because of the uncertain stock status of the subareas, the regional impacts have been designated as 'maybe not sustainable' rather than 'not sustainable'. The population in central California has been subjected to long-term losses due to interactions with fishing gear (Szczepaniak and Webber, 1985). It is currently estimated to be at 30–97% of original population size (Barlow and Hanan, 1994). Mortality in passive gear has declined during the last two years because of restrictions on the use of set gillnets. The take in gillnets has been biased towards juveniles (Hohn and Brownell, 1994). The number of harbour porpoises in British Columbia appears to be declining, possibly due to gillnet mortality (Cowan, 1988; Stacey *et al.*, 1994).

P. sinus (vaquita)

The incidental kill in passive gear is known to have been at least 32–33 per year in 1985 and 1990 based on direct counts (Turk Boyer and Silber, 1990). At least seven vaquitas have been caught in shrimp trawls since 1985. The population size is unknown but could be as low as several hundred (Vidal, 1994). The vaquita has the smallest geographic range of any marine cetacean.

P. spinipinnis (Burmeister's porpoise)

The *western South Atlantic* region includes Uruguay and Argentina. Burmeister's porpoises are killed in gillnets set for fish and sharks (Corcuera *et al.*, 1994). In the 1970s, at least some were taken in centolla (crab) tangle nets in Tierra del Fuego (Goodall and Cameron, 1980). The estimated kill for one port in Argentina, Necochea/Claromecó was 12 animals/year (SC/O90/G2). Along the rest of the coast, no estimates are available. In Uruguay, the estimated take is less than one year, although all organised shark fisheries along the Uruguayan coast are thought to kill this species (SC/O90/G1).

In the *eastern South Pacific*, this species is taken in a variety of coastal fisheries from northern Peru to southern Chile (SC/O90/G11; SC/O90/G54). Counts of animals killed have been reported for specimens landed at the fish markets at Pucusana, Peru, while additional animals are known to be killed in the sciaenid fishery in southern Chile. The total kill probably numbers in the low thousands (Brownell and Praderi, 1982; Read *et al.*, 1988) and is increasing in some areas (Van Waerebeek and Reyes, 1990a; b). More males than females are caught in the Peruvian fishery.

Phocoenoides dalli (Dall's porpoise)

Stocks in the *coastal and offshore Japan* region can be incidentally taken by Japanese large-mesh driftnets and Korean squid gillnets, but the details are unknown. In coastal waters they are killed in trap nets. In addition, there is a direct kill, totalling 30,000 animals in 1989, in the Sea of Japan and Okhotsk Sea (SC/O90/G36). The kill is of both the *dalli* and *truei* types, although the proportion of the kill of each type is unknown (SC/O90/G8).

In the *western and central North Pacific*, two putative stocks inhabit the range from 155°-172°E (IWC, 1990b).

Incidental kill is by the Japanese high seas salmon fisheries and Korean, Taiwanese and Japanese high seas driftnet fisheries for squid. The estimate of kill was made on the basis of observations on Japanese squid driftnet vessels and extrapolated to all nations fishing the region (SC/O90/G8). For the salmon fishery, the mean kill rate from 1981–87 in the US Fisheries Conservation Zone (FCZ) collected by US and Japanese scientific observers was used with the relevant fishing effort data for each fishery. Kill rates outside the US FCZ may be somewhat lower than the rate used. Although the number of observations from Japan is high, the observations do not cover the entire fishing season and may not be representative of the areal distribution of the fishing effort. In addition, Korean and Taiwanese vessels were not observed; they used different mesh sizes and operated in different areas and time periods. The kill estimate is therefore preliminary. Information is available on life history.

For the *Bering Sea*, population estimates are based on the US Platform of Opportunity Programme (NMFS, unpubl. data). Sightings data are collected during surveys by trained observers and analysed using line transect methodology. Jones reported that these estimates were used in US official determinations of status of the populations. Kill estimates are based on the mean kill rate over the period 1981–87. Data were collected by Japanese and US scientific observers on salmon catcherboats. Fishing effort and area are currently decreasing. Additional mortality may be incurred in the extensive trawl fisheries in the Bering Sea (SC/O90/G35). Data are available on life history.

In the *eastern North Pacific*, mortality occurs in the Alaska trawl fishery (SC/O90/G28) and in nets off the coast of British Columbia (Stacey *et al.*, 1994).

FAMILY DELPHINIDAE

Cephalorhynchus eutropia (Chilean dolphin)

This species is killed incidentally in passive gear in southern Chile. There is also incidental kill in purse-seines and a harpoon fishery where the animals are taken for crab bait (Goodall *et al.*, 1988b).

C. heavisidii (Heaviside's dolphin)

Mortality occurs in near-shore set nets and in trawls and purse-seines along the southern African coast. Some animals are also taken illegally with hand harpoons (Best, 1984).

C. hectori (Hector's dolphin)

Mortality figures are from 1984–88 from Pegasus Bay/ Canterbury Bight only. Entanglement rates are probably highest in this area, but additional entanglements undoubtedly occur elsewhere (Dawson and Slooten, 1988; Slooten and Dawson, 1988). The Banks Peninsula Marine Mammal Sanctuary was established in 1989 to reduce incidental mortality of this species (Dawson, 1991).

C. commersonii (Commerson's dolphin)

Kill occurs in gillnets in southern Patagonia, on the northeast coast of Tierra del Fuego and in Chile (Goodall *et al.*, 1988a; Leatherwood *et al.*, 1988; Lichter and Goodall, 1988). Bottom and mid-water trawlers kill an additional unknown number in northern Patagonia. In Tierra del Fuego, this species is intentionally killed by harpoon and gunshot for use as crab bait. No systematic monitoring of mortality or collection of carcasses has occurred but the number killed is thought to be high. Abundance has decreased to low levels in the Magellan Straits (Goodall *et al.*, 1988a; Lichter and Goodall, 1988).

Delphinus delphis (common dolphin)

In many ocean basins, there are two reported morphological forms of common dolphins, a long-beaked and a short-beaked form. In the eastern North Pacific the long-beaked form has been described as *D. bairdii* or *D. delphis bairdii.* Off South Africa it has been called *D. capensis* and in the northern Indian Ocean *D. tropicalis.* The short-beaked form has been referred to as *D. delphis.* It has not been fully resolved whether these two forms represent two species of common dolphins or two distinct ecological races[2]. In either case they need to be managed as separate populations. Most reports only list the kill as common dolphins, making the impact of such kills impossible to ascertain, but potentially a problem.

The incidence of mortality for the *Mediterranean* was given in SC/O90/G34.

In the *eastern North Atlantic*, common dolphins are killed in French and Irish driftnet fisheries (Duguy and Hussenot, 1982; SC/O90/G35).

In the *western North Atlantic*, a recently expanded driftnet fishery for swordfish and tuna has developed along the continental shelf edge of the northeastern United States and is currently being monitored. During August-November 1989, 19 common dolphins were caught on 12 trips (SC/O90/G6). The number of common dolphins killed annually has been estimated on the basis of 5–10% of fishing trips observed. Common dolphins are also killed in the squid trawl fisheries in the shelf and shelf-edge region of the northeast US (Waring *et al.*, 1990). Abundance estimates from aerial surveys are given in Winn (1982).

Estimates for the *Brazil region* are given in SC/O90/G26.

In *coastal Argentina*, mortality in gillnets was estimated to be eight animals/fishing season for one port (Claromecó). Additional mortality occurs in bottom trawls and purse-seines. The annual level of mortality in purse-seines is estimated to be 50–100. This total also includes kills of dusky dolphins, likely the predominant species (Corcuera *et al.*, 1994; SC/O90/G2).

In *coastal West Africa*, numerous fisheries probably kill common dolphins in passive gear. Other kills occur in tuna purse-seines (SC/O90/G5).

In the *eastern South Atlantic Ocean* basin, kills occur in high seas driftnets and around islands (SC/O90/G20).

In the *southwestern Indian Ocean* basin, dolphins are taken in high seas driftnets and around islands (Cockcroft and Peddemors, 1990; SC/O90/G20).

For the *Indian Ocean coast of South Africa*, estimates are reported in Cockcroft (1990) and Cockcroft and Peddemors (1990).

In the *northern Indian Ocean*, mortality in passive gear has been reported from the Arabian Sea (Papastavrou, 1990), India (SC/O90/G12; SC/O90/G22), Sri Lanka (Alling, 1983; Leatherwood and Reeves, 1989) and Pakistan (SC/O90/G30).

Over a two-year period in the *Tasman Sea*, 4,600 dolphins, mostly *Delphinus delphis* were killed in driftnets (SC/O90/G35).

[2] Editor's note: The IWC Scientific Committee accepted the species *Delphinus capensis*, the long-beaked common dolphin, at its 1994 meeting (IWC, 1995, in press) based on Heyning and Perrin (1994).

In *coastal Japan*, this species has been taken by drive fisheries in the past. Currently data are being collected by means of an observer programme (SC/O90/G36).

In the *central North Pacific*, data are currently being collected in observer programmes in the high seas squid driftnet programme and large-mesh driftnet programme (SC/O90/G35, SC/O90/G52).

In *coastal California and Baja California* common dolphins are caught in set and drift gillnets along central and southern California (SC/O90/G24) and may be caught in high number in the Gulf of California (SC/O90/G7). The majority of common dolphins killed off California are of the long-beaked form (Evans, 1982; Perrin *et al.*, 1985).

For *coastal Peru*, Heyning, Reyes and Van Waerebeek reported that mortality is of the long-beaked form. The estimate of mortality is for the ports of Pucusana and Cerro Azul only (Read *et al.*, 1988; Van Waerebeek and Reyes, 1990a; SC/O90/G54). Van Waerebeek reported that the mortality off northern Peru is thought to be much higher.

Feresa attenuata (pygmy killer whale)
For *coastal Sri Lanka*, estimates are reported by Leatherwood and Reeves (1989).

In the *central North Pacific*, data on the mortality of this species in the large mesh driftnet fishery in the central North Pacific are being collected (SC/O90/G52).

For *coastal Peru*, one specimen is known to have been taken (Read *et al.*, 1988; Van Waerebeek and Reyes, 1990a).

Globicephala sp. (unidentified pilot whale)
In the *western North Atlantic*, pilot whales are killed incidentally in the drift gillnet fishery and distant-water fleet mackerel and squid trawl fisheries. The mortality has not been recorded by species; the fishery operates well beyond the known range of the short-finned pilot whale. Seven animals were observed killed on 12 trips in the swordfish driftnet fishery during 1989. It is estimated that 5–10% of the fishing trips were observed. From 1977–1990, a minimum of 409 specimens have been observed killed in the mackerel and squid fisheries, with an annual average of 46 observed killed from 1984–88. The estimate of population size (Winn, 1982) given in the table pertains to both species over the range of the survey and does not cover the known range of the short-finned pilot whale in the North Atlantic. When extrapolated over total fishing effort, the total mortality in the foreign squid and mackerel trawl fishing gear is 2.0–2.7% of the estimated population size (Waring *et al.*, 1990). This rate may not be sustainable. From 1948–1971, the Newfoundland drive fishery killed an average of 2,260 each year (Mercer, 1975).

Globicephala melas (long-finned pilot whale)
For the *Mediterranean*, Notarbartolo di Sciara reported that other sources of man-induced mortality include entanglement in longlines and direct kill by gunshot. This species is distributed mainly in the western basin.

In *France*, some kill occurs in gillnets (Duguy and Hussenot, 1982).

G. macrorhynchus (short-finned pilot whale)
Some kill occurs in the *Caribbean* in passive gear (SC/O90/G7). A directed fishery for pilot whales occurred in the waters around St. Vincent (Caldwell and Caldwell, 1975).

For the *northern Indian Ocean*, Leatherwood reported that incidental mortality probably occurs in the China, Taiwanese (abbreviated as 'Taiwanese' in the remainder of this section) driftnet fishery. Pilot whales are killed in the coastal fisheries around Sri Lanka (Leatherwood and Reeves, 1989) and in the waters of Pakistan (SC/O90/G30).

Pilot whales of the *Japanese southern form* are killed in trap nets and in the drive fisheries and small-type whaling (SC/O90/G36; Kasuya and Miyashita, 1989; Miyashita, 1993). Data are being collected from whaling operations.

Some individuals of the *Japanese northern form* are killed in Japanese and Korean gillnets. The other fishery mortality is from small-type whaling (SC/O90/G36; Miyashita, 1993). Data are being collected from whaling operations.

In *coastal California*, prior to the early 1980s, a migratory group of pilot whales entered the Southern California Bight in winter to feed on spawning squid. The developing squid fishery resulted in the deaths of an unknown number of whales by entanglement in nets and by gunshot (Miller, 1983). Since 1983, a year with a major El Niño Southern Oscillation event concomitant with the years of highest incidental mortality, few pilot whales have been seen nearshore. Pilot whales are currently killed in drift gillnets (SC/O90/G28).

In *coastal Peru*, counts of pilot whales in the fish market at Pucusana gave one whale each in 1985 and 1986, years of relatively low observer coverage, three whales in 1987 with 298 days of coverage and five whale in each 1988 and 19899 with 492 days of monitoring. As only one fishing market was sampled, these estimates are undoubtedly low (Read *et al.*, 1988; Van Waerebeek and Reyes, 1990a; b; SC/O90/G54).

Grampus griseus (Risso's dolphin)
In the *Mediterranean*, Risso's dolphins are killed in several gillnet fisheries (SC/O90/G34). Notarbartolo di Sciara reported that, in addition to mortality in driftnets, kills include those resulting from harpoons, gunshot and entanglement in longlines. Risso's dolphins are distributed mainly in the western basin. For the *eastern North Atlantic*, some kills were reported by Duguy and Hussenot (1982).

Along the *western North Atlantic coast of the USA*, mortality has occurred in the swordfish driftnet fishery and the foreign trawl fisheries for mackerel and squid (Waring *et al.*, 1990; SC/O90/G6). During August-November 1989, three *Grampus* were caught in the driftnet fishery on 12 observed trips, representing an estimated coverage of 5–10%. The estimate of population size (Winn, 1982; Kenney, 1990) was based on a survey that may not have covered the entire range of Risso's dolphin in the western North Atlantic.

Caribbean data are provided in SC/O90/G7.

In *coastal Sri Lanka*, a harpoon fishery exists in addition to the incidental kills in coastal gillnets and in the Taiwanese driftnet fishery (Leatherwood and Reeves, 1989).

In *coastal Japan*, incidental mortality occurs in trap nets and possibly in the large-mesh driftnet fishery. Kasuya reported that the impact of kills in trap nets is thought to be not significant. Risso's dolphin was previously taken in the drive fishery at Iki Island (SC/O90/G36; Miyashita, 1993).

In the *central North Pacific*, mortality results from the high seas driftnet fishery and the large-mesh net fishery. Data are being collected by means of an observer programme (SC/O90/G52).

Along the *Pacific coast of the USA*, some animals are thought to be killed in gillnets. The squid purse-seine fishery is responsible for additional mortality (SC/O90/G24).

In *coastal Peru*, only one Risso's dolphin was observed in the fish market in Pucusana, Peru in 1987, when there were 298 days of monitoring (Van Waerebeek and Reyes, 1990b). Another specimen was landed in Pucusana in 1988–89 during 492 days of monitoring (SC/O90/G54).

Lagenodelphis hosei (Fraser's dolphin)
Mortality in *coastal Sri Lanka* has been reported by Leatherwood and Reeves (1989).

In the *Philippines*, mortality occurs in driftnets, as bycatch in purse-seines and by harpoon (SC/O90/G29).

In *coastal Japan*, the documented take is by Japanese trap nets. This stock may also be taken by large-mesh gillnets in higher numbers (SC/O90/G36). Data are being collected by means of an observer programme (SC/O90/G52). This species is also killed in drive fisheries.

Lagenorhynchus acutus (Atlantic white-sided dolphin)
Along the *western North Atlantic coast of the USA*, Gilbert and Wynne (1987) reported the incidental take of several of this species in the winter surface-gillnet fishery for mackerel in Cape Cod Bay. A small number of white-sided dolphins have been reported killed in the foreign trawl fisheries for mackerel (Waring *et al.*, 1990). The estimate of abundance was given by Kenney (1990).

L. albirostris (white-beaked dolphin)
For the *western North Atlantic*, reports of mortality in passive gear were given in Alling and Whitehead (1987).

L. australis (Peale's dolphin)
In *coastal South America*, incidental kill in passive gear occurs in gillnets in the south of Patagonia and in Tierra del Fuego. Two specimens were observed caught in bottom and mid-water trawls at Puerto Deseado (SC/O90/G2). A direct fishery kills some animals for use as crab bait. In 1978, 23 dolphins were known killed (Goodall and Cameron, 1980).

L. obliquidens (Pacific white-sided dolphin)
In *coastal Japan*, incidental mortality occurs in trap nets. Partial observations showed an average of 7.8 dolphins killed annually (SC/O90/G36). Population estimates are for the East China Sea – Sea of Japan (Miyashita, 1986).

In the *central North Pacific*, most of the kill in passive gear is in the high seas driftnet fishery (SC/O90/G8; SC/O90/G35; SC/O90/G42). The total mortality of this species in high seas squid driftnets has been extrapolated from the observed Japanese take rate. Japanese salmon driftnets have killed 0–2 animals annually from 1978–87 (SC/O90/G35). One animal was reported killed in a research operation using large-mesh gillnets.

In the *eastern North Pacific*, two stocks may occur, with the northern temperate and southern temperate forms meeting in the Southern California Bight (Leatherwood *et al.*, 1984; Walker *et al.*, 1986). Incidental mortality occurs in the California and British Columbia driftnet fisheries (Stacey *et al.*, 1994; SC/O90/G28). Some animals stranded along the California coast were thought to have been killed in gillnets (SC/O90/G24). Some mortality occurred during the experimental fishery for squid but that fishery did not develop. Additional sources of mortality are Alaskan trawls (SC/O90/G28).

L. obscurus (dusky dolphin)
For *coastal Argentina*, mortality in gillnets was estimated to be 1.4 animals/fishing season for one port (Necochea/Claromecó). The catches were considered sporadic. Additional mortality occurs in bottom trawls in northern Patagonia and purse-seines in Necochea/Claromecó. In 8–10 months, eight dolphins were recovered from one bottom trawl vessel (Corcuera *et al.*, 1994; SC/O90/G2). The annual level of mortality in purse-seines is estimated to be 50–100, a total which also includes kills of common dolphins, although the majority of the kill is suspected to be of dusky dolphins (Corcuera *et al.*, 1994; SC/O90/G2).

In *coastal South Africa*, mortality in mullet and elephant fish gillnets occurs but at an unknown and probably minimal level. Additional mortality occurs in purse-seines and there is also some removal for transfer to oceanaria (SC/O90/G20; Best and Ross, 1977).

Cawthorn reported that in *New Zealand* mortality occurs in deep-set gillnets.

For *coastal Peru*, the reported kill of >1,800 includes landings at the port of Pucusana only. Mortality is incidental as well as directed using drift gillnets, with a few specimens taken by harpoon (Read *et al.*, 1988; Van Waerebeek and Reyes, 1990a; b). Some counts from other ports are available but the representativeness of the counts throughout a single year and across years and ports is unknown. All age classes are taken and the sex ratio is about 1:1.

Lissodelphis borealis (northern right whale dolphin)
In the *central North Pacific*, right whale dolphins are killed incidentally in the squid driftnet area (SC/O90/G8, G35, G52). In 1989, 455 were observed killed in Japanese squid gillnets. This number represented partial coverage only. When extrapolated over the Japanese, Taiwanese and Korean fleets, the total estimated kill is 19,000 (SC/O90/G35). Some (0–4 per year) also are killed in Japanese salmon driftnets (SC/O90/G35). In research cruises using large-mesh gillnets, 22 right whale dolphins were killed (SC/O90/G52).

Along the *Pacific coast of North America*, two mortalities are known to have occurred in drift gillnets in US waters, while in four years 13 were known to have been killed in Canadian waters (SC/O90/G28). A population size for *Lissodelphis* in the Northeast Pacific is available for limited regions along the coast of California through a series of aerial surveys (Leatherwood and Walker, 1979). However, stock structure and total distribution is unknown.

L. peronii (southern right whale dolphin)
Along the *Pacific coast of South America*, three were reported killed in gillnets in Peru from 1985–90. In Chile, several were found near fish terminals and landings sites after having been killed in swordfish driftnets. The number reported accelerated rapidly in 1989–90, which is cause for concern. A few are also harpooned by artisanal fishermen in Chile in the swordfish harpoon fishery (SC/O90/G11). Van Waerebeek reported that the animals landed in Peru have been adults.

Orcaella brevirostris (Irrawaddy dolphin)
In most areas where this species occurs, data on incidental kills are limited. Some kill is known from India and the northern Indian Ocean coast (SC/O90/G12; SC/O90/G22). In the Queensland, Australia area from 1967–1989, a total of 522 dolphins was killed in shark nets (Harwood *et al.*, 1984; Harwood and Hembree, 1987; Paterson, 1990). Four species of dolphins were involved: *Tursiops truncatus*, *Delphinus delphis*, *Orcaella brevirostris* and *Sousa chinensis*. The number of each species killed is not known

because mortality counts were not stratified by species. The fishery subsequently moved into the waters of Papua New Guinea and Indonesia (Liu, 1989), probably eliminating that fishery as a source of additional mortality in coastal waters of Australia but inflicting mortality on animals in nearby waters that probably constitute the same population. In some areas, this species is killed for local consumption and some live capture occurs (Marsh *et al.*, 1989).

Orcinus orca (killer whale)
The incidence of mortality in the *Mediterranean* was given in SC/O90/G34. Notarbartolo di Sciara reported estimated mortality rates and relative abundance.

The abundance of killer whales in the entire *North Atlantic* is unknown. Killer whales are reported to become entangled occasionally in inshore herring nets off Norway (Lien *et al.*, 1988a). Changes in killer whale migrations, caused by changes in herring migration, may explain the increase in abundance of killer whales in Norwegian coastal and inshore waters since the early 1980s (Christensen, 1988) and subsequent entanglements. Directed fisheries for killer whales that take an average of less than 10 animals per year occur in Greenland (Heide-Jørgensen, 1988). Approximately 700 killer whales (average 58 per year) were killed in the North Atlantic by Norwegian vessels between 1970–1981 (Øien, 1988). From 1976–1988, 59 killer whales were caught off Iceland for public display (Sigurjónsson and Leatherwood, 1988).

Some kill has been reported in the Caribbean off Trinidad and Tobago (SC/O90/G7).

In *coastal Argentina*, one kill is known to have occurred in the Necochea gillnet fishery in October 1990 (Corcuera *et al.*, 1994).

In *Sri Lanka*, an average of <1 animal per year is killed (Leatherwood and Reeves, 1989; Leatherwood *et al.*, 1991).

Information for *Indonesia* is given in Hembree (1980).

In the *central North Pacific/Bering Sea* region, some kill has been reported in Japanese salmon gillnets (SC/O90/G35). Squid gillnets and large-mesh gillnets may also take this species. Some additional kill by US salmon boats in the Bering Sea has been documented (Dahlheim, 1988).

In the *eastern North Pacific*, a low level of kill has been reported from gillnets (SC/O90/G24). In the period 1986–88, two animals were known killed in the Alaska trawl fishery for pollock (SC/O90/G28).

Peponocephala electra (melon-headed whale)
For the *northern Indian Ocean* area, a small kill has been documented for Sri Lanka (Leatherwood *et al.*, 1991). In addition, there is a small live-capture removal of this species. Leatherwood reported that this species is likely taken in coastal and high seas gillnet operations throughout the temperate and tropical Indian Ocean.

Pseudorca crassidens (false killer whale)
In the *Brazil* region, some mortality in passive gear occurs (SC/O90/G26).

This species is killed in the coastal net fisheries of *Sri Lanka* (Leatherwood and Reeves, 1989; Leatherwood *et al.*, 1991).

In *Australasia*, this species is one of several killed in Taiwanese drift gillnets off the coast of northeast and northwest Australia (Harwood *et al.*, 1984; Harwood and Hembree, 1987). From 1981–1985, an annual mortality of 11 animals was estimated on the basis of an observer programme. Significant declines in cetacean catch rate with both time and increasing cumulative effort occurred from 1981–83. Similar analyses for 1984–85 were not done because of changes in observer coverage, fishing methods and area of operation. The fishery subsequently moved into the waters of Papua New Guinea and Indonesia (Liu, 1989), probably eliminating the fishery as a source of additional mortality in coastal waters of Australia but inflicting mortality on animals in nearby waters that probably constitute the same population. One kill in longline gear offshore has been recorded. Two animals were removed by live capture in 1989. Some seasonal movement is known.

In *coastal China*, mortality in passive gear has been reported by several authors (Wang, 1979; Zhou *et al.*, 1982; Shi and Wang, 1983; SC/O90/G21).

In *coastal Japan*, incidental mortality occurs in Japanese trap nets (SC/O90/G36). Additional kills occur in the drive fishery and in culls (Tamura *et al.*, 1986). The population estimate is 2,700 in the East China Sea and 13,000 off the Pacific coast (Miyashita, 1993). Several stocks may be included. Biological information suggests a low reproductive rate.

Mortality has been reported for *coastal Peru* in SC/O90/G11.

Sotalia fluviatilis (tucuxi)
Two stocks are recognised, a marine and a freshwater form (Borobia and Sergeant, 1989). Both stocks are killed in passive fishing gear (SC/O90/G7; SC/O90/G26). Artisanal net fisheries in Brazil kill at least some of the marine form (Simões-Lopes and Ximenez, 1990).

Sousa chinensis (Indo-Pacific hump-backed dolphin)
Hump-backed dolphins are killed in anti-shark nets off Natal, South Africa. Available information suggests that the level of mortality may lead to the depletion of local groups (SC/O90/G20; Ross, 1984; Ross *et al.*, 1989).

Kills for *coastal Sri Lanka* were reported by Leatherwood and Reeves (1989).

In the *northern Indian Ocean*, incidental mortality is known to occur in Sri Lanka, India, Pakistan and Thailand (Bhatia *et al.*, 1989; SC/O90/G22, SC/O90/G30) and probably occurs in other countries as well.

In *Australasia*, this species is one of several killed in Taiwanese drift gillnets off the coast of northeast and northwest Australia (Harwood *et al.*, 1984; Harwood and Hembree, 1987). From 1981–1985, an annual mortality of 11 animals was estimated on the basis of an observer programme. Significant declines in cetacean catch rate with both time and increasing cumulative effort occurred from 1981–83. Similar analyses for 1984–85 were not done because of changes in observer coverage, fishing methods and area of operation. This fishery has since moved into waters of Papua New Guinea and Indonesia (Liu, 1989), probably eliminating the fishery as a source of additional mortality in coastal waters of Australia but inflicting mortality on animals in nearby waters that probably constitute the same population. Other incidental catches include observed catches of up to an average of 25 dolphins/year in shark nets (that estimate includes four species of dolphins) (Paterson, 1990). Anderson reported that inshore set nets kill about 80 per year, although this number is probably an underestimate, and that some may be killed in the shark/tuna/mackerel driftnets in the Northwest Territory. Estimates of total incidental take are probably low.

S. teuszii (Atlantic hump-backed dolphin)
Mortality along the *West coast of Africa* was reported by Cadenat and Paraiso (1957).

Stenella attenuata (pantropical spotted dolphin)
For the *northern Indian Ocean*, incidental kill has been reported from coastal Sri Lanka and Pakistan (Leatherwood and Reeves, 1989; SC/O90/G30) and it probably occurs in other regions.

In *Australasia*, this species is one of several killed in Taiwanese drift gillnets off the coast of northeast and northwest Australia (Harwood *et al.*, 1984; Harwood and Hembree, 1987). In the period 1981–1985, an annual mortality of 126 animals was estimated on the basis of an observer programme. Significant declines in cetacean catch rate with both time and increasing cumulative effort occurred 1981–83. Similar analyses for 1984–85 were not done because of changes in observer coverage, fishing methods and area of operation. This fishery has since moved into waters of Papua New Guinea and Indonesia (Liu, 1989), probably eliminating the fishery as a source of additional mortality in coastal waters of Australia but inflicting mortality on animals in nearby waters that probably constitute the same population. Estimates of total incidental take are probably low.

In the *Philippines*, these dolphins are taken by purse-seines, harpoons and driftnets (SC/O90/G29).

In the *western North Pacific*, research operations with large-mesh gillnets incurred some incidental kill (SC/O90/G52). A drive fishery is still active but at lower levels than in the past. The estimate of population size may include more than one stock (Kasuya and Miyashita, 1989).

Some animals are known to be caught in gillnets off central *Peru* (Read *et al.*, 1988). This stock is of the coastal subspecies of the spotted dolphin that ranges from Mexico to Peru and is killed in the tuna purse-seine fishery in small numbers (Perrin *et al.*, 1985). The abundance was estimated as 36,000 in 1989 (Gerrodette and Wade, 1991).

S. clymene (clymene dolphin)
For the *Caribbean*, Vidal reported an animal killed off Venezuela.

S. coeruleoalba (striped dolphin)
Notarbartolo di Sciara reported that in the *Mediterranean*, large numbers were killed in the recently-banned driftnet fishery. Other sources of mortality include purse-seines, longlines, trawls, harpoons and gunshot (SC/O90/G34) and a recent mass die-off due to unknown causes.

For the *eastern North Atlantic*, mortality was reported by Duguy and Hussenot (1982) and in SC/O90/G35.

In the *western North Atlantic*, four striped dolphins were observed killed during 1989 in the swordfish driftnet fishery conducted in northeast US shelf-edge waters (SC/O90/G6). The annual kill has been estimated on the basis of 5–10% of trips observed. The estimate of abundance was reported in Kenney (1990).

In addition to the incidental kill in *coastal Sri Lanka*, there may be a small directed harpoon fishery (Leatherwood and Reeves, 1989). Leatherwood reported that there are probably additional takes in the large-mesh gillnet and Taiwanese driftnet fisheries in the Indian Ocean.

In *coastal Japan* and the *western North Pacific*, incidental mortality occurs in the gillnet fishery (SC/O90/G8) and possibly in the large-mesh gillnet fishery (SC/O90/G52). Until the 1960s, the drive fishery killed 15–30,000 each year. The level has gradually declined to 2–5,000 (Kasuya and Miyashita, 1989).

S. frontalis (Atlantic spotted dolphin)
In the *western North Atlantic*, this species is killed in the swordfish driftnet fishery in US shelf-edge waters (SC/O90/G6). The annual kill has been estimated on the basis of 5–10% of trips observed.

For the *Caribbean*, some mortality has been reported off Venezuela (SC/O90/G7).

Mortality in the *Brazil region* was reported in SC/O90/G26.

S. longirostris (spinner dolphin)
For the *Caribbean*, Vidal reported an animal killed in passive gear off Venezuela. A directed fishery occurred in the past (Caldwell and Caldwell, 1975) that may still be active.

This species is killed in large numbers in *Sri Lanka* (Leatherwood and Reeves, 1989). Observations of fisheries in Sri Lanka suggest that even larger numbers may be killed in gillnets when all regions of the northern Indian Ocean are considered. A small harpoon fishery also exists. Mortality in Taiwanese driftnets is likely. This dolphin may be the most common species in the northern Indian Ocean, but the cumulative impact of the various fisheries may be dangerously high.

A dwarf form of spinner dolphin is killed in waters of *Thailand* (Perrin *et al.*, 1989).

In *other northern Indian Ocean* areas, this species is killed in Bangladesh, India and Oman, but the levels of mortality are unknown (SC/O90/G12; SC/O90/G22; SC/O90/G30).

In *Australasia*, this species is one of several killed in Taiwanese drift gillnets off the coast of northeast and northwest Australia (Harwood *et al.*, 1984; Harwood and Hembree, 1987). From 1981–1985, an annual mortality of about 1,000 animals was estimated on the basis of an observer programme. Significant declines in cetacean catch rate with both time and increasing cumulative effort occurred from 1981–83. Similar analyses for 1984–85 were not done because of changes in observer coverage, fishing methods and area of operation. This fishery has since moved into waters of Papua New Guinea and Indonesia (Liu, 1989), probably eliminating the fishery as a source of additional mortality in coastal waters of Australia but inflicting mortality on animals in nearby waters that probably constitute the same population. Estimates of total incidental take are probably low.

Mortality in the *Philippines* is reported in SC/O90/G29.

Steno bredanensis (rough-toothed dolphin)
The occurrence of incidental mortality in the *Mediterranean* is reported in SC/O90/G34. Notarbartolo di Sciara reported that this species is an occasional visitor to the Mediterranean.

Incidental mortality for the *Brazil region* is reported in SC/O90/G26.

Low numbers are killed in gillnets in *coastal Sri Lanka* (Leatherwood and Reeves, 1989).

In *coastal Japan*, some dolphins are killed in Japanese trap nets (SC/O90/G36). They are occasionally killed in Japanese drive fisheries.

Tursiops truncatus (bottlenose dolphin)
For the *Mediterranean*, Notobartolo di Sciara reported that mortality occurs in drift gillnets, longlines and trawls and by harpoon and gunshot. The abundance estimate was based on a series of research cruises. See the explanation of the abundance estimate in annotation section I (above).

In the *offshore western North Atlantic*, mortality has occurred in the swordfish driftnet fishery operating at the shelf-edge of the northeast US (SC/O90/G6). During August-November 1989, 10 offshore bottlenose dolphins were observed killed. The estimated kill represents an adjusted number for a maximum of the 5–10% of the trips observed, as reported by Waring and Payne. Abundance estimates are reported in Kenney (1990).

In the *coastal areas of the western North Atlantic*, a die-off of bottlenose dolphins occurred along the US Atlantic coastline during 1987–88 (Scott *et al.*, 1988). From June 1987 through June 1988, over 700 dolphins stranded from New Jersey south to Florida. Scott *et al.* (1988) suggested that the coastal form was reduced by as much as 53% and, assuming a constant rate of mortality equal to pre-epidemic estimates, the average expected recovery time for this population while sustaining human-induced mortality is greater than 100 years.

Few direct reports are available for the incidental kill in the *Gulf of Mexico*. Interviews with fishermen and examination of stranded animals suggested that in some areas up to 1% of local populations may be taken each year (Reynolds, 1985; Burn and Scott, 1988). Bottlenose dolphins in this region are also removed by live capture. Burn and Scott (1988) summarised stranding data for the southeastern USA and found that human-related mortality may range as high as 7% of all observed mortality in the region.

Mortality in the *Caribbean* is reported in SC/O90/G7.

In *Uruguay*, bottlenose dolphins are killed incidentally in the catfish fishery but reportedly 'cooperate' with mullet fishermen (Simões-Lopes, 1991). Mortality in Uruguay is reported in SC/O90/G1.

Mortality for *coastal West Africa* is reported in SC/O90/G5.

The population along the south coast of Natal, South Africa, may be unable to sustain the level of incidental take in shark nets and may be declining. Most of the kill comprises lactating females and their calves (Cockcroft, 1990; Cockcroft and Ross, 1991). The population along the north coast of Natal may also be adversely affected by the level of shark-net catches, and (as for the south coast) most of the kill comprises lactating females and their calves (Cockcroft, 1990; Cockcroft and Ross, 1991). In addition, studies have shown that the population may be suffering further impact from the high levels of pollutants (Cockcroft *et al.*, 1990).

Mortality in *Sri Lanka* alone is estimated to be over 500 annually (Leatherwood and Reeves, 1989). Observations of fisheries in Sri Lanka suggest that large numbers of this species may be killed in gillnets when all regions of the northern Indian Ocean are considered.

In the *northern and western Indian Ocean*, incidental mortality of coastal forms also occurs in gill nets along the east coast of Africa (Mozambique, Madagascar) and the northern Indian Ocean (e.g. Thailand, Pakistan). Information is given in Leatherwood and Reeves (1989) and SC/O90/G12, G20, G22, G26 and G30. Local populations may have become depleted in many of these areas.

In *Australasia*, this species is one of several killed in Taiwanese drift gillnets off the coast of northeast and northwest Australia (Harwood *et al.*, 1984; Harwood and Hembree, 1987). From 1981–1985, an annual mortality of about 1,700 animals was estimated on the basis of an observer programme. Significant declines in cetacean catch rate with both time and increasing cumulative effort occurred from 1981–83. Similar analyses for 1984–85 were not done because of changes in observer coverage, fishing methods and area of operation. This fishery has since moved into waters of Papua New Guinea and Indonesia (Liu, 1989), probably eliminating the fishery as a source of additional mortality in coastal waters of Australia but inflicting mortality on animals in nearby waters that probably constitute the same population. Estimates of total incidental take are probably low. Other incidental catches include observed annual catches of up to an average of 25 from shark nets around Australia (that estimate includes four species of dolphins – Paterson, 1990). Anderson reported that inshore set nets probably kill a few per year and that some (<10) may be killed in the shark/tuna/mackerel driftnet in the Northwest Territory. The inshore population is probably vulnerable in some areas.

In the *western North Pacific and coastal Japan*, incidental kill occurs in trap nets (SC/O90/G36) and in research operations using large-mesh gillnets (SC/O90/G52). A direct kill occurs by Japanese harpoon and drive fisheries (Kasuya and Miyashita, 1989). The estimate of population size is only for the East China Sea-Sea of Japan area (Miyashita, 1986).

In *coastal California and the Gulf of California*, two stocks are currently recognized (Walker, 1981). The stock structure of the incidental kill is unknown, however, making it difficult to assess the impact of local mortality. Abundance in California was estimated by Hansen (1990). Sources and levels of mortality are discussed in SC/O90/G7, G24 and G28.

Inshore and offshore stocks exist along the *Pacific coast of South America*. Incidental mortality occurs in the artisanal drift gillnet fishery which takes animals mainly from the offshore stock. The estimates of kill are based on observations made in the port of Pucusana only (Read *et al.*, 1988; SC/O90/G54).

FAMILY ZIPHIIDAE

Ziphiids (unidentified beaked whales)
The 19 nominal species in this family are often difficult to identify in the field, especially for untrained observers. This difficulty is compounded by the fact that, due to their size, entangled animals are usually cut adrift from nets rather than hauled aboard. This lack of species identification is a problem in determining the impact of fisheries.

Berardius arnuxii (Arnoux's beaked whale)
Information is given in SC/O90/G52.

B. bairdii (Baird's beaked whale)
This species is taken in a direct fishery off Japan. The number taken is controlled by a Japanese quota that has ranged from 40 to 57 animals annually. Ohsumi (1975)

documented the kill of Baird's beaked whale in Japanese high seas salmon drift gillnets. Miyashita (1990) estimated population size.

Hyperoodon ampullatus (northern bottlenose whale)
Although there are few documented cases of entangled bottlenose whales, this species was subjected to heavy exploitation in a direct fishery. The species was provisionally listed as a Protected Stock by the IWC in 1977.

H. planifrons (southern bottlenose whale)
Although no absolute abundance estimates are available, this species seems to be the most abundant beaked whale species in sub-Antarctic and Antarctic waters (Kasamatsu *et al.*, 1988).

Pygmy beaked whale (unidentified mesoplodont)
This group of 13 species is extremely difficult to identify in the field. In two regions, the westen North Atlantic and coastal Sri Lanka, kills of pygmy beaked whale are potentially high. In addition, the Sri Lankan data probably underestimate the kill of all ziphiids as the catch must be brought ashore in small boats to be counted in the fish markets. Only calves or small juvenile animals are represented in the estimates. Without identification, the most conservative approach would be to assume that all the kills in each region are from only one species.

In the *western North Atlantic*, 12 mesoplodonts of unknown species were observed killed during 1989 in the swordfish drift gillnet fishery conducted in northeast US shelf-edge waters. The total kill presented in the Table has been estimated on the basis of 5–10% of fishing trips observed during 1989.

Information for *coastal Sri Lanka* is reported in Leatherwood and Reeves (1989).

M. carlhubbsi (Hubbs' beaked whale)
Information for the *eastern North Pacific* is reported in SC/O90/G24 and G28.

M. densirostris (Blainville's beaked whale)
Information for *coastal Sri Lanka* is reported in Leatherwood and Reeves (1989).

M. peruvianus (lesser beaked whale)
This new species of beaked whale was described from specimens killed in gillnets along the coast of Peru (Reyes *et al.*, 1991).

Ziphius cavirostris (Cuvier's beaked whale)
Notarbartolo di Sciara reported that this species is taken in gillnets in the *Mediterranean*.

Information for *coastal Sri Lanka* is reported in Leatherwood and Reeves (1989).

In the *western North Pacific*, Kasuya and Miyashita reported that carcasses of this species were sighted during the Japanese sighting cruises. Miyashita also confirmed a carcass entangled in a monofilament gillnet.

Information for the *eastern North Pacific* is reported in SC/O90/G24.

FAMILY PHYSETERIDAE
Physeter macrocephalus (sperm whale)
Notarbartolo di Sciara reported that the stock structure in the *Mediterranean* is unknown. If this population represents a separate stock from the North Atlantic, then the kills of sperm whales may not be sustainable. However, it is likely that the small numbers of sperm whales in the Mediterranean represents part of some larger North Atlantic stock that migrates in and out of this sea. If the latter scenario is correct, then the kills in swordfish driftnets represent a smaller impact to this population of sperm whales.

Information for *coastal Sri Lanka* is reported in Leatherwood and Reeves (1989).

Information for the *eastern North Pacific* is reported in SC/O90/G11, Perrin (1990) and Darling (1988).

Kogia sp. (unidentified kogiid)
These two closely related species are difficult to identify in the field (Ross, 1984). Because of this, incidental kills are sometimes only identified to genus.

In the *central North Pacific*, an unidentified kogiid was reported killed in the Japanese driftnet fishery by Omura *et al.* (1984).

Kogia breviceps (pygmy sperm whale)
Information for the *Caribbean coast of Colombia* is reported in SC/O90/G7.

Information for *coastal Brazil* is reported in Caldwell and Caldwell (1989) and SC/O90/G26.

Information for *coastal Sri Lanka* is reported in Leatherwood and Reeves (1989).

Kasuya reported that this species has been taken in Japanese squid gillnets in the *North Pacific*

Kogia simus (dwarf sperm whale)
Information for *coastal Brazil* is reported in Caldwell and Caldwell (1989) and SC/O90/G26.

Information for *coastal Sri Lanka* is reported in Leatherwood and Reeves (1989).

Information for *coastal Peru* is reported in Van Waerebeek and Reyes (1990a).

6. CAUSES AND SOLUTIONS

Lien chaired the sub-group reviewing causes of entanglement and possible solutions. Donovan acted as rapporteur with assistance from Lien. The sub-group agreed to review the following topics:

(1) behaviour and sensory abilities;
(2) modifications to existing fishing gear; and
(3) alternative technology and management;

making use of the meeting documents and information furnished directly by the participants and from the published literature.

6.1 Sensory abilities – thresholds and detection

The sub-group agreed that under this section of its report it would concentrate on the physiological thresholds and sensory capabilities of cetaceans. The relevance of this information to possible solutions to the fishing gear entanglement problem is discussed further under Item 6.6, although inevitably some aspects are discussed here also.

6.1.1 Acoustics
The acoustic capabilities of cetaceans have probably been better studied than other sensory capabilities they have (e.g. see review in Watkins and Wartzok, 1985). Details are not presented here. Several papers were available that provided information on the detection on nets by odontocetes using echolocations (SC/O90/G9, G15; Au,

1990; Au and Jones, 1991) and on echolocation in general (SC/O90/G13, G16, G17). Table 2 shows, for some species, the theoretical echolocation detection ranges for monofilament gillnet used in the North Pacific salmon mothership fishery and for polyester rope/metallic bead chain. Bubbles created by high sea states (see Item 4.2.6) will decrease these detection ranges. Table 2 and field observations (SC/O90/G9) indicate that dolphins are able to detect the monofilament section of gillnets at sufficient ranges to avoid entanglement. Gillnets modified by added gear such as rope and metallic bead chain should be detected at considerably greater distances than unmodified gillnet. However, experiments with such modification added to increase sonar detection have not been successful in reducing entanglements (e.g. SC/O90/G13, G15, see also Annex E). Possible reasons why dolphins are still being entangled in modified and unmodified nets despite their acoustic capabilities are summarised below. They are discussed in more detail under the indicated report items.

Table 2

Theoretical 90% probability of detection ranges as a function of biosonar source level, based on bottlenose dolphin biosonar performance data, for sea states 0-3 (Au, pers. comm.)

Peak-to-peak source level (dB re 1μPa)	Monofilament gillnet[1]	Polyrope[2]	Metallic bead chain[3]
150	2.2m	8.9m	7.3m
160	4.0m	15.9m	13.0m
170	7.1m	28.2m	23.0m
180	12.6m	50.1m	41.0m
190	22.4m	89.1m	72.9m
200	39.8m	158.5m	129.6m

[1] 0.49mm diameter nylon monofilament, 10cm mesh size; [2] 0.635cm twisted polyester rope; [3] household light switch chain.

(1) Dolphins may not echolocate all the time. Some species such as Hector's dolphin often do not echolocate when navigating in a familiar environment (Dawson, 1988) and may echolocate only when foraging for food (SC/O90/G16). However, Norris reported that there is a school phenomenon with some pelagic dolphins whereby a number of individuals in a school are always echolocating.
(2) Dolphins may detect a gillnet but may not perceive the net as a barrier. Barriers may be totally alien to pelagic dolphins accustomed to roaming freely in the ocean and they may not have evolved behaviour patterns to deal with them (see Item 6.2.2). The diffuse echoes from nets (SC/O90/G15) may resemble a penetrable volume such as the deep scattering layer or kelp and other seaweed.
(3) Dolphins may be foraging for food in the vicinity of nets and be oblivious to nets and other obstacles while focusing their attention on prey (see Items 6.1.2 and 6.2.1). Attention to social activity such as play or competitive behaviour may also distract them (see Item 6.3).
(4) There are indications that dolphins are attracted to nets either by the presence of entangled fish or the presence of prey congregated near the nets (see Item 6.2.1). Some dolphins may be caught through 'carelessness' or inattention when around nets (see Item 6.3.2). Dolphins, especially young and inexperienced ones, may be attracted to nets as novel objects to explore and play with.
(5) Sleep, especially at night when most dolphin entanglement seems to occur, may be a factor in the non-detection of nets (see Item 6.2.2). However, as noted above in some schools of pelagic dolphins it seems that a number are always awake.

It should be also be noted that fishing gear emits noise that might be detected by cetaceans (see Item 6.5.2). The 'self noise' generated by water movement through a set net or by wave action pulling at surface float lines may be very loud, louder than the returning echoes produced from the dolphins, echolocating signals (Lien *et al.*, 1990). The acoustic energy is low frequency and large cetaceans with good low frequency hearing may be better able to take advantage of gear noise than small cetaceans that do not typically have good low frequency hearing. Detection and localisation of nets by passive hearing (i.e. when the animals are not echolocating) will be less precise than by echolocation.

The sub-group agreed to the following recommendations for future research:

(1) determine the sonar detection capabilities of some of the smaller odontocetes such as Dall's porpoise, harbour porpoise, Commerson's dolphin and Hector's dolphin;
(2) perform research to understand the acoustic and behavioural dynamics involved with dolphin-gillnet interaction and with fish-gillnet interaction, to determine why and how dolphins get entangled and the proportion of a pod or school of dolphins that typically gets entangled;
(3) determine the amount of self-noise in nets for different sea states for surface nets and current conditions for bottom set nets, and compare fish and dolphin entanglement with sea state conditions (see Item 6.2.6).

6.1.2 Prey size/ target strength

SC/O90/G16 examined the acoustic behaviour of a wild bottlenose dolphin during foraging. Slowest sonar click rates corresponded to maximum search range and may be related to the detection of preferred prey size and effort to capture. The dolphin was insensitive to secondary echoes from ranges beyond those defined by the click rate. Sonar click rate also varied inversely with the dolphin-prey closure range, becoming higher as the closure range decreased.

6.1.3 Vision

In addition to echolocation and hearing, vision is important to many cetaceans. Cetaceans have excellent underwater vision (e.g. Dawson, 1980; Watkins and Wartzok, 1985). It is important to understand the characteristics of cetacean eyes in order to assess the visual problems they may face in dealing with nets. One tends to think of dolphins as echolocating animals, forgetting that they may sometimes carry out much of their behaviour wholly without phonation, especially in times of danger. Baleen whales are not known to orient by echoes, although the possibility of such a capability should not be discounted (Lien, 1987). They can orient in very murky water and over considerable distances in conditions when vision would not seem to serve them well (Lien, 1980). Listening to the sounds produced by objects themselves may be the basis for detection (Lien *et al.*, 1990) but the possible use of vision cannot be eliminated.

Vision is important to cetacean orientation and it appears to mediate some aspects of the schooling of dolphins; manoeuvring may be related to pattern marks and their movement across the visual field of adjacent animals. Such patterns are best developed in clear water cetaceans and are reduced to whole-body flash signalling in murky water animals (Madsen and Herman, 1980; Norris and Dohl, 1980; Norris *et al.*, 1985). In the dark, bioluminescence is certain to be important, especially in the visualisation of moving nets. Cetacean eyes are especially adapted for low light levels (e.g. Herman *et al.*, 1975). They are amongst the few mammalian species in which the optic cup is fully tapetalised over its entire area (Dawson *et al.*, 1987a; 1987b). Their eyes are also able to deal with the extremely difficult visual environment of the surface sea, where the flicker effect may reverse intensities many times a minute, sometimes reaching peaks at several times the intensity of direct sunlight.

Most evidence suggests an almost or total lack of colour vision in cetaceans, although the highest sensitivity of the retina in coastal species is centred in the blue to yellow green, while that of open sea species emphasises the blue (Madsen and Herman, 1980).

For these reasons the visibility of nets may provide important orientation signals during both night and day and even in rather murky water. The question of diurnal variation is discussed under Item 6.2.2.

As in the case of acoustic perception of nets, there are many behavioural observations indicating that cetacean species *can* perceive nets using sight (e.g. bottlenose and hump-backed dolphins off Natal: Cockcroft, 1990; Dall's porpoises in the high sea: SC/O90/G9; humpback whales off Newfoundland: Lien, 1980). The potential reasons why entanglement still occurs are similar to those listed above in Item 6.1.1.

6.1.4 Other

The sub-group agreed that acoustics (hearing/echolocation) and vision were the most important sensory capabilities of cetaceans with respect to the entanglement problem. However, the other senses may also play some role and they are reviewed briefly below. It should be noted that little direct evidence of their role is available.

MECHANICAL

Mechanical senses include touch, pressure, position, acceleration and vibration sensing. The anatomy of many of these receptors is reviewed in SC/O90/G18. The author concludes that in general cetaceans appear well-equipped to sense the mechanical aspects of their surroundings and that this may include an ability to follow currents in the water. This is of some interest in the light of a review of environmental factors and entanglement of bottlenose and hump-backed dolphins off the Natal coast of South Africa by Cockroft (1990). He found that current direction on the day of capture was often different from the normally prevailing direction. No correlation between entanglement and fullness of stomach was found, suggesting that it is not simply a function of dolphins following prey species that may be influenced by the currents.

Clearly, mechanical senses will detect the gear itself only when the animals come into contact with it, by which time entanglement may have already occurred. However, since nets may be set either with or across currents, analysis of entanglements with respect to orientation of the nets and current direction may be useful.

THERMAL

The anatomy and physiology of thermal control are reviewed in SC/O90/G18. The ranges and/or seasonal distribution of many cetacean species can be described with reference to surface isotherms or to the temperature characteristics of particular water masses. The range of temperatures at which most cold-blooded prey species can live tends to be narrow, in comparison with the ranges which cetacean species can tolerate. Water surface temperature and temperatures at specific depths are sometimes used to locate fishery target species (e.g. SC/O90/G14 – swordfish fishery; SC/O90/G8 – flying squid fishery).

All cetaceans have the means to sense environmental temperature and at least some fishing gear is set in relation to water temperature. If cetaceans follow temperature gradients as a travel cue or as a guide to prey, they could be brought into collision with nets set across the travel path. This possibility requires investigation.

CHEMORECEPTORS

The anatomy of chemoreceptors and the experimental investigation of chemoreception is reviewed in SC/O90/G18. Chemoreception may provide social information (e.g. reproductive state, alarm), directional information (e.g. following salinity gradients) or foraging information (e.g. detecting the excreta of prey). Evidence for this is at present anecdotal and further research is needed to establish the true role of chemoreception in the life of cetaceans.

Natural history literature often refers to the presence of blood in the water as an 'alarm' substance. Italian fishermen reportedly throw back carcasses of incidentally killed dolphins, believing that this will deter other animals. Lien (1980) reported that fresh humpback blood did not prevent another humpback whale getting caught in a set net off Newfoundland. Hawaiian fishermen were unsuccessful in discouraging bait stealing by dolphins (including bottlenose and rough-toothed dolphins and pygmy and false killer whales) by lacing the bait with quinine. However, bottlenose dolphins readily eat fish containing quinine in captivity so perhaps this is not surprising (Schallenburger, 1979).

Myrick (1988) reported that spotted dolphins chased and set upon by purse-seiners are hypocalcaemic, a common stress reaction in other mammals. A further characteristic of stress in mammals is the presence of chemicals in the urine that may constitute an 'alarm' substance. Kleinenberg *et al.* (1964) report an incident of an unmolested group of white whales fleeing when they reached an area where an earlier group had fled due to the presence of hunters. This could be indicative of an alarm substance.

Fishing gear has its own chemical characteristics, as do target and non-target species caught in that gear. Lien reported that older Newfoundland fishermen relate that there were fewer collisions by animals with cotton and hemp nets that were dipped in oily tar; they believed that animals such as whales and seals could smell them. Chemoreception may play some role in entanglements either due to stimulants provided by gear, prey species or conspecifics, but considerable research is needed to determine this and investigate the possibility of developing effective chemical 'deterrents'.

MAGNETIC AND ELECTRICAL

SC/O90/G18 reviews magnetic and electrical detection by cetaceans. Behavioural evidence suggests that cetaceans may be able to sense the flux density of the earth's magnetic field as a travel guide, generally swimming parallel to the contours (i.e. in areas with low field gradient). Beaches where strandings and drive fisheries for long-finned pilot whales have taken place tend to have perpendicular magnetic contours. Travelling (but not feeding) fin whales have been shown to use magnetic contours as a travel guide, based on data from the UK, Ireland and USA east coast. There is also some evidence for a 'travel clock' re-set by geomagnetic information and used in monitoring position and progress (Kirschvink, 1990; Klinowska, 1990).

While it seems unlikely that gear itself would provide any magnetic information, it is not inconceivable that cetaceans following magnetic contours could be brought into collision with gear deployed across these contours. In such situations gear could be re-oriented to align with cetacean movement.

6.2 Environmental/ecological correlates

6.2.1 Food

Entanglements may occur where: the target species are prey or potential prey for cetaceans; the fish caught are not prey species but cetaceans are attracted to the nets because other potential prey are associated with the net; the target and incidental species are seeking similar prey; or the cetaceans and fisheries occur in the same vicinity for reasons related to physiography and biological productivity.

(1) SITUATIONS IN WHICH MARINE MAMMALS ATTEMPT TO REMOVE PREY FROM NETS

There is evidence from some fisheries that marine mammals attempt to remove prey from nets. This includes harbour porpoises in the North Atlantic (e.g. SC/O90/G46; SC/O90/G8; Read and Gaskin, 1988). Lien (1994) reported that in Newfoundland, long-finned pilot whales intentionally frequent traps to remove the target species of squid (*Illex illecebrosus*). There are no reports of such behaviour in baleen whales. Many pinniped species are known to actively and efficiently remove prey from nets and traps (e.g. see Beddington *et al.*, 1985).

(2) SITUATIONS IN WHICH MARINE MAMMALS ARE NEAR NETS, BUT DO NOT REMOVE PREY FROM THE NETS

Nets may serve as attractants which lure fish and other animals to the area of the net; nets are known to have a 'calling area'. The use of fish attracting devices (FADS) is a technique whereby objects are installed which serve as the focus for the establishment of a marine community. Prado reported that FADS are known to draw in fish from distances of 4–5 n.miles. Cetaceans may be attracted to nets in a similar manner, or may respond to prey species which react in this way.

Marine mammals may also be attracted to scavengers feeding on fish in the nets.

Another possibility is that target and non-target species have similar prey items or are linked in some way through the food web. This is probably common in many situations e.g. *Tursiops* in South African shark nets (Cockcroft, 1990; SC/O90/G20), Dall's porpoises in salmon driftnets reported by Jones), harbour porpoises in the halibut fishery and vaquitas in the totoaba fishery.

In some cases marine mammals, for example humpback whales in Newfoundland, use nets as a backdrop to corral fish (Lien, 1980). Minke whales may be attracted to nets by the scrapefish discarded by fishermen as they clean their gear (Lien, 1994).

In many cases nets are set in areas of high biological productivity and as a result both target species and mammals are present.

6.2.2 Physical conditions

DIURNAL CYCLES

Diurnal behaviour patterns may be considered with regard to the timing of net sets, the soak time and the behaviour of both target and non-target species.

Like most organisms, cetaceans have specific diurnal patterns and cycles (e.g. Klinowska, 1980). These cycles may contribute to the likelihood of entanglement. Some species may travel considerable distances on a daily basis. Diurnal travel patterns may increase the likelihood of encountering nets, and travel may be associated with food sources, migration or other factors such as tides and currents (Klinowska, 1980).

Many diurnal cycles are linked closely to prey behaviour. One of the most obvious is the daily vertical migration of the deep scattering layer (DSL). Linkage to the DSL is probably strong in most oceanic species, notably *Stenella longirostris* (Norris *et al.*, 1985).

Some cetaceans descend to rest, sleep or reduce their activity during parts of the day. This behaviour may increase the chances of entanglement due to decreased awareness of surroundings, but it also reduces travel and the probability of encountering a net. Some species have a general tendency toward increasing group size later in the day (Norris and Dohl, 1980; Scott *et al.*, 1990) and large groups may have a greater ability to detect threats such as nets. Some cetaceans are active at dawn and dusk, when low or changing light levels may decrease the likelihood of net detection, although as noted under Item 6.1.3, cetacean vision is good in low light.

The diurnal behaviour patterns of target and incidental species are probably closely linked. However, in fisheries where this is not the case it may be possible to reduce entanglement rates while concurrently maintaining catch levels by adjusting the timing of gear setting and soak durations.

TURBIDITY

This is potentially an important factor if vision is the major sense used by the cetacean to detect fishing gear. There is little direct information of the effect of turbidity on entanglement rates of cetaceans. The only attempt at a quantitative study is that described by Cockroft and Ross (1991) for dolphins caught in shark nets off the Natal coast of South Africa. Nets are examined daily and so turbidity on the day of capture is known but turbidity at the precise time of capture is not.

Cockroft found that animals were caught at all levels of turbidity, although at one location near a river mouth where the water visibility was <1m, hump-backed but not bottlenose dolphins were caught. This is thought to reflect the fact that bottlenose dolphins tend to avoid turbid water off that coast while hump-backed dolphins are often associated with riverine conditions (e.g. Ross, 1977; Norris *et al.*, 1985). Turbidity may also be a factor in the seasonal changes in distribution of bottlenose dolphins off the coast (Cockcroft, 1990).

Visual characteristics of fishing gear, including brightness, colour and size, were found to be less important than turbidity in determining distances at which gear could be visually detected (Lien, 1980).

AMBIENT NOISE

Ambient noise could be an important factor as it has the potential for making gear less acoustically detectable. Again, almost no quantitative information exists on entanglement rates at different levels of ambient noise. In the Cockroft (1990) study off Natal, no direct measure of ambient noise was available. However, the author looked at swell height and depth of net as some indication of likely ambient noise and found no significant correlation with entanglement rate, although he noted the paucity of data. Lien *et al.* (1990) suggest that high risk areas for entrapments of humpback whales may be characterised by high levels of ambient noise.

Ambient noise may be a factor in entanglements for certain fisheries and species. However, this cannot be determined without carefully designed experiments. Until these are completed it will be impossible to consider ambient noise when trying to develop possible modifications to fishing practice or gear which may help to reduce entanglement problems.

TIDES AND CURRENTS

Tides and currents are known to affect the distribution of some cetacean species in certain areas (e.g. Würsig and Würsig, 1979), probably by influencing the distribution of prey species. Again there is almost no direct information on the influence of either tide or currents on entanglement rates of cetaceans. In the Cockroft (1990) study off Natal, however, there was a significant correlation between current direction and entanglement rate, with most captures occurring when the current direction was northerly. The reason for this is unclear.

Tides and currents may be a factor in entanglements for certain fisheries and species. However, as for the other factors discussed, without carefully designed experiments it will be impossible to try to develop possible modifications to fishing practice or gear which may help to reduce entanglement problems. This is discussed further under Items 6.1.4 and 6.3.3.

DEPTH

This is clearly an important factor in some entanglement situations. Different cetacean species spend differing amounts of time at different depths depending on their feeding strategy and whether they are travelling, etc. The depths at which fishermen set their nets depends on the target species and the type of gear. The potential for deploying nets at depths less likely to cause potential contact with cetaceans is high for some fisheries. Experiments along those lines have already been carried out with some degree of success (SC/O90/G58; Harwood and Hembree, 1987). These are discussed further under Item 6.2.2.

SEA STATE AND BUBBLES

The surface sea is often turbulent and waves can drive plumes of bubbles into the water for several meters. Such bubble plumes will probably be largely opaque to echolocating cetaceans. The bubbles can be divided into three categories: (1) tiny bubbles that quickly dissolve; (2) mid-range bubbles that may develop films over their surfaces that can cause them to persist for long periods; and (3) larger bubbles whose greater hydrostatic lift causes them to rise quickly to the surface.

The mid-sized bubbles can be very persistent, remaining in the upper sea water column for a matter of hours. They are also of a range of diameters that form excellent echolocation reflectors (*ca* 60 microns and above) and may appear as much as seven times their actual size to an echolocating animal. This means that the surface sea, especially during times of rough weather, can completely obscure the echolocation trains of dolphins. Translated to the driftnet problem this could mean that in the upper few meters of the sea, bubbles might completely blot out echo returns from nets in the area.

If cetaceans typically swim through such acoustically-opaque water, they could be especially vulnerable to entanglement. Since there are no true obstacles at sea except for occasional floating debris, dolphins may deliberately swim 'blind' through such water, making them especially prone to entanglement. Differential entanglement during various sea states should be examined as part of a preliminary assessment of this question (see Item 6.1.1).

6.3 Behaviour

While we understand some cetacean behaviour, there is much more to know. In particular the behaviour of cetaceans near nets is little studied and poorly understood; there is little systematic knowledge of many behavioural processes which may dispose them to entrapment risk near fishing gear.

6.3.1 Curiosity, exploration

There are few published accounts which describe exploration behaviour of cetaceans (SC/O90/G49) and it is not possible from these studies to infer how cetaceans might react when first encountering fishing gear or what changes these initial encounters may produce in subsequent activities near nets.

Entrapments frequently involve disproportionate numbers of young cetaceans, which may be due to the animals lack of experience with fishing gear. This lack of familiarity may encourage curiosity, exploration or play which could result in entrapment (Cockcroft, 1990; SC/O90/G51). Age-dependent mortality resulting from risky exploration and play activities has been observed in terrestrial animals. Studies of social and play activities have found that they commonly have high costs in terms of injury or predation in young animals (Fagen, 1981). The observed age or sex skew in frequency of entrapments of young cetaceans in some fisheries may be a result of age or sexual segregation in certain species and some increased probability that these groups encounter fishing gear (Cockcroft, 1990).

For small cetaceans in particular, many close encounters with nets result in mortality (Table 3, Item 6.4), with consequently no opportunity for an individual's initial curiosity about nets to change. Observational learning is well documented in odontocetes; entrapment events could result in changes in the behaviour of other animals in a group. Cetaceans may learn to associate nets with negative events. They may also habituate to the novelty of nets as they more frequently encounter them. While this may produce fewer approaches for exploration, close approaches because of lack of attention may occur.

In baleen whales, it is also younger animals that appear to be those most commonly caught in fishing gear. In Newfoundland, entrapments typically involve small humpbacks (Lien, 1980; Lien, 1994). Humpback collisions with fishing gear appear to result from their failure to detect it; the higher probability of accidents by young animals would appear to reflect 'recklessness' or inexperience.

There is an urgent need for studies to examine the exploratory behaviour of young cetaceans and the role this behaviour may have in producing entrapments in fishing gear.

6.3.2 Attention and perception

Although in some populations the frequency of incidental entrapments by cetaceans is quite high, it is likely that the animals usually detect nets and avoid entrapment (Awbrey *et al.*, 1979; Cockcroft *et al.*, 1990; Hatakeyama, 1986). Generally, it has been assumed that detection of nets is accomplished by their acoustical properties (see Item 6.1.1).

While nets appear to be within dolphins' acoustical detection thresholds (SC/O90/G15; Au, 1990; Au and Jones, 1991), there may be reduced attention to acoustic cues or selective processing of information that is simultaneously being presented while feeding, travelling or resting. Animals may attend to particular stimuli over others both because the ability to process information is limited and through more 'voluntary' control over their attentional capacity (SC/O90/G48).

It is known that dolphins and porpoises may spend large amounts of time during which they produce no echolocation signals. Dawson (1990) found that Hector's dolphin did not echolocate regularly while navigating in a familiar environment. SC/O90/G16 reported that a wild bottlenose dolphin echolocated only when foraging for food. During periods while not echolocating, dolphins may be less capable of detecting nets.

Humpback whales have been observed feeding near fishing nets at night and to avoid becoming entrapped, without vocalising. (Lien, 1980). Collisions with fishing gear by this species in Newfoundland most frequently occur on the first day the gear is placed in the water; probability of a collision with a particular net decreases as soak time increases (Lien, 1988). It appears the animals are 'surprised' by the presence of new fishing gear but, following an encounter, learn its location. Similarly, accidents are most common on the first day whales move into an area where fishing gear has previously been installed; accidents decrease over time (Lien *et al.*, 1990).

Many observations indicate that dolphins are aware of the presence of nets as judged by their swimming behaviour around the gear (e.g. Silber *et al.*, 1994). In some cases the dolphin may perceive the net as a barrier. Tests of terrestrial species that have evolved in circumstances without barriers typically find that these animals have great difficulties learning to solve barrier problems (Maier and Maier, 1970). Fishermen setting on swordfish in the northwest Atlantic leave gaps between nets in a fleet to allow marine mammals to escape; Smolowitz reported that if there are no gaps fishermen feel that animals encountering the net are more likely to get caught.

6.3.3 Orientation

Orientation cues used by an animal can affect the likelihood of entrapment in fishing gear. If travelling, the navigational strategy used by an animal may modify the probability of encountering and detecting fishing gear (see Item 6.1).

According to Keeton (1974), animals generally have redundant navigation systems which are used in a hierarchical order. Little is known of cetacean navigation strategies; the satellite technology which may provide this information is still developing.

Proximate orientation by an animal while near nets may also be a factor in entrapments. If a dolphin echolocates on a fish target near nets, it may have difficulty detecting the net behind it (SC/O90/G17). Depth of field in the echolocation abilities of dolphins is poorly understood (Penner, 1988).

6.3.4 Escape patterns

There are few studies which provide information on escape efforts of small cetaceans when they collide with fishing gear or once they are entrapped in nets (SC/O90/G51; Hatakeyama *et al.*, 1988). The percentage of animals that encounter nets and successfully escape is not known; it is believed that this varies among species (Table 3, Item 6.4). Smaller cetaceans may not escape as often as the larger whales and the nature of the fishing gear and the depth of set may also be important factors.

Anecdotal accounts of observed escapes from fishing gear entrapments vary. Systematic disentanglement of dead animals from nets may provide information on their escape efforts (J. Coe, pers. comm.; Barham *et al.*, 1977). Lien reported that in Newfoundland, monitoring by side scanning sonar and underwater video cameras of fishing gear installed at locations where collisions are frequent may provide information on collisions and escape efforts of humpback whales.

6.3.5 Social patterns

There are important differences in social organisation among species of cetaceans; these differences may result in species being differently vulnerable to entrapment. They will also determine, in part, the effectiveness of efforts to minimise bycatch.

A body of theory (Norris and Dohl, 1980) proposes that schools, such as those of open-ocean dolphins, are sensory integration systems which mediate the behaviour of individual animals in the presence of danger in the three dimensional world of the open sea. Understanding how such cetacean schools communicate and process information may facilitate analysis of behaviour observed during encounters with nets. Norris reported that open ocean dolphins seem to have much difficulty if required to swim in smaller groups, or to pass through escape gates or spaces between nets smaller than will allow the school to pass. In dealing with these species, schools rather than individuals may be the appropriate unit for analysis with respect to the entanglement question. Cetaceans living in more restricted, nearshore habitats tend to travel in smaller groups.

In some cetaceans, the tendency for reciprocal or kin altruism acts (Caldwell and Caldwell, 1966; Conner and Norris, 1982) may contribute to entrapments. Many have reported mothers and young which are captured together in nets (Cockcroft, 1990); in some cases entrapped young have tooth marks on the body which appear to be the result of adult attempts to remove them from the net (Dawson, 1990).

6.3.6 Feeding behaviour

As noted under Item 6.2.1, feeding behaviour by cetaceans may be a significant contributing factor in many entanglements. Animals may be chasing prey species that are either the target species of the fishery, or others that occur in the same area as the target fishery. In some cases, animals may actually be taking prey species from the net (SC/O90/G2), or they may simply be attracted by entangled fish. Harbour porpoises in the Bay of Fundy feed on hagfish (*Myxine glutinosa*) that are feeding on fish captured in the nets (SC/O90/G6).

There is evidence that the smaller odontocetes are capable of acoustically and visually locating nets and observational data suggesting that free-ranging animals avoid capture in nets (Dawson, 1990; Hatakeyama, 1986; SC/O90/G9, G13, G15 and G20). This information implies that the entanglement problem may be less one of detection capabilities than one of alertness and attention (see Item 5.2). Observations of feeding porpoise and dolphins indicates that high speed chases culminating in prey capture is common in several species. If prey fish attempt to escape by swimming into or through a nearby net, a dolphin predator maybe so focused upon the target of the pursuit that the less salient visual and acoustic signals of a net fail to alert the animal (SC/O90/G17; SC/O90/G48).

For the more gregarious species, an additional confounding feature of feeding behaviour may be the feeding 'frenzy' that occurs in several species of small cetaceans when a school of fish is encountered. Highly active behaviour of a large group of feeding dolphins may reduce visibility or mask cues that would normally alert animals to the presence of nets and may distract normally wary animals in the excitement. Further, large schools of prey species may obscure visual or acoustic cues that would alert cetaceans to the presence of nets.

In the mysticetes, the levels of entanglement involving humpback and right whales in the North Atlantic, gray whales along the Pacific coast of North America and minke whales in the several areas of the Northern Hemisphere suggest that the animals have difficulty detecting the presence of gear, at least under certain conditions, or that they fail to attend properly to the gear while they are feeding or engaged in other activities. Mysticetes are not known to echolocate but from environmental constraints it seems likely that they detect the presence of gear using acoustical cues. Humpbacks in Newfoundland feed on capelin (*Mallosus villosus*) at night in turbid water next to cod traps in complete silence but their behaviour indicates that they can locate fishing gear and avoid it (SC/O90/G51; Lien, 1994).

The feeding lunges of humpback and minke whales and the bubble clouds used by humpbacks in feeding activities may make these animals susceptible to entanglement. In Newfoundland, capelin collect and school densely next to the leaders of cod traps; most collisions by humpbacks are observed to occur with leaders during these times (Lien *et al.*, 1988b). Entrapment of humpback whales is frequently by a net and rope bridle through the mouth, indicating it has been feeding when the collision occurred (Lien, 1980). Right whales may be vulnerable to entanglement while feeding because they engage in long skimming transits with their mouths open; in the northwest Atlantic about 50% exhibit scars in the corners of their mouths which are believed to be the result of fishing gear (Kraus *et al.*, 1984; Kraus, 1990).

6.4 Morphology: anatomy of entrapment

Cetacean entanglement in fishing gear probably occurs in a variety of ways, but there are almost no quantitative data on this. Where detailed reports exist, it appears that the head, mouth, flippers, dorsal fins and flukes are involved (SC/O90/G1,G2,G8,G25 and G26; Heyning and Lewis, 1990; Lien *et al.*, 1990). In a four year study of 10,259 Dall's porpoise entanglements in the North Pacific salmon driftnet fishery, Snow (1987) found that 27% were caught by the flukes, 10% by the pectoral flippers, 9.5% by the mouth and 24% in a 'complex' fashion. In anecdotal reports, the evidence indicates that the animals strike the net with their rostrum first, then roll themselves up into the net, presumably in the panic following the initial strike. There is one record of a Dall's porpoise breaking and swimming through a drift gillnet in the North Pacific (SC/O90/G9). In the case of many of the larger whales, particularly the mysticetes, lines or nets are caught in the mouth and may end up being carried around for several years (e.g. Kraus, 1990). Animals trailing such gear appear to be at a higher risk for subsequent entanglements (Lien, 1980) and may have a lower survivorship. The barnacles and callosities of humpback, gray and right whales may render these species more susceptible to entanglement (Lien, 1994).

The level of mortality associated with observed entanglements appears to be related to the size of the animal, although other factors such as gear type, mesh size and proximity to the surface, may also affect mortality rates. Small cetaceans suffer extremely high mortality from gillnets, but lesser mortality from encounters with weirs or seines (unless, as in the eastern tropical Pacific, deliberately captured in the purse seines). Larger animals tend to escape from most gillnets, probably because the gear is not strong enough to contain them, but in fisheries with heavier gear (e.g. cod traps or weirs), larger whales usually require assistance to escape.

Information on entanglement/mortality rates has two significant gaps: (1) animals may be entangled but escape carrying gear and/or injuries, thus lowering their probability of survival and (2) animals may strike the fishing gear and 'bounce' off without becoming entangled. Both possibilities will lead to undercounting cetacean/fishing gear encounters. Scarring indicating prior entanglement events and animals carrying gear have been reported in right whales (Kraus, 1990) and humpbacks (Lien, pers. comm.). About 4 to 5 times as many holes (presumably made by whales) as whales have been reported in nets by fishermen in Newfoundland and California (Lien, 1980, reported by Lagrange).

If animals escape entanglements but are carrying gear that subsequently affects survival, then the lethal effects of entanglements will be underestimated. Alternatively, if animals are bouncing off gear without any adverse effects, then the degree of mortality from net encounters will be overestimated. Given these caveats, data on survivorship from observed entanglements are presented in Table 3.

6.5 Types of gillnet and marine mammal bycatch risk

It is important that in the description of gillnet fisheries (as for any other) and in reports on research and experiments, the specifications of the gillnet or other gear used are complete and unambiguous. The lack of such information will preclude understanding of the true situation and comparison among experiments. Annex F presents guidelines for the correct description of gillnets.

Different types of gillnet are involved with entanglement of different cetacean species under different conditions. Entanglement problems should be considered case by case,

Table 3

Mortality in observed entanglements of cetaceans. These data do not include records of animals that struck gear but did not become entangled or those that became entangled and then escaped.

Species	Location	Year	Type of gear used	n	Mortality	Source
Harbour porpoise	Gulf of Maine	1975-89	Gillnet, bottom or midwater	71	99%	SC/O90/G6
Harbour porpoise	Baltic Sea	1988-89	Gillnet, bottom or midwater	70	100%	SC/O90/G25
Harbour porpoise	Newfoundland	1989	Gillnet, bottom or midwater	39	95%	SC/O90/G51
Harbour porpoise	Bay of Fundy	1979	Weirs	27	39%	Read & Gaskin, 1988
Harbour porpoise	Southern California	1983-86	Gillnet, bottom or midwater			
Small cetaceans	Peru		Gillnet, bottom or midwater		100%	SC/O90/G11
Franciscana	Uruguay	1974-89	Gillnet, bottom or midwater	3,008	100%	SC/O90/G1
Franciscana & Burmeister's porpoise	Argentina	1988-89	Gillnet, bottom or midwater		100%	SC/O90/G2
Small cetaceans [1]	Northwest Pacific	1988-89	Surface drift nets	1,167	96%	SC/O90/G8
Sperm whale	Italy	1988-89	Surface drift nets	9	0% [2]	SC/O90/G34
Humpback whale	Newfoundland	1979-90	Cod traps, gillnets	576	16% [2]	Lien, this volume
Right whale	North Atlantic		Cod traps, lobster gear	20	12% [2]	Kraus, 1990
Minke whale	Gulf of Maine	1975-89	Gillnets, lobster gear, weirs	28	64%	Kraus, pers. comm.
Minke whale	Newfoundland		Gillnet, bottom or midwater		70%	Lien, 1988

[1] Mainly Dall's porpoise, northern right whale dolphin, Pacific white-sided dolphin
[2] Numbers affected by disentanglement efforts by researchers and fishermen

considering the characteristics of the particular fishery, as well as the characteristics and behaviour of the susceptible cetacean species.

6.5.1 Bottom gillnets
Gillnets set on the bottom in coastal waters from nearshore areas to depths of around 200m are commonly used to catch demersal fish. Although they have been shown to entangle several cetacean species, the most critical problem area currently appears to involve coastal bottom-feeding small cetacean species such as the harbour porpoise. These species may be more susceptible to mortality in gillnets than larger cetaceans because they are less able to escape by breaking the gear. Other factors which may be involved in coastal bottom gillnet entanglements include:

(i) turbid water;
(ii) shared prey species (herring, mackerel, etc.);
(iii) depth of net relative to depth of water (in very shallow places);
(iv) long net soak time, in some cases;
(v) proximity to shore;
(vi) acoustically complex environment;
(vii) strong construction.

Relevant characteristics of the small cetacean species involved include their general tendency to stay in relatively small groups and use echolocation more than the open ocean species.

6.5.2 Bottom driftnets
The use of coastal bottom driftnets, particularly for shrimp, has increased tremendously during the past ten years. This technology sometimes gives artisanal fishermen access to a valuable resource. Although a small scale fishing method, the aggregate quantity of gear in the water in a given area may be substantial. Reliable information from such fisheries is not available but cetacean mortality may not occur at a high rate, possibly due to the following factors:

(i) the relatively short soak times (commonly 15–120 minutes);
(ii) continuous monitoring of the condition of the gear;
(iii) the acoustically 'noisy' character of nets drifting on the bottom;
(iv) the relatively small mesh size of shrimp driftnets (65–80mm stretched);
(v) the depth of the net relative to depth of water in shallow places.

6.5.3 Coastal drifting midwater or surface gillnets
Coastal drifting midwater or surface gillnets are used to catch salmon, mackerel, sardine, herring, etc. They are also known to take cetaceans, and relevant factors may include:

(i) the depth of net relative to the depth of water (in very shallow places);
(ii) the target fish species also being the cetaceans' prey species;
(iii) the nets often being aimed at dense schools of fish, rather than dispersed populations – a foraging strategy known for many cetacean species.

6.5.4 Large-mesh pelagic driftnets
Large-mesh pelagic (also often used within 200 n.miles) driftnets of the type used for swordfish, sharks and other large pelagic fish are known to entangle cetaceans.

Swordfish and shark driftnets are often made of relatively strong multifilament twine with diameter over 2mm, which is more visible than the monofilament often used on smaller mesh nets. Stretched mesh size often exceeds 200mm and often ranges up to 560mm. These nets are either surface or midwater set. Smaller cetaceans appear to be more susceptible to mortality. Relatively large mesh driftnets (>100mm mesh size) are also used to catch several species of tuna.

6.5.5 High seas monofilament driftnets
High seas monofilament driftnets are set at or near the surface stretch up to 60km or more in length and are known to entangle several species of open-ocean cetaceans (SC/O90/G4, G8, G9, G43). Some species of small cetacean such as Dall's porpoise appear to be particularly vulnerable. The low visibility of monofilament and the flexibility associated with its drifting condition may be factors which increase its tendency to take mammals.

6.5.6 Traps and weirs

Fish traps and weirs comprise another type of passive fishing gear which takes cetaceans. This type is not intended to entangle fish, but rather to guide fish into some type of 'pen' from which escape is difficult. Both large and small cetaceans are caught in these traps. It appears that mortality for small cetaceans in this gear is relatively low, and in some areas both large and small cetaceans are routinely released alive. Several studies have documented tendencies for cetacean entanglement in such gear and recorded relevant information regarding deterrence, learning and particularly high entrapment rates at specific sites (Lien *et al.*, 1988b; 1990).

6.6 Technical aspects of modifying gillnets

Cetacean entanglement has been documented from many different types of gillnets. Attempts to alleviate this problem have sometimes involved modifications of the fishing gear and methods, and this continues to be a very important area of study and development.

A gillnet is a combination of several components. The characteristics of each component should be considered, as well as the ways the components are assembled. A great many technical options are available. Different types of modifications are likely to be appropriate for different types of fisheries, different environments and different cetacean species. Research and development should be planned accordingly.

There are a number of problems with designing and evaluating experiments on gear modification. These include:

(a) the fact that experiments must be carried out on a sufficient scale and over a long period of time for statistically significant results to be obtained;
(b) the lack of baseline data;
(c) the fact that results from one area under one set of conditions may not be valid for another area.

Annex E lists papers describing gear modification experiments.

6.6.1 Types of modifications

MODIFICATIONS TO INCREASE THE TARGET STRENCTH OF GILLNETS

Japanese researchers have experimented with two types of passive modifications to gillnets (SC/O90/G9, G13) to reduce entanglement of Dall's porpoise in the North Pacific driftnet fishery for salmon. In the first, three hollow air-tube threads were intertwined into the central band of an otherwise standard gillnet. The air-tube threads had a target strength only marginally higher (3–4dB) than standard monofilament. Mean catches of cetaceans in these modified nets were about 21% lower than those for standard nets, although the reduction was not statistically significant in two of the six seasons tested. Practical difficulties were encountered in handling the modified nets.

The second modification consisted of intertwining three multifilament threads into the central band of an otherwise standard gillnet. These threads had a target strength about 10dB higher than standard monofilament. Overall, these nets had marginally lower catch rates than the air-tube nets (above), but the reduction was not significant in either season tested (1986, 1987). Data comparing only adjacent sets showed a significant difference in June 1987, but not July. Paradoxically, the distribution of entanglements within the nets showed that significantly more porpoises were caught in the central (modified) band of multifilament nets than in the corresponding band of the air-tube nets.

The strongest test yet of the effect of passive acoustic modifications to gillnets was conducted by Harwood and Hembree (1987). The target strength of the nets was raised by over 20dB by weaving 4mm bead chain into the driftnets used for sharks in northern Australian waters (SC/O90/G15). No significant difference in the catch rate of cetaceans (predominantly bottlenose and spinner dolphins) was found. Hembree and Harwood (1987) also tested 8mm air-filled plastic tubing, but found it operationally unusable (for practical constraints see SC/O90/G13).

There are designs for acoustic reflectors that would have much higher target strengths than any of the materials tested so far (SC/O90/G17) and these warrant further research. Such reflectors may have the additional advantage of allowing fishermen to find lost gear. However, it should be noted that while such designs are much more promising for acoustical reasons, the effectiveness of all types of acoustic reflectors is subject to the constraints outlined in section 6.1.1 above and in several papers (SC/O90/G13, G15, G16 and G17).

ACTIVE SOUND EMITTERS

The benefit of adding sound emitters to gillnets to reduce entanglement of small cetaceans appears equivocal. When sound emitters were added to Japanese air-tube nets, there was no significant decrease in catch rates in any of the years tested (data from Ogiwara, 1986; Hatakeyama, 1988; Snow *et al.*, 1988). Neither did the addition of sound emitters significantly effect the horizontal distribution of entanglements (SC/O90/G13).

Even if sound emitters reduced catches of dolphins and porpoises it is extremely unlikely that it would be practical in the foreseeable future to place them in all gillnets. Current devices are large, heavy (Hatakeyama, 1986), reasonably expensive (Ogiwara, 1986) and need to be regularly recharged (Hatakeyama, 1988). It is possible that many small sound emitters that are designed to have short ranges would be more effective at alerting cetaceans to the presence of nets than are the current large, long-range emitters.

There are also a number of problems which may occur in efforts to reduce entanglement of cetaceans by adding sound emitters to nets (SC/O90/G13):

(a) any sound sufficiently aversive to scare cetaceans away may also decrease fish catches;
(b) sounds might attract the attention of nearby cetaceans and encourage them to investigate the source of the danger;
(c) cetaceans must associate the sound with the danger of entanglement, which, in the absence of sophisticated communication between individuals, will only be learned by animals that experience both the danger and the warning sound and survive to associate the two – the proportion of small cetaceans that experience entanglement and survive is unknown but presumably small (see Item 6.3 above);
(d) habituation to the sounds is a general problem – randomising the sounds used (e.g. Hatakeyama, 1986) might prevent habituation, but it would also prevent association of any particular sound with the danger of gillnets;
(e) there are cases in which marine mammals appear to feed directly on fish caught in gillnets, or on fish

associated with nets (SC/O90/G6) – attaching sound emitters to nets could have the effect of 'ringing the dinner bell'.

These problems apply chiefly to small cetaceans. Large cetaceans, because they have higher survival rates in interactions with gear, have a far greater potential to be conditioned to avoid fishing gear (or at least fish traps, SC/O90/G51). Early tests (Lien *et al.*, 1994) show some promise.

SUB-SURFACE GILLNETTING

Hembree and Harwood (1987) examined the effect of setting driftnets lower in the water column. They compared nets set 4.5m below the surface with nets set at the surface. The sub-surface nets had significantly lower (50%) catches of cetaceans, but also significantly lower (25%) catches of target fish. SC/O90/G58 presents preliminary results of Japanese research examining the effect of sub-surface setting in both the North and South Pacific. Encouragingly, the sub-surface nets took very few cetaceans, while catch rates of target species were about the same, but the small sample sizes make statistical comparison with nets set at the surface difficult. The economic viability of sub-surface driftnetting in these fisheries is not yet clear, as the nets are more expensive and have longer handling times than normal driftnets set at the surface. SC/O90/G45 reported on the commercial use of subsurface nets in the California swordfish gillnet fishery.

6.6.2 Summary and conclusions

Reductions so far achieved in entanglement rates of small cetaceans via modifications to gillnets have been equivocal and of a marginal nature. However, there are many aspects of the acoustical interaction between cetaceans and gillnets that warrant further study. Current knowledge suggests that it is unlikely that acoustic modifications will provide a total solution in the foreseeable future. Acoustic modification may be useful in reducing entanglement in species where impacts on populations are not immediately threatening. In addition, acoustic modifications could be used in concert with other management actions (e.g. gear or area restrictions) to achieve necessary reductions in catch. For seriously reduced (or rare) species or populations of cetaceans it will be necessary to implement other means of reducing entanglement rates.

In view of the promising results obtained from the subsurface gillnet experiments, it is recommended that further experiments be carried out to address the following:

(1) the statistical validity of the results;
(2) seasonal or geographical effects;
(3) applicability of the technique to other gillnet fisheries.

6.7 Alternative technologies

When a new technology becomes available there is a group of fishermen, sometimes referred to as early innovators and who are usually local industry leaders, who utilise it in solving problems they have before them. There is a second group of people within the industry who will then apply the technology when it has proved its value. A third group often exists that will oppose the technology ('the Luddite Tendency').

Properly defining a problem is half its solution. What is necessary in the case of cetacean capture in fixed gear is to help the fishermen understand that this is a problem that they have to face and that will affect their livelihood (possibly by draconian regulatory methods if a solution is not found) and encourage them to solve it. Incidental catch of cetaceans in fishing gear is, first of all, a fisherman's problem. The Workshop believes that the approach most likely to succeed is to identify and talk to these early innovators in the relevant fisheries, help them to define the problem and give them the equipment and assistance (in expertise and personnel, particularly with respect to cetaceans) they need to find a solution.

A less desirable way to let fishermen know they have a problem is to place a financial disincentive on the taking of cetaceans (SC/O90/G40). This has the advantage of not defining the solution. It presumes the problem is 'the taking of cetaceans'.

If governments define solutions *vis a vis* regulations (e.g. banning gillnets, modifying gear characteristics, fishing methods and strategy etc.) it risks perverting innovation and causing inefficiencies in the fishery and may result in unforeseen and undesirable consequences (e.g. increasing takes of other non-target species).

It must also be recognised that the problems and their severity vary from species to species and area to area. In certain cases immediate action may be required to save a cetacean species from local extinction (see also Item 11).

6.7.1 Industry involvement

Experience has shown that fishermen must be involved from the earliest opportunity in solving fisheries' problems. For many years, various organisations in diverse situations have worked to improve fishing technology and introduce new methods. Both the improvement of existing fishing technology and the introduction of new technology have the best chance of success if the fishermen themselves are directly involved in the process. Many fishermen have a great deal of knowledge and expertise with local technology, species, fishing conditions and ecology. They are also familiar with the economic and social conditions in their fishery. Their involvement throughout the project enhances the potential of obtaining the best solution and the fastest application.

In some areas, fishermen have demonstrated concern for mammal entanglement problems and have expressed an interest in collaborating with scientists and authorities to help solve the problems.

6.7.2 Understanding why a fishery uses gillnets

When alternative fishing technologies are considered, many characteristics of the envisioned alternatives should be compared with the characteristics of gillnets. Effects on resources, technical feasibility, economic feasibility and social acceptability should be considered. The first step would be to examine alternative gears in use in the specific fishery in question or used in similar fisheries in other areas for the same target species.

An essential pre-requisite to assisting fishermen changing from gillnets is to understand why particular fishermen are using them. Gillnetting often:

(i) has been traditionally used;
(ii) matches the vessels and technology locally available;
(iii) involves lower operational costs;
(iv) results in greater profits;
(v) is used for species that do not take bait or hooks;
(vi) is used where the bottom is too rough for trawling;
(vii) results in a lower fish bycatch problem (size and species);

(viii) is used where there are neither the means nor incentive to develop alternatives

In considering alternative gear and methods, a large number of factors should be considered, including the following:

(i) effectiveness for taking the target species and likely catch levels;
(ii) effects on target and incidentally caught resources;
(iii) fish market considerations and opportunities;
(iv) capital costs of fishing and economic feasibility under local conditions;
(v) foreign exchange inputs required;
(vi) energy costs of fishing;
(vii) appropriateness for economic and educational levels of fishermen;
(viii) safety factors for fishermen.

Several possible scenarios emerge if one considers proposals to ban gillnetting in an area.

(1) The fishermen may stop fishing entirely and find alternative employment and/or suffer economically.
(2) Larger gillnet boats may be able to convert to trawling. However, most coastal gillnet vessels lack the size and power to trawl effectively. Trawling in general is more capital intensive, consumes more fuel and often involves more serious problems with fish bycatch, as illustrated by a comparison of shrimp trawl fisheries and shrimp gillnet fisheries.
(3) A few vessels may be able to convert to purse-seining, which is practised on both large and small scale in different areas. Effects on resources, as well as technical and economic feasibility, would have to be evaluated.
(4) Some coastal gillnetters may convert to longlining, which can be done effectively in many areas from relatively small boats, without great capital investment and with relatively low fuel consumption. There are many different types of longlining, coastal and open ocean, and each must be evaluated individually. In many conditions, economic longlining takes up more bottom area than gillnetting, possibly leading to increased conflicts with other gear types. Longlining in many areas can be less selective for fish species and size and more dangerous for fishermen.
(5) Some gillnetters, particularly those in areas with significant pelagic resources, may convert to trolling. Although this method is used effectively in some areas, its disadvantages must be considered. It is effective for a limited number of species, many of which are highly seasonal. Fuel consumption and time required for finding fish may be high. Productivity per line is often low and it is generally only commercially feasible only for relatively high-priced species. It is practised primarily by small-to-medium sized vessels and may be an auxiliary method practised in combination with others.
(6) Fishing with vertical lines and hooks may be considered as an alternative in some areas. Handlines, automated reels and jigging machines are all in use in different areas. The productivity of handlines may be relatively low and the technology for automated systems may be appropriate only in certain fisheries at this time.

Many other fishing methods are practised commercially in different areas and their potential for a given area should be considered. It should be noted that many organisations have devoted substantial resources to the development and introduction of improved fishing methods. The problems encountered are often substantial and in many cases the success rate has not been very encouraging.

6.8 Disentanglement technology and resources

It is frequently possible to disentangle large whales from fishing gear if appropriate methods are used (Lien, 1988). Large whale entanglements can be classified into those where animals are anchored or fixed in place (such as an entanglement in a codtrap) and those where animals are free-swimming (such as an animal with gillnetting through the mouth or around the tail which has broken away from the anchors). All disentanglement procedures with cetaceans entail an element of risk to the rescuers and should be undertaken with caution. However, these efforts are important, particularly for endangered species.

For entangled cetaceans that are well anchored, current procedures use vessels of various sizes and lift the animals tail to the surface where it is accessible from the vessel. Cutting of the gear away from the whale is done from the vessel until the animal is free. Cooperation with the fishermen, who have a good working knowledge of where different lines are attached and/or anchored, is important to minimise both the time the disentanglement takes and the damage to the gear (Lien, 1988; Lien *et al.*, 1990). Divers are never placed in the water, because of the risk involved with large amounts of fishing gear.

For free-swimming animals, two approaches have been employed. Both require catching and clipping ropes onto the fishing gear trailing from the swimming animal. Lien (pers. comm.) favours anchoring the whale immediately at this point and working the animal as described above. Mayo (pers. comm.) has used inflatables to attach (with carabineers) buoys and sea-anchors to slow the whale down. When the whale becomes tired, Mayo uses the inflatable as the working platform to slide up to the tail area along the entangled gear and cuts away the gear as it is accessible. Di Natale (pers. comm.) has attached a large vessel to free-swimming entangled sperm whales, then used divers to cut away netting from the tethered animal. However, several large diameter ropes have been broken during some of these disentanglement operations by the thrashing of the animal.

Generally, larger vessel disentanglement efforts pose the least risk to researchers and fishermen; any operation which places divers in the water is the most dangerous. A list of some institutions which have disentangled whales regularly and may serve as information and/or rescue centres is given below.

Memorial University of Newfoundland, 230 Mt Slio Road, St. John's, Newfoundland, Canada, A1B 3X9.

Center for Coastal Studies, PO Box 1036, Provincetown, MA 02657, USA.

New England Aquarium, Central Wharf, Boston, MA 02110, USA.

Natural History Museum of Los Angeles County, 900 Exposition Blvd, Los Angeles, CA 90007, USA.

Tethys, Istituto per lo studio e la Intela dell'Ambiento Marino, piazza Duca D'Aosta 4, 20124 Milano, Italy.

6.9 Management

The Workshop had been asked to address the management options for controlling, reducing or eliminating the cetacean bycatch. It recognised the importance of determining management objectives and methods implementation as primary elements in the alleviation of marine mammal bycatch in specific fisheries. However, it also recognised that, in addition to its areas of interest, fruitful discussion of functional management would range across subjects outside its expertise, including legal authority, jurisdictions, economics, social and cultural considerations and enforcement resources and technology. Throughout the report the group's recommendations and priorities are made or set in full recognition that non-scientific constraints on the management process may affect their utility.

Notwithstanding the above, the group noted the following general points with respect to management and the incidental take of cetaceans.

(1) Bycatch is the collection of non-target species caught but not retained in any fishery. Bycatch may be unharmed, injured or dead when discarded. It includes both commercial and non-commercial fish and shellfish, marine mammals, birds, turtles and invertebrates. Bycatch is a fact of life for most fisheries. It typically becomes a management issue when a second or third party attaches some value to the discarded animals. The higher the value, the more likely some authority will be created or invoked to justify management actions to control, reallocate or eliminate the bycatch.

(2) Marine mammals usually have almost no commercial value to passive gear fishermen. As bycatch they are cumbersome, aggravating and occasionally dangerous. However, many people attach considerable value to marine mammals and wish to protect them from harm in fisheries through statute and regulation. By establishing an economic consequence to the taking of marine mammals in the act of fishing, some control may be exercised over that taking. This type of 'artificial' valuation of marine mammals may be necessary if their bycatch in passive fishing gears is to be reduced or eliminated. It implies the creation of authority permitting governmental agencies to apply appropriate measures. This type of authority varies widely around the world, as does the value people and cultures attribute to marine mammals.

Recognising these limitations on management capabilities, some examples of management methods that may be employed to help control the bycatch of marine mammals and other species are discussed below. Almost all will reduce the economic productivity of the target fisheries and it might be expected that fishermen will try to avoid being included e.g. by changing country of registration or vessel class.

6.9.1 Time and area restrictions
Recent developments in satellite transmitter technology have made it possible to track and record the movements of vessels far from shore, thereby making the application of time and area restrictions feasible in medium to large scale fisheries. The success of such restrictions in reducing bycatches depends on the degree to which the target and non-target species separate. This information is lacking for most passive fisheries.

6.9.2 Bycatch quotas
This method limits the number/weight of the bycatch of one or more species. Its implementation presumes some means to track the take of controlled species in a near-real time frame. Obvious problems with this approach lie in deciding which species or species group will be limited and how the limitation (closure, relocation, gear change, etc.) may affect other bycatch species.

6.9.3 Effort and access limitations
This could achieve a broad target limitation on combined bycatches. For example, if bycatch levels are known for certain fishing zones and acceptable aggregate targets or limits for the bycatch exist, a simple limitation on effort by zone could achieve the desired result. It is a less stringent hybrid of the time/area and bycatch quota methods.

6.9.4 Bans on practices and technologies
This approach has always been a tool for the management of living resources in specific situations. Examples include bans on the use of explosives for fishing, on sundown sets by US tuna seiners and on import of fisheries products not taken in conformity with domestic regulation. It is under consideration as a solution to the high seas driftnet bycatch problem.

6.9.5 Individual or fleet performance criteria
With enough information concerning the bycatch performance of a specific fishing technology, it is possible to establish performance targets that allow fishermen some influence over their regulation. Setting a take-per-unit-effort limit per vessel or fleet that is monitored and reported on a regular schedule may engage the ingenuity of individual fishermen to find ways to keep the rate below the limit, thus extending their access to the fishery. Typically, this approach is used in conjunction with direct or implied quotas and effort limitations. For example, when the current take rate exceeds the specified limit it triggers closure or relocation of the fishery or mandates the use of alternate technology (e.g. from gillnets to longlines).

6.9.6 Retention of all catch – the 'no bycatch' option
This is not being used as a management method at this time but its impact on fishery profitability could motivate current high bycatch fishery participants to seriously explore bycatch reducing measures or alternate gears. This is an artificial manipulation of the economics of the fishery that is difficult to enforce and has unknown practical and market consequences.

6.9.7 Limitations on non-marine mammal bycatch levels
In cases where authority exists to limit takes of species other than marine mammals, this authority might be exercised to control marine mammal bycatch indirectly. For example, both halibut and harbour porpoises are taken as bycatch in certain coastal gillnet fisheries. Controlling the fishery to limit the bycatch of halibut and protect another commercial fishery might also reduce the take of harbour porpoises. This approach can take advantage of existing fishery management laws and implied property rights of conflicting fisheries to reduce bycatch of many other species.

6.9.8 Stipulations on gear and procedures
Gear and procedures that are effective and economical are likely to be implemented with little difficulty since less bycatch means more efficient fishing operations. Gear and procedures which are expensive or reduce vessel efficiency will meet significant resistance, requiring solid justification and potent authority. This is the approach whereby techno-behavioural solutions can be implemented.

6.9.9 Economic assistance and subsidies
If the above methods do not work or cannot be implemented, then it is conceivable that the implied property rights of fishermen can be purchased. By

measuring what tangible losses must be inflicted to achieve a bycatch goal, society/government/managers, etc. may make a first approximation of its cost. Governments have devised myriad ways to transfer value to industry ranging from direct payments, to subsidies for construction, insurance and price support, to protection from both foreign and domestic competition. Under this heading it should be recognised that market manipulation can be used both to support and coerce industry.

6.9.10 Conclusions

Each management situation will be in some ways unique. As an initial step in evaluating management latitude and options for controlling marine mammal bycatch, the Workshop **recommends** that the following questions be addressed:

(1) What is/are the specific management objective(s), including full definitions of the terms used?
(2) Who is being managed?
(3) Under what authority(s) is this objective legitimate?
(4) Under what/whose jurisdiction(s) does the problem reside?
(5) What other management objectives interact with this, and how?
(6) What entity(s) is responsible for attaining the objective(s)?
(7) What resources are available for management and enforcement?
(8) What management methods are applicable?
(9) What alternatives are available to those being managed?

In answering these questions, the ease or difficulty of achieving a specific objective will become obvious. Also, a number of further, more detailed questions will arise, giving insight into needed work plans and strategies to build the information (including technical and scientific) and authority foundation for meeting the objective. In cases where authority and jurisdiction are limited or absent, this process may be lengthy and political.

7. CONCLUSIONS AND RECOMMENDATIONS

In a plenary session on the last day of the Workshop, the group reviewed and adopted the conclusions and recommendations put forward by the three sub-groups.

7.1 Global review of fisheries

7.1.1 General

(1) Throughout all regions there is a general lack of adequate statistics on gillnet and trap usage and on marine mammal entrapment.

It is **strongly recommended** that:

(a) fishery agencies and regional bodies (including those of the FAO) ensure that statistically valid data on gillnet and trap effort and cetacean catches are collected and promptly analysed and reported;
(b) adequate statistics on marine mammal entanglement be obtained through independent observer programmes, following scientifically established designs.

(2) Fleets from China, Taiwan and some other distant-water driftnet fleets continue to operate without documentation in the Atlantic and with inadequate data for operations in the Indian and Pacific Oceans. This is a matter of grave concern, not only for nations adjacent to the fishing areas but also with respect to the status of marine mammals taken in these fisheries.

It is **recommended** that, while such activities continue, data on all distant-water fleets must be collected by the flag nations and nations servicing these fleets and independent observers placed on board vessels. The bycatches must be reported and evaluated and appropriate management actions taken before further fishing is authorised.

(3) The Workshop **recommends** that the development of any new fisheries, or expansion of existing fisheries, should only be countenanced after a rigorous multidisciplinary environmental impact assessment that includes the potential effects on target and non-target species, including cetaceans. To this end, aid and development agencies, including UN, national and non-governmental organisations, should be advised of the potentially detrimental effects of these fisheries.

(4) It is **recommended** that national and international organisations address the education of fishermen, officials and scientists as well as the general public concerning the problem of cetacean interactions with gillnet and traps. Specific recommendations for the nations most critically involved are listed in the regional reviews.

(5) Japan and the USA are conducting research to assess the possible impact of lost and discarded fishing gear ('ghost nets'). The Workshop **recommends** that similar research programmes be initiated elsewhere. Specific goals of such programmes should be to reduce the number of nets and pieces of net webbing lost and discarded and to alter net manufacture and design to minimise danger from them.

(6) As has happened in Peru and Sri Lanka, a dolphin bycatch can become a directed fishery under certain economic conditions, leading to heavy exploitation of cetacean stocks of unknown size and status. This could happen in regions such as India and the Philippines where the bycatches are already fully utilised. This is a particular danger to cetacean conservation.

It is **recommended** that national and international fishery and environmental agencies monitor such situations closely. Such directed fisheries should not be allowed to develop until the status of affected stocks has been evaluated.

(7) Many developing countries are unable to fund the stock assessment and fishery monitoring programmes that must be carried out to ensure that incidental catches of cetaceans in particular fisheries are sustainable. It is **recommended** that:

(a) such nations consider the incorporation of such costs in license fees for fishing in their exclusive economic zones (EEZs);
(b) intergovernmental and private international funding organisations and agencies give high priority to financing such activities.

(8) Given the broad scope of the fishery/cetacean (and other bycatch species) interactions, regional cooperation in examining and addressing the various issues is extremely important. The Workshop **recommends** that such cooperation should be encouraged among, for example, the Baltic and northeastern European states through the agencies of the European Community and International Council for the Exploration of the Sea (ICES), among Caribbean states, between Argentina and Chile

(because of the crab-bait situation – see regional account for Southeastern Pacific), among West African states, among Indian Ocean states, among the North Pacific Rim nations and among the Pacific island nations.

7.1.2 High priority recommendations for specific regions

A series of recommendations for regional action are given above in the report of the sub-group on the global review of fisheries. Some of these recommendations are considered to be of especial urgency and are repeated here for emphasis.

(1) It is **recommended** that solving problems associated with the incidental capture of the vaquita in totoaba gillnets in Mexico and the baiji on longline hooks in China is accorded the highest priority. In the case of the totoaba the fishery is illegal, except for some fishing under experimental permits. The fishery affecting the baiji is totally illegal. However, both fisheries continue to operate at high levels because of inadequate enforcement and continue to threaten the species with extinction.

(2) The Workshop commends Italy for its decision to ban swordfish and albacore driftnets in Italian waters and their use by Italian vessels in other parts of the Mediterranean. It is **recommended** that similar actions be taken elsewhere in the Mediterranean. International cooperation and action by the General Council for Mediterranean Fisheries (CGPM) is required to ensure that large-scale driftnet fisheries do not restart from other nations and that reflagging of vessels for the purpose of continuing the fishery does not occur.

(3) Gillnet fisheries continue to expand rapidly in Pakistan, India, Sri Lanka and Bangladesh. As noted in General Recommendation 4 above, it is **recommended** that new fisheries should not be initiated in this region or existing fisheries expanded until after evaluation of their effects on non-target species.

(4) Throughout the Indo-Pacific region, and particularly in Southeast Asia, drift and set gillnets are widely used, but there is extremely limited information on incidental catches in such gear in these fisheries. It is **recommended** that this area be given high priority for future research into the impacts of gillnets and other fishing gear on marine mammals.

(5) Large numbers of coastal trap and gillnet fisheries exist in Chinese coastal waters; one estimate is that 3,500,000 gillnets are in use. It is **recommended** that incidental mortality of cetaceans in these fisheries be addressed as a matter of urgency.

7.2 Impacts on species and populations

7.2.1 Conclusions

(1) Cetacean populations in general seem unable to sustain rates of kill of more than a small percentage of the population per year. Even kill rates as low as 2% per year may not be sustainable, depending on the life history of the species and the age and sex composition of the kill.

(2) Agencies that are responsible for the management of marine resources should manage from a conservative point of view, i.e. fisheries should not be allowed to operate at a particular level until there is evidence that the kill of cetaceans associated with that level of fishing effort is sustainable.

(3) Information on kill rates and total fishing effort in passive net and trap fisheries and on the size of cetacean populations can be difficult to accumulate. Kill rates and fishing effort can be expected to vary among years, areas and seasons. Estimates of population size will necessarily be imprecise, especially where data on stock structure are lacking. Despite problems with the collection and analysis of data on kill rates, total fishing effort and population size, it is important that the agency responsible for managing a particular fishery collect these data on a systematic basis. In the absence of such information, the environmental impact of most gillnet and trap fisheries cannot be assessed.

(4) The impacts of coastal gillnet and trap fisheries on strictly coastal species are especially noted. Such fisheries and cetacean populations are in urgent need of assessment and in many cases the levels of fishery mortality need to be reduced or eliminated.

(5) The best available information at this time indicates that several stocks of cetaceans are unable to sustain current levels of removal caused by passive net and trap fisheries. These include:

(a) vaquita in the Gulf of California;
(b) baiji in the Yangtze River;
(c) Indo-Pacific hump-backed dolphins on the Natal coast of South Africa;
(d) striped dolphins in the Mediterranean Sea;
(e) harbour porpoises in the western North Atlantic;
(f) bottlenose dolphins on the Natal south coast, South Africa.

Furthermore, there are additional stocks where all of the information needed to evaluate the impact of passive net and trap fisheries is not available, but where the potential for current levels of removals not being sustainable is likely. This is particularly true where rates of kill are known to be large. Of particular concern are the following stocks:

(a) dusky dolphins in the eastern South Pacific,
(b) northern right whale dolphins in the central North Pacific;
(c) sperm whales in the Mediterranean Sea.

7.2.2 Recommendations

Arising from the discussions in the working group on the impact of fisheries on species and populations of cetaceans, the Workshop agreed to the following recommendations.

(1) It is **recommended** that the killing of:

(a) the vaquita in the Gulf of California;
(b) the baiji in the Yangtze River;
(c) Indo-Pacific hump-backed dolphins on the Natal coast of South Africa;
(d) striped dolphins in the Mediterranean Sea;
(e) harbour porpoises in the western North Atlantic;
(f) bottlenose dolphins on the Natal south coast, South Africa;

in passive and trap fisheries be reduced immediately.

Mechanisms for reducing the take of these species will have to be developed by the agencies with management authority.

(2) Where the directed or incidental kill of any cetacean stock is thought to exceed a small percentage of the population or where a particular stock is declining and known to be taken in passive net and trap fisheries, it is

recommended that the fishery bycatch should be limited while the following information is collected:

(a) *Kill rates*. These can be collected either by placing observers on fishing vessels, placing observers on research vessels that can observe fishing vessels or making experimental sets of gear similar to that used in the fishery. Estimates of kill rates from mail surveys to fishermen or dockside interviews alone are not adequate. For directed fisheries, kill rates can be estimated by monitoring the number of cetaceans landed.

(b) *Age and sex composition of the kill*. This will require biological specimens to be collected by trained technicians.

(c) *Stock identification*. Specimen material must be collected.

(d) *Total fishing effort for all passive net and trap fisheries*. These data should be collected and analysed prior to the start of the next fishing season.

(e) *Population size*. Initially, estimates of minimum population size on a stock-by-stock basis are adequate for management purposes. However, these estimates should be replaced by estimates of absolute abundance with their associated levels of precision. Estimates of population trends alone are not adequate.

7.3 Causes and solutions

7.3.1 Conclusions

(1) The incidental capture of cetaceans appears to be almost universal in drift and set gillnets and a common occurrence in some trap fisheries. Wherever cetaceans and gillnets are found in the same area, at least some cetaceans are caught.

(2) However, there is no universal cause or solution to the incidental capture of cetaceans in fishing gear. The precise nature of the interaction varies from area to area, fishing gear type to fishing gear type, species to species, culture to culture, and any combination of these.

(3) Small cetaceans have sensory abilities which can detect the webbing and rigging of gillnets and other passive fishing gear. Encounters with nets may occur as they forage or engage in other activities which increase the chances that they will fail to detect nets. Less is known of the sensory abilities of large cetaceans. There are a variety of environmental, social and sensory conditions which may interfere with detection of nets. Additional study on the role such factors play in entrapment of cetaceans is necessary.

(4) Even if the cetaceans detect nets, a variety of behavioural factors contribute to the entrapment or entanglement. These include curiosity, exploration and perception, escape reactions and social organisation.

(5) There is almost no behavioural information on how and when entanglement of cetaceans occurs. There is little quantitative information on how many animals in the vicinity of a net become entangled, or on how many entangled animals escape. There are few quantitative data on many of the factors which cause entanglement or which might provide solutions. Basic information on entanglement must be collected as a matter of urgency. More rigorous scientific procedures must be followed in experiments so that causes and solutions can be properly evaluated.

(6) As noted in (2) above, at this time there is no practical, universal modification of fishing gear which can be suggested to solve all problems of incidental entrapment of cetaceans. In urgent cases, such as that of the vaquita, there may be no alternative but to ban the fishery.

(7) Some fishing gear modification and management regimes do provide potential solutions and can be suggested for specific fisheries where entanglements of cetaceans occur. In all cases careful assessment and monitoring of the effectiveness and impact of modifications introduced to lower incidental catches of cetaceans must be made.

(8) There are a number of promising research areas which may lead to reduction of incidental catches of cetaceans and which should be further explored; these include time/area restrictions on fisheries, adjustment of gear strategies and selectivity of gear, and the enhanced detection of gear. Management techniques for dealing with the incidental take of cetaceans which are most promising at this time are time/area restrictions and area closures.

(9) In most areas fishermen are unaware of the extent and impact of cetacean entanglement. Fishing communities should be made aware of this and become involved in the process of finding solutions. Methods to accomplish this should be carefully researched and evaluated.

7.3.2 Recommendations

In addition to the specific research recommendations included in the body of the report, the Workshop agreed to the following more general recommendations.

(1) It is **recommended** that research on causes and solutions of entanglements focus on those fisheries where urgent action is required. This should be achieved by organising local workshops including scientists, engineers, fishermen, managers and others.

(2) It is **recommended** that particular priority in research be given to:
(a) behavioural factors which predispose cetaceans to entanglement including those immediately prior to and during entanglement;
(b) monitoring time and area closures;
(c) gear strength and strategy adjustments and alternative gears;
(d) environmental and ecological factors influencing these behaviour patterns.

(3) It is **recommended** that studies on solutions to cetacean bycatch be conducted in such a manner that bycatch of other species is also considered.

(4) It is **recommended** that significant technological changes within fisheries be preceded by an assessment of their likely impacts.

8. EDITING AND PUBLICATION OF REPORT

Although the major conclusions and recommendations of the sub-groups were adopted in full in plenary session, it was not possible to review fully and finalise the complete sub-group reports during the workshop. It was agreed that the participants would forward comments on the draft reports to the sub-group chairmen for consideration and that the chairmen would finalise the reports, with the help of the rapporteurs and forward them to the workshop chairman for inclusion in the workshop report. The workshop report will be published in a special issue of *Reports of the International Whaling Commission*, which will include selected working papers from the workshop and submitted papers from the symposium that preceded the workshop and will be edited by Perrin, Donovan and Barlow. It was noted that authors wishing to submit working papers or symposium papers for publication in the special issue should revise them in light of comments received at the meeting and have them reviewed by at least two colleagues before sending them to the Scientific Editor. The submitted papers will then be subject to anonymous peer review.

9. OTHER BUSINESS

The Workshop thanked the Director of the Southwest Fisheries Science Center for hosting the Workshop and the Center staff for their very efficient and cheerful services during the meeting. The Chairman expressed his appreciation to the sub-group chairmen and the rapporteurs for their hard work and dedication to the success of the Workshop.

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Annex A
List of Participants

G=Global Review Sub-Group (Item 4); I=Impact Sub-Group (Item 5);
C=Causes and Solutions Sub-Group (Item 6).

Gordon Anderson (G)
Marine Conservation Unit
Australian Nature Conservation Agency
PO Box 636
Canberra
ACT 2601
Australia

Whitlow Au (C)
Naval Ocean Systems Center
P.O. Box 997
Kailua, Hawaii 96734
USA

Jay Barlow (G)
Fisheries/Marine Mammal Interactions Division
Southwest Fisheries Center
U.S. National Marine Fisheries Service
P.O. Box 271
La Jolla, CA 92038
USA

Arne Bjørge (G)
Norwegian Institute for Nature Research
University of Oslo
PO Box 1037
Blindern
0315 Oslo
Norway

Robert L. Brownell, Jr. (I)
Southwest Fisheries Science Center
PO Box 271
La Jolla
CA 92038
USA

V. N. Burkanov (G)
Kamchatka Department of the Environment
Pacific Institute of Geography
Academy of Sciences
Prospect Ribakov 19/a
Petropavlovsk-Kamchatsk.
683024
Russian Federation

Martin W. Cawthorn (G)
53 Motuhara Road
Plimmerton
Wellington
New Zealand

Bjarne Clausen (G)
DMU
Box 358
Fredriksbergvej 399,
D-4000 Roskilde
Denmark

Victor Cockcroft (G)
Port Elizabeth Museum
P.O. Box 13147
6013 Humewood
South Africa

James M. Coe (C)
NMFS Marine Engtanglement Research
Alaska Fisheries Science Center
7600 Sand Point Way NE
BIN C15700
Seattle, Washington 98115–0070
USA

Enrique A. Crespo (G)
Centro Nacional Patagónico
28 de Julio 28
9120 Puerto Madryn
Chubut
Argentina

Stephen M. Dawson (C)
Zoology Department
Otago University
P.O. Box 56
Dunedin
New Zealand

Douglas P. DeMaster (I)
National Marine Mammal Laboratory
7600 Sand Point Way NE
Seattle
WA 98115
USA

Antonio Di Natale (G)
Aquastudio
Via Trapani isol. 466 n. 6
98121 Messina
Italy

M. Louella Dolar (G)
Marine Laboratory
Silliman University
Dumaguete 6200
Phillipines

G. P. Donovan (C)
Scientific Editor
International Whaling Commission
The Red House
135 Station Road, Histon
Cambridge CB4 4NP
United Kingdom

Steven Drew (I)(C)
Manomet Bird Observatory
Manomet, MA 02345
USA

Michael Earle (G)
Greenpeace International
Rue Cochetay, 54
B-4140 Gomze-Andoumont
Belgium

Shannon Fitzgerald (G)
Resource Ecology and Fishery Management
U.S. National Marine Fisheries Service
7600 Sand Point Way NE
Seattle, WA 98115
USA

Karin Forney (I)
Southwest Fisheries Science Center
P.O. Box 271
La Jolla, CA 92038
USA

Ray Gambell (I)
International Whaling Commission
The Red House
135 Station Road, Histon
Cambridge CB4 4NP
United Kingdom

A. D. Goodson (C)
Sonar and Signal Processing Group
Electronic and Electrical Engineering Department
Loughborough University of Technology
Loughborough, Leicestershire LE11 3TU
United Kingdom

Doyle A. Hanan (C)
California Department of Fish and Game
Southwest Fisheries Science Center
P.O. Box 271
La Jolla, CA 92038
USA

Y. Hatakeyama (C)
National Research Institute on Fishery Engineering
5–5–1, Kachidoki, Chuo-ku
Tokyo
Japan

John E. Heyning (I)
Natural History Museum of Los Angeles County
900 Exposition Boulevard
Los Angeles, CA 90007
USA

Aleta Hohn (I)
National Marine Fisheries Service
Office of Protected Resources, F/PR1
1335 East-West Highway
Silver Spring, MD 20910
USA

P.U. Jepsen (C)
Wildlife Research Station,
Aalholtvej 1
Okstol. DK 6840
Denmark

Linda Jones (C)
Northwest Fisheries Science Center
2725 Montlake Blvd E
Seattle
WA 98112
USA

Toshio Kasuya (I)
Section of Cetacean Research
National Institute of Research on Far Seas Fisheries
5–7–1 Orido, Shimizu-shi
Shizuoka-ken 424
Japan

Michael Kingsley (I)
Maurice Lamontagne Institute
Fisheries and Oceans
P.O. Box 1000
Mont-Joli (Quebec)
Canada

Carl Kinze (G)
Zoological Museum of Copenhagen
Universitetsparken 15
DK-2100 Copenhagen
Denmark

Margaret Klinowska (C)
University of Cambridge
Animal Welfare and Human-Animal
Interactions Group
Dept. of Clinical Veterinary Medicine
Madingley Road
Cambridge
CB3 0ES
United Kingdom

Scott D. Kraus (C)
New England Aquarium
Central Wharf
Boston, MA 02110
USA

Roger Krohn (G)
Benguela Ecology Programme
University of Cape Town
Cape Town
South Africa

John LaGrange (C)
Captain, "Cloud Nine"
533 North Rios Ave.
Solana Beach
CA 92075
USA

David M. Lavigne (C)
Department of Zoology
University of Guelph
Guelph, Ontario N1G 2W1
Canada

J. Stephen Leatherwood (G)
Ocean Park Conservation Foundation
Ocean Park
Aberdeen
Hong Kong

Jon Lien (C)
Whale Research Group
Memorial University of Newfoundland
St. Johns, Newfoundland
Canada A1C 5S7

Ingalill Lindstedt (G)
Institute of Marine Research
P.O. Box 4
S-453 00 Lysekil
Sweden

Jacques Maigret (G)
Museum National d'Histoire Naturelle
Galerie de l'Evolution
45 Rue Cuvier
75231 Paris cedex 05
France

Albert M. Manville (C)
Senior Staff Wildlife Biologist
Defenders of Wildlife
1244 Nineteenth Street, NW
Washington, DC 20036, USA

R.S. Lal Mohan (G)
Conservation of Nature Trust
B/24, Grandhingar, C
Calicut – 673 005
Kerala
India

Kazuhiko Nagao (G)
Fisheries Agency
Ministry of Agriculture, Forestry and Fisheries
2–1, 1-Chome Kasumigaseki
Chiyoda-ku, Tokyo 100
Japan

Mohammad Sadiq Niazi (G)
Deputy Director
Marine Fisheries Department
Government of Pakistan
Fish Harbour, West Wharf
Karachi
Pakistan

Eugene T. Nitta (G)
Pacific Area Office, Protected Species
Management Branch
U.S. National Marine Fisheries Service
2570 Dole St., Rm. 106
Honolulu, Hawaii 96822–2396
USA

Kenneth S. Norris (C)
Institute of Marine Sciences
University of California
100 Shaffer Road
Santa Cruz, CA 95060
USA

Simon Northridge (G)
Renewable Resources Assessment Group
Imperial College of Science, Technology and Medicine
8 Prince's Gardens
London SW7 1NA
United Kingdom

Giuseppe Notarbartolo di Sciara (I) (C)
Tethys Research Institute
Via Giusti 5
20154
Milano
Italy

Jorge A. Oporto B. (G)
CIMMA, c/o Instituto de Biología Marina
Universidad Austral de Chile, casilla 567
Valdivia
Chile

Victoria Ortiz (G)
Laboratorio Oceanográfico
Apdo 240
39080 Santander
Spain

P. Michael Payne (I)
Manomet Bird Observatory
PO Box 936
Manomet
MA 02345,
USA

William F. Perrin (G)
Southwest Fisheries Science Center
U.S. National Marine Fisheries Service
P.O. Box 271
La Jolla, CA 92038
USA

Maria Cristina Pinedo (G)
Lab. Mamíferos Marinhos
Depto. Oceanografia-FURG
C.P. 474
Rio Grande RS 96.200
Brazil

J. Prado (C)
Fishery Industries Division
FAO
Via delle Terme di Caracalla
00100 Rome
Italy

Andrew J. Read (G)
Northeast Fisheries Science Center
Woods Hole
MA 02543
USA

Julio C. Reyes (G)
Casilla 392
Talcahuano
Chile

Marina L. Sequeira (G)
Servico Nacional de Parques,
Reservas e Conservacao da Natureza
R. Filipe Folque, 46 – 3
1000 Lisbon
Portugal

Gregory Silber (C)
Marine Mammal Commission
1825 Connecticut Avenue, NW
Room 512
Washington, DC 20009
USA

Joyce Sisson (G)
Southwest Fisheries Science Center
P.O. Box 271
La Jolla, CA 92038
USA

Ronald Joel Smolowitz (C)
Coonamessett Farm
277 Hatchville Road
East Falmouth, MA 02536
USA

Suraphol Sudara (G)
Faculty of Science
Chulalongkorn University
Bangkok 10500
Thailand

Omar Vidal (G)
Instituto Tecnológico y de Estudios Superiores
de Monterrey - Campus Guaymas
Apartado Postal 484
C.P. 85400, Guaymas, Sonora
Mexico

Koen Van Waerebeek (I)
CEPEC c/o Grupo-Cetáceos-ECCO
Casilla 1536
Lima 18
Peru

Gordon T. Waring (I)
Northeast Fisheries Center
No. 1 Water Street
Woods Hole, MA 02543
USA

Alfredo Ximenez (G)
Div. de Zoologia
Depto. de Biologia
Universidad Federal de
Santa Catarina
Trinidade
88000 Florianópolis - SC
Brazil

A. Yatsu (G)
Squid Section
National Institute of Research on
Far Seas Fisheries
5-7-1 Orido, Shimizu-shi
Shizuoka-ken 424
Japan

Zhou Kaiya (G)
Department of Biology
Nanjing Normal University
122 Ninghai Road
Nanjing 210097
People's Republic of China

Annex B
List of Documents

* = Published in this volume. Please note that these are the titles and authors as presented at the meeting. These may have changed in the published version. Abstracts of those papers not published are included at the end of the volume.

SC/O90/G1 PRADERI, R. Mortality of dolphins in shark gillnet fisheries off Uruguay.

SC/O90/G2 CRESPO, E.A. and CORCUERA, J.F. Interactions between marine mammals and fisheries in some fishing areas off the coast of Argentina and Uruguay.*

SC/O90/G3 PINEDO, M.C. Age structure of the incidental catch of *Pontoporia blainvillei* in southern Brazil and Uruguay.*

SC/O90/G4 KROHN, R. Driftnet fishing in the South Atlantic.

SC/O90/G5 MAIGRET, J. Relationship between marine mammals and the fisheries on the West African coasts.*

SC/O90/G6 READ, A. Gill net and trap fisheries in the Northwest Atlantic.*

SC/O90/G7 VIDAL, O., van WAEREBEEK, K. and ALVAREZ-MANILLA, G. Cetaceans and gillnet fisheries in Mexico, Central America and the Caribbean: a preliminary review.*

SC/O90/G8 YATSU, A. A review of the Japanese squid driftnet fishery.*

SC/O90/G9 HATAKEYAMA, Y., ISHII, K., AKAMATSU, T., SOEDA, H., SHIMAMURA, T. and KOJIMA, T. Studies on the reduction of entanglement of Dall's porpoise, *Phocoenoides dalli*, in the Japanese salmon gillnet.*

SC/O90/G10 [No paper]

SC/O90/G11 REYES, J.C. and OPORTO, J.A. Gillnets, trap fisheries and cetaceans in the South East Pacific.*

SC/O90/G12 LAL MOHAN, R.S. A review of entanglement of small cetaceans in gill nets and the gill net fisheries of the Indian coast.

SC/O90/G13 DAWSON, S.M. Reducing entanglement of dolphins and porpoises via acoustic modifications to gillnets.*

SC/O90/G14 PRADO, J. and SMITH, A. Possibilities of reducing incidental catch and mortality of marine mammals in driftnet fisheries.

SC/O90/G15 AU, W.W.L. Sonar detection of nets by dolphins.*

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SC/O90/G17 GOODSON, A.D. Environment, acoustics and biosonar perception. Optimising the design of passive acoustic net markers.

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SC/O90/G20 COCKCROFT, V.G. Passive gear fisheries and their possible impact on cetaceans in the south western Indian and south eastern Atlantic Oceans.*

SC/O90/G21 ZHOU, K. and WANG, Z. Brief review of passive fishing gears and incidental catches of small cetaceans in Chinese waters.*

SC/O90/G22 LAL MOHAN, R.S. A Review of the mortality of cetaceans in gillnets and the gillnet fisheries of the northeastern Indian Ocean region.*

SC/O90/G23 HOHN, A. and PERRIN, W. Sources for a global review of mortality of cetaceans in passive fishing nets and traps.

SC/O90/G24 HEYNING, J.E. and WOODHOUSE, C. Mortality of odontocetes from fishing gear off southern California.*

SC/O90/G25 KINZE, C., Chr. Cetacean mortality in passive fishing nets and traps in the Baltic Sea: a review.

SC/O90/G26 CANNELLA, G. and XIMENEZ, A. Review of gillnet and trap fisheries in the Brazilian region.

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SC/O90/G28 BARLOW, J., BAIRD, R., HEYNING, J., WYNNE, K., MANVILLE, A.M. II, LOWRY, L., HANAN D. and SEASE. J. A review of cetacean mortality in coastal fisheries of the eastern North Pacific and USSR Far East.*

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SC/O90/G35 NORTHRIDGE, S. Driftnet fisheries and their impact on non target species.

SC/O90/G36 TOBAYAMA, T., INAGAKI, Y., RYOHNO, M. and HIRATSUKA, K. Review of the incidental catches of cetaceans in Japan.

SC/O90/G37 SAKUMA, T. Large scale trap net fishery in Japan.

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SC/O90/G39 COE, J.M. Discussion paper on management operations to control marine mammal mortality in passive fishing gear.

SC/O90/G40 SMOLOWITZ, R.J. and GOUDEY, C. Mitigating cetacean mortality in fisheries: appropriate alternatives.

SC/O90/G41 PAYNE, M.P., POWER, G. and YUSTIN, C.T. Interactions between the New England sink-gillnet fishery and the harbour porpoise, *Phocoena phocoena*.

SC/O90/G42 EARLE, M. Observations on tuna and swordfish driftnet fisheries.*

SC/O90/G43 JONES, L., DAHLBERG, M. and FITZGERALD, S. High seas driftnet fisheries of the North Pacific Ocean.

SC/O90/G44 SMITH, T.D., WARING, G.T. and POLACHECK, T.W. Factors important in initial evaluation of biological significance of cetacean bycatch.

SC/O90/G45 LA GRANGE, J. Captain "Cloud Nine" (gillnetter).

SC/O90/G46 NORRIS, K.S. Gillnets and marine mammals.

SC/O90/G47 SEQUEIRA, M. and FERREIRA, C. Portuguese fisheries--- draft report.*

SC/O90/G48 NELSON, D. A review of gear and animal characteristics responsible for incidental catches of marine mammals in fishing gear.

SC/O90/G49 NELSON, D. and LIEN, J. Responses of naive, captive dolphins to prototype whale alarms.

SC/O90/G50 LIEN, J., STENSON. G.B., CARVER, S. and CHARDINE, J. How many did you catch? The effect of methodology on bycatch reports obtained from fishermen.*

SC/O90/G51 LIEN, J., VERHULST, A., HUNTSMAN, T., JONES, J. and SETON, R. Reactions of humpback whales to novel sounds: curiosity and conditioning.

SC/O90/G52 WATANABE, Y. Japanese large-mesh driftnet fishery in the Pacific.*

SC/O90/G53 BONNEMAINS, J. and KANAS, M. The French albacore tuna fishery in the North Atlantic.

SC/O90/G54 Van WAEREBEEK, K. and REYES, J.C. The Peruvian small cetacean fishery interaction catch statistics: 1988–1989 and analysis trends.*

SC/O90/G55 NAGAO, K. Regulation of the high seas driftnet fishery of Japan.*

SC/O90/G56 CLAUSEN, B. Health status and bycatch of harbour porpoise (*Phocoena phocoena*) in Danish waters.

SC/O90/G57 KINZE, C.C. Incidental catches of harbour porpoises (*Phocoena phocoena*) in Danish waters 1986–1989: Recent data and behavioural implications.*

SC/O90/G58 HAYASE, S. and WATANABE. Y. Preliminary report on the Japanese fishing experiment using subsurface gillnets in the south and the north Pacific, 1989–1990.

SC/O90/G59 ANDERSON, G. Encounters with gillnets: preliminary results from a simple model and simulation of the porbability of encounters with long pelagic driftnets by cetaceans.

Annex C
Agenda

1. Welcome and introduction
2. Terms of reference and adoption of agenda
3. Arrangements for meeting
   3.1 Procedures and time schedule
   3.2 Appointment of rapporteurs
   3.3 Establishment of sub-groups
   3.4 Typing, photocopying and other services
4. Global review of gillnet and trap fisheries
5. Impacts on species and populations
6. Causes and solutions
7. Conclusions and recommendations
8. Editing and publication of report
9. Other business

Annex D
Re-estimation of Incidental Cetacean Catches in Sri Lanka

S. Leatherwood

Very large catches of cetaceans have been reported in the waters around Sri Lanka. That country's National Aquatic Resources Agency (NARA) estimated that approximately 12,950 individuals are incidentally caught in gillnets, and others (no estimate) are harpooned for use as food and bait in longline fishing (Dayaratne and de Silva, 1990). Methods used to estimate mortality were not presented in sufficient detail to support critical evaluation. Methods of estimating the total catch in Sri Lankan fisheries are reported here as an update from Leatherwood and Reeves (1989).

1. SPECIES COMPOSITION OF THE CATCH

The most complete data on composition of the cetacean bycatch in Sri Lanka are from the fish landing site at Trincomalee, on the northeastern coast, where landings were monitored by the same worker (W. P. Prematunga) for major portions of 1984–86 (Leatherwood and Reeves, 1989: table 12). The species composition of the observed landings at Trincomalee during those years is given in Table 1.

Table 1

Stenella longirostris	45.3%	*Pseudorca crassidens*	1.4%
Stenella attenuata	16.8%	*Globicephala macrorhynchus*	1.1%
Grampus griseus	14.7%	*Kogia breviceps*	0.9%
Stenella coeruleoalba	8.0%	*Mesoplodon* spp.	0.9%
Tursiops truncatus	5.4%	*Steno bredanensis*	0.6%
Kogia simus	2.6%	Unidentified dolphin	0.4%
Feresa attenuata	1.9%	*Lagenodelphis hosei*	0.1%

To obtain some estimate of takes of each species in all of Sri Lanka, the total estimated kill (see below) can be apportioned among species based on the composition of the observed landed catch at Trincomalee. This approach assumes that the species composition throughout the country is the same as that observed in Trincomalee. This assumption is violated to some extent, for example by the presence of other species (e.g. *Ziphius cavirostris*, *Orcinus orca*, *Peponocephala electra*, *Megaptera novaeangliae*, *Physeter macrocephalus* and *Balaenoptera physalus*) in small numbers in landed catches in western and southwestern Sri Lanka as well as at Trincomalee during recent seasons since monitoring ceased (e.g. *Delphinus delphis*, 1987) and by the fact that some species (e.g., *Lagenodelphis hosei*, *Kogia breviceps* and *Feresa attenuata*) are found more frequently in the fish landing sites in the west and southwest than they are in Trincomalee. However, in the absence of more detailed data for the country as a whole, estimates based on landed catches observed at Trincomalee are probably the best that can be made at present.

2. EFFORT PER BOAT/FISHING VILLAGE

Prematunga attempted to examine every cetacean landed at the Trincomalee fish landing site for three years, 1984–6, although his work was compromised to an unknown extent in 1986 by the civil strife in the region, resulting in lower counts of cetaceans than in previous years. Therefore, the total observed kills for 1984 and 1985 (310 and 323, respectively) were used to estimate average minimum landings per year at this site (316.5). There were 103 inboard boats registered at Trincomalee during that period, but Prematunga was not able to note how many of these boats were fishing and, therefore, contributing to the cetacean kill, at any given time (Leatherwood and Reeves, 1989, p.47)

3. NUMBER OF INBOARD FISHING BOATS IN SRI LANKA AND NUMBER OF FISHING DAYS PER YEAR (TOTAL EFFORT)

According to government statistics, there were an average of 2,943.8 inboard fishing boats registered in Sri Lanka 1984–1986 (Leatherwood and Reeves, 1989: table 3). However, not all registered boats are thought to be fishing all or even part of the year; so workers have used the figures 2,284 (Josephs and Siddeek, 1985) to 2,568 (Leatherwood and Reeves, 1989: table 7) in characterisations of fishing effort.

In the absence of better statistics, the more conservative of these two figures is used for the present calculations. A total of 1,385 of the boats are believed to fish in the Mannar District to Kulmanai District (west and southwest region); 899 in the Batticaloa District to the Jaffna District (east and northeast region) (Joseph and Siddeek, 1985; Leatherwood and Reeves, 1989: table 7). In previous calculations by Sri Lankan government scientists, it has been assumed that inboard vessels in the country fish at least 75% of the time (274 days/year) (Joseph and Siddeek, 1985).

4. CATCH RATES

The catch rate for the east and northeast coast can be estimated only with the data from Trincomalee. The resultant catch rate will be biased downward to an unknown extent because of overestimates in the number of vessels actually fishing at any time and the fact that some animals were discarded at sea and some of the animals landed were very probably not accounted for in Prematunga's tallies.

When the average minimum annual catch observed landed at Trincomalee in 1984 and 1985 (316.5) is divided by the maximum number of inboard boats registered in Trincomalee in that period (103), and the resultant minimum annual catch rate (3.07 cetaceans/boat/year) is then multiplied by the minimum number of inboard boats thought to be operating in the east and northeast region (899), one obtains a minimum estimate of 2,763 cetaceans landed per year in the region. This is lower than the range reported by Leatherwood and Reeves (1989: table 7). However, their calculations of minimum mortalities for this area as presented in that table contain an error (the catch rate is off by one decimal point). When the erroneous catch rates are replaced with the catch rate for Trincomalee recalculated for this report (0.0084), the resultant estimates of minimum annual mortality in the east and northeast region ranged from 2,297 – 3,729.

For the west and southwest region, Mannar District to Kulmanai District, the best catch rates available are those from observers stationed in four villages for 21–98 days each. These observers noted minimum landings of cetaceans (466) (Other duties prevented complete tallies.) and total numbers of inboard boats actually fishing during periods of observation (mean for the four combined = 134.3) (calculated from Leatherwood and Reeves, 1989: table 5). These estimates of fishing effort are more likely to be accurate than those calculated, as in Trincomalee, based on the total number of boats registered. The general utility of these estimates is further enhanced by the fact that the observers worked in four fish landing sites rather than one, suggesting that their figures are more likely to be representative of the entire region than figures from a single landing site would be. When catch rates for the west and south coasts are recalculated using this minimum estimated catch rate (0.0163 cetaceans/vessel/day) and multiplied by the minimum number of fishing boats thought to be in the area (1,385) and the number of fishing days (274), following Josephs and Siddeek (1985), one obtains a minimum estimate of 6,182 cetaceans killed in the west and southwest region each year. When the same conservative catch rate is used to recalculate the estimates in Leatherwood and Reeves (1989: table 7), the range of estimates corrects to 5,745–8,092.

The minimum annual landed kill for all of Sri Lanka, derived by combining the above two regional estimates, is 8,951 using the very conservative approach outlined above and 8,042–11,821 using the conservative approach taken by Leatherwood and Reeves (1989) in revising their table 7. The numerical catch estimates in Table 1 of the Workshop report are derived from the minimum estimate of 8,951 and the species composition of observed landings at Trincomalee.

It must be emphasised that all these estimates are biased downward to an unknown extent by cetaceans which are killed but not landed or landed but not tallied, and most are further biased downward by the use of the number of registered vessels rather than number of vessels actually fishing. As stated by Leatherwood and Reeves (1989:47)

> "All attempts to estimate mortality of cetaceans in Sri Lankan fisheries from the data available are compromised in significant ways...The best (one) could do was to calculate a series of estimates using conservative assumptions and present the basis and details for those estimates in sufficient detail that they can be recalculated as more information becomes available."

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Annex E
Guidelines for the Correct Description of a Gillnet (either driftnet or bottom set)

(1) Target species:
(2) Country or region:
(3) Mesh size: preferably to be given as stretched length, if not (e.g. bar length), specify precisely
(4) Twine webbing material: e.g. PA for nylon, PE for polyethylene, PP for polypropylene, PES for polyester. For other material, indicate the full trade name
(5) Twine construction: multifilament, monofilament or multimonofilamemt
(6) Twine size:
- for multifilament, indicate either number of denier, Rtex, or yard/lbs, m/kg. For any other measurement indicate its equivalence with one of the above or give the diameter
- for monofilament, indicate the diameter
- for multimonofilament, indicate the number of monofilaments and the diameter of one of these

(7) Height of the net: number of meshes or stretched height of the netwebbing, specify
(8) Length of the net: total strengthed length of the net webbing or number of meshes in the horizontal direction
(9) Hanging ratio (E): if possible
(10) Framelines (upper=floatline, lower=leadline, side=sidelines): indicate their material (see 4), diameter, length
(11) Floatation: needed measure is floatation per meter, so indicate: float material + main dimensions of the float + number of floats either per metre of the floatline or per given length of gillnet
(12) Weight on the leadline: indicate either: weight of a unit of lead + number of units either per metre of leadline or on the whole net or if the lower frameline is made of a lead core rope, indicate the weight of this rope per metre
(13) Make a drawing or sketch of the net in the fishing position: show the position of the gillnet versus the surface or the bottom, the anchor if any, buoy(s) and buoyline(s), secondary floatlines or leadlines if any (in this case give an indication of the floatation and the ballast)
(15) Total length of the string (or fleet) of net:
(16) Time of fishing:
(17) Duration of soak:
(18) Areas:
(19) Depth range:
(20) Approximate price:
(21) Vessel length:
(22) Vessel horsepower:
(23) Source of information and date:

Annex F
A Review of Modifications to the Webbing and Setting Strategies of Passive Fishing Gear to Reduce Incidental Bycatch of Cetaceans

Sean Todd and Dawn Nelson

Biopsychology Programme, Department of Psychology, Memorial University of Newfoundland, St. John's, Newfoundland, Canada, A1B 3X9

INTRODUCTION

This Annex reviews all known studies to date in which gear was modified to reduce cetacean bycatch. Certain fields have been deliberately excluded; for example, the methods used in pinniped-fishery interactions have been omitted, as well as studies in which modifications were not actually attached to nets. As a result, this review focuses specifically on in situ research. For a detailed review of the practicalities of gear modification, see Dawson (1991).

Modifications to passive fishing gear

Modifications can be divided into three broad categories; active sound generators, passive reflectors and changes in setting strategy. Active sound generators and passive reflectors are used on the assumption that they increase the acoustic and/or the visual detectability of fishing gear, whereas changes in setting strategy attempt to reduce the initial interaction between the bycatch species and the gear. Each type of modification is dealt with in turn.

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The authors would like to thank Dr. Jon Lien, Julie Huntington and Frank Chopin for their constructive criticisms in writing this paper and the members of the Causes and Solutions Sub-Committee at the IWC Workshop on the Mortality of Cetaceans in Passive Fishing Gear and Traps, especially Linda Jones, for their help in supplying source material.

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Modification type	Results/Comments	Source[1]
Active Sound Generators		
SG-1 9kHz pulse generator	No significant reduction in bycatch, awkward operation.	Hatakeyama, 1986a Hatakeyama *et al.*, 1991a,b Kumagai *et al.*, 1983 Ogiwara, 1986 Ogiwara *et al.*, 1985
SG-2 145kHz, simple form	Avg. <10% reduction in bycatch In 1984, a 5% decrease in directed catch was reported (no significance given).	Hatakeyama, 1986a Hatakeyama *et al.*, 1990a,b Kumagai *et al.*, 1983 Ogiwara, 1986 Ogiwara *et al.*, 1985 Ogiwara *et al.*, 1986
SG-3 145kHz, `porpoise-like'	Avg. <10% reduction in bycatch, significant in 1983, 1984, but not 1985.	Hatakeyama, 1986a Hatakeyama *et al.*, 1990a,b Kumagai *et al.*, 1983 Ogiwara, 1986 Ogiwara *et al.*, 1985 Ogiwara *et al.*, 1986 Hatakeyama, Ishii and Taketomi, 1985
SG-4 20-50kHz, random pulse	Avg. <30% non-significant reduction in bycatch. Generally, entrapment occurred in areas of net where alarms were not positioned. Some problems with alarm entanglement.	Hatakeyama, 1986a,b, 1987 Hatakeyama *et al.*, 1990a,b Ogiwara, 1986 Ogiwara *et al.*, 1986 Takagi, 1987
0.5-1kHz `clanger'	No significant reduction in bycatch, awkward operation.	Lien *et al.*, 1990
27-50kHz `pinger'	No significant reduction in bycatch, but a significant decrease in damage cost.	Lien *et al.*, 1990
3.5kHz `beeper'	Significant reduction in bycatch and damage cost.	Lien *et al.*, 1990
Low frequency `clanger'	No change in dolphin movements near nets. Increase in directed catch. Corrosion problems.	Peddemors *et al.*, 1991 Peddemors and Cockcroft, 1990
Low frequency `rattle'	No change in dolphin movements near nets. Reliant on sea state. Awkward operation.	Peddemors *et al.*, 1991 Peddemors and Cockcroft, 1990
Low frequency bell buoy	No change in dolphin movements near nets. Reliant on sea state. Awkward operation.	Peddemors *et al.*, 1991 Peddemors and Cockcroft, 1990
Passive Devices		
1m ABS air-filled piping	No significant reduction in bycatch.	Lien, 1980
1m ABS water-filled piping	No significant reduction in bycatch.	Lien, 1980
White plastic disc	No significant reduction in bycatch.	Lien, 1980
Plasticised aluminium foil squares	Tests inconclusive, problems with corrosion.	Peddemors *et al.*, 1991 Peddemors and Cockcroft, 1990
Aluminium discs	Tests inconclusive, problems with corrosion, awkward operation.	Peddemors *et al.*, 1991 Peddemors and Cockcroft, 1990
Stainless steel twine	Tests inconclusive, unmanageable.	Peddemors *et al.*, 1991 Peddemors and Cockcroft, 1990
AT-1 3 air-filled tubes in central portion of net	Avg. <30% reduction in bycatch, significant for years 1981 and 1982, but not for 1983. Data for 1984, 1985 and 1986 show an ambiguous significant decrease in bycatch (depending on type of statistical test).	Hatakeyama *et al.*, 1990a,b Hatakeyama, 1987 Jones, Bouchet and Turnock, 1987 Kumagai *et al.*, 1983 Ogiwara, 1986 Ogiwara *et al.*, 1985 Ogiwara *et al.*, 1986 Ogiwara *et al.*, 1987 Snow *et al.*, 1988 Takagi, 1987

Modification type	Results/Comments	Source
AT-2 5 air-filled tubes in central portion of net	<10% non-significant reduction in bycatch.	Kumagai *et al.*, 1983 Ogiwara, 1986 Takagi, 1987
AT-3 3 air-filled tubes in top 1/3 of net	<25% non-significant reduction in bycatch.	Hatakeyama *et al.*, 1990b Ogiwara, 1986 Ogiwara *et al.*, 1986 Takagi, 1987
MT-1 multi-filament thread	<30% reduction in bycatch, but of ambiguous significance. In 1987, there was a significant reduction in bycatch relative to AT-1 (solo) tests, with a slight non-significant) reduction in directed catch.	Hatakeyama *et al.*, 1990b Ogiwara, 1986 Ogiwara *et al.*, 1987 Snow *et al.*, 1988
Air filled tubes	No significant reduction in bycatch, problems with maintenance.	Hembree and Harwood, 1987
Bead chain	No significant reduction in bycatch, but decrease in directed catch.	Hembree and Harwood, 1987
Vinyl string (horizontal)	Tests inconclusive, some losses of strings from net.	Hasegawa *et al.*, 1987 Hatakeyama *et al.*, 1990a
1 rope (vertical)	Tests inconclusive.	Hasegawa *et al.*, 1987 Hatakeyama *et al.*, 1990a
3 ropes (vertical)	Tests inconclusive.	Hasegawa *et al.*, 1987 Hatakeyama *et al.*, 1990a
Blister sheet	Tests inconclusive, some losses of blister sheets from net.	Hasegawa *et al.*, 1987 Hatakeyama *et al.*, 1990a
Setting Strategies		
Lowering net by 2m	No bycatch in modified net, but some experimental design problems. Also a significant decrease in directed catch.	Hayase *et al.*, 1990
Lowering net by 4.5m	Significant decrease in bycatch by 50% (approx.). Also a decrease in directed catch, significant for one species only.	Hembree and Harwood, 1987
Lowering net by 2m	Tests inconclusive, but some decreases in bycatch.	Hayase *et al.*, 1990
Lowering trap leader by 5m	Modified traps resulted in no entrapments.	Kingsley, 1982
Combinations		
AT-1 with SG-1	<40% reduction in bycatch, no significance reported.	Ogiwara, 1986 Takagi, 1987
AT-1 with SG-2	<20% non-significant decrease in bycatch.	Hatakeyama *et al.* 1990b Ogiwara, 1986 Ogiwara *et al.*, 1987 Takagi, 1987
AT-1 with SG-3	<30% non-significant decrease in bycatch.	Hatakeyama *et al.*, 1990b Ogiwara, 1986 Ogiwara *et al.*, 1987 Takagi, 1987
AT-1 with SG-4	<40% non-significant decrease in bycatch. In 1987, inconclusive tests showed a reduction in bycatch relative to AT-1 (solo) tests.	Hatakeyama, 1988 Hatakeyama *et al.*, 1990b Ogiwara, 1986 Ogiwara *et al.*, 1987 Snow *et al.*, 1988 Takagi, 1987

[1] In several cases, different sources may refer to the same study; all sources are included here.

Annex G
List of Cetacean Species

There follows a list, in taxonomic order, of the living cetacean species recognised by the IWC Scientific Committee (scientific names and English common names).

Order Cetacea (whales and porpoises)	
Suborder Mysticeti (baleen whales or mysticetes)	
Family Balaenidae	
Eubalaena australis	southern right whale
Eubalaena glacialis	northern right whale
Family Neobalaenidae	
Caperea marginata	pygmy right whale
Family Eschrichtiidae	
Eschrichtius robustus	gray whale
Family Balaenopteridae	
Subfamily Balaenopterinae	
Balaenoptera acutorostrata	minke whale
Balaenoptera borealis	sei whale
Balaenoptera edeni	Bryde's whale
Balaenoptera musculus	blue whale
Balaenoptera physalus	fin whale
Subfamily Megapterinae	
Megaptera novaeangliae	humpback whale
Superfamily Physeteroidea	
Family Physeteridae	
Physeter macrocephalus	sperm whale
Family Kogiidae	
Kogia breviceps	pygmy sperm whale
Kogia simus	dwarf sperm whale
Suborder Odontoceti (toothed whales including porpoises)	
Superfamily Platanistoidea	
Family Platanistidae	
Platanista gangetica	Ganges river dolphin
Platanista minor	Indus river dolphin
Family Pontoporiidae	
Subfamily Lipotinae	
Lipotes vexillifer	baiji
Subfamily Pontoporiinae	
Pontoporia blainvillei	franciscana
Family Iniidae	
Inia geoffrensis	boto
Superfamily Delphinoidea	
Family Monodontidae	
Subfamily Delphinapterinae	
Delphinapterus leucas	white whale
Subfamily Monodontinae	
Monodon monoceros	narwhal
Family Phocoenidae	
Subfamily Phocoeninae	
Phocoena phocoena	harbour porpoise
Phocoena spinipinnis	Burmeister's porpoise
Phocoena sinus	vaquita
Neophocaena phocaenoides	finless porpoise
Subfamily Phocoenidinae	
Australophocaena dioptrica	spectacled porpoise
Phocoenoides dalli	dall's porpoise
Family Delphinidae	
Subfamily Stenoninae	
Steno bredanensis	rough-toothed dolphin
Sousa chinensis	Indo-Pacific hump-backed dolphin
Sousa teuszii	Atlantic hump-backed dolphin
Sotalia fluviatilis	tucuxi
Subfamily Delphininae	
Lagenorhynchus albirostris	white-beaked dolphin
Lagenorhynchus acutus	Atlantic white-sided dolphin
Lagenorhynchus obscurus	dusky dolphin
Lagenorhynchus obliquidens	Pacific white-sided dolphin
Lagenorhynchus cruciger	hourglass dolphin
Lagenorhynchus australis	Peale's dolphin
Grampus griseus	Risso's dolphin
Tursiops truncatus	bottlenose dolphin
Stenella frontalis	Atlantic spotted dolphin
Stenella attenuata	pantropical spotted dolphin
Stenella longirostris	spinner dolphin
Stenella clymene	clymene dolphin
Stenella coeruleoalba	striped dolphin
Delphinus delphis	short-beaked common dolphin
Delphinus capensis	long-beaked common dolphin
Lagenodelphis hosei	Fraser's dolphin
Subfamily Lissodelphinae	
Lissodelphis borealis	northern right whale dolphin
Lissodelphis peronii	southern right whale dolphin

Subfamily Cephalorhynchinae	
Cephalorhynchus commersonii	Commerson's dolphin
Cephalorhynchus eutropia	black dolphin
Cephalorhynchus heavisidii	Heaviside's dolphin
Cephalorhynchus hectori	Hector's dolphin
Subfamily Globicephalinae	
Peponocephala electra	melon-headed whale
Feresa attenuata	pygmy killer whale
Pseudorca crassidens	false killer whale
Orcinus orca	killer whale
Globicephala melas	long-finned pilot whale
Globicephala macrorhynchus	short-finned pilot whale
Subfamily Orcaellinae	
Orcaella brevirostris	Irrawaddy dolphin

Superfamily Ziphioidea

Family Ziphiidae	
Tasmacetus shepherdi	Shepherd's beaked whale
Berardius bairdii	Baird's beaked whale
Berardius arnuxii	Arnoux's beaked whale
Mesoplodon pacificus	Longman's beaked whale
Mesoplodon bidens	Sowerby's beaked whale
Mesoplodon densirostris	Blainville's beaked whale
Mesoplodon europaeus	Gervais' beaked whale
Mesoplodon layardii	strap-toothed whale
Mesoplodon hectori	Hector's beaked whale
Mesoplodon grayi	Gray's beaked whale
Mesoplodon stejnegeri	Stejneger's beaked whale
Mesoplodon bowdoini	Andrews' beaked whale
Mesoplodon mirus	True's beaked whale
Mesoplodon ginkgodens	ginkgo-toothed beaked whale
Mesoplodon carlhubbsi	Hubbs' beaked whale
Mesoplodon peruvianus	pygmy beaked whale
Ziphius cavirostris	Cuvier's beaked whale
Hyperoodon ampullatus	northern bottlenose whale
Hyperoodon planifrons	southern bottlenose whale

Significant Direct and Incidental Catches of Small Cetaceans

A REPORT BY THE SCIENTIFIC COMMITTEE OF THE INTERNATIONAL WHALING COMMISSION TO THE UNITED NATIONS CONFERENCE ON ENVIRONMENT AND DEVELOPMENT (UNCED)

EDITED BY

A. Bjørge
Norwegian Institute for Nature Research
University of Oslo
Norway

R.L. Brownell Jr
Southwest Fisheries Science Center
La Jolla, California
USA

G.P. Donovan
International Whaling Commission
Histon, Cambridge
UK

W.F. Perrin
Southwest Fisheries Science Center
La Jolla, California
USA

This report originally formed part of the report of the sub-committee on small cetaceans, published in 1992 in *Rep. int. Whal. Commn* 42: 178–234.

Contents

Significant Direct and Incidental Catches of Small Cetaceans

Edited by A. Bjørge, R.L. Brownell Jr, G.P. Donovan and W.F. Perrin

INTRODUCTION

Background to the Review

The Commission's Resolution

In the Resolution on Small Cetaceans (IWC, 1991a) adopted by the IWC last year, the Commission requested the Scientific Committee to commence a process of drawing together all available relevant information on the present status of those stocks of small cetaceans which are subjected to significant directed and incidental takes and on the impact of those takes on the stocks, and to provide such scientific advice as may be warranted.

The report to UNCED

The Commission also decided to present a report on the work carried out under the terms of the Resolution on Small Cetaceans to the United Nations Conference on Environment and Development (UNCED) in June 1992.

Editors' notes on the 1994 version

The present report comprises the relevant section (section 5) of the review of small cetacean stocks subjected to significant directed and incidental takes carried out by the sub-committee on small cetaceans and agreed by the full Scientific Committee and sent to the UNCED meeting. For convenience, the report follows the numbering system of the report of the sub-committee on small cetaceans published in *Rep. int Whal. Commn* 42: 178–234. Similarly the use of the word 'sub-committee' has been retained. The only changes that have been made to that report is the updating of 'In press' or 'unpublished' references where these have subsequently been published; Appendices 1 and 4 of the sub-committee report are not included as they are not relevant to the review.

Species names

The report uses English common names recognised by the IWC for small cetacean species as of October 1994. A full list of species in taxonomic order is given in Appendix 2. It should be noted that at the time of the report, only one species of common dolphin, *Delphinus delphis* was recognised. Since then two species, the short-beaked common dolphin (*D. delphis*), and the long-beaked common dolphin (*D. capensis*) have been recognised. Appendix 2 has been modified to this effect, but in most cases it is impossible to retrospectively reallocate animals assigned originally to 'common dolphin' to the two species.

5. REVIEW OF SIGNIFICANT DIRECTED AND INCIDENTAL CATCHES OF SMALL CETACEANS

Four categories of catches were identified and discussed; directed fisheries, incidental catches, deliberate incidental catches and live-capture fisheries. Information published in *Rep. int. Whal. Commn* or elsewhere, information presented to the IWC Workshop on Incidental Mortality in Passive Fishing Nets and Traps (IWC, 1994) and new information submitted to the sub-committee were reviewed. Priorities were given to those fisheries in each category where significant impacts on stocks are likely to occur. For these fisheries, previous recommendations made by the Scientific Committee, and any management response upon such recommendations were evaluated. New recommendations were made where appropriate.

The sub-committee, however, reviewed only those fisheries and stocks of small-cetaceans for which detailed information was available for consideration. It was emphasised, therefore, that while the review addresses many of the stocks which are significantly impacted by directed or incidental catches, it cannot be considered to be comprehensive, either with regard to species or to geographic regions covered. The sub-committee emphasised this problem that apply to all four categories of catches, and **recommends** that areas should be identified where there are urgent needs for basic information on status of small cetacean stocks and on impacts of any takes of those stocks. The sub-committee further **recommends** that areas should be specified where international cooperation is required (or beneficial) for developing further competence in research and management.

Problems related to pollution and habitat degradation were not addressed in the IWC Resolution on Small Cetaceans. These factors may have significant impacts on small cetaceans, in particular for those species occurring in coastal, inshore and riverine habitats. The sub-committee **underlines**, therefore, that these factors should be emphasised in a comprehensive assessment of threats to small cetaceans.

5.1 Directed fisheries[1]

5.1.1 Directed fisheries on small cetaceans in Japan

Over 20 species of small cetaceans are found in the nearshore waters around Japan. Various local fisheries for some of these species have a long history. This section

[1] Initial draft by Kasuya and Brownell.

reviews the history of exploitation for the four main small cetaceans (Dall's porpoise, striped dolphin, short-finned pilot whale, and Baird's beaked whale) hunted in Japanese waters and presents a brief review of the situation with other small cetaceans caught in direct Japanese fisheries.

5.1.1.1 *Phocoenoides dalli*

COMMON NAMES

Dall's and True's porpoise, *ishi iruka* and *rikuzen iruka* (Japanese names for *dalli* and *truei* forms, respectively), *belokrylaya morskaya svin'ya* (Russian).

DISTRIBUTION

This genus is endemic to the North Pacific basin. Its southern limits during winter are around the Boso Peninsula, near Tokyo (about 35°N) in the western Pacific and off northern Baja California, Mexico (approximately 28°N) in the eastern Pacific. The southern boundary in the central Pacific is about 39°N during summer (Jones *et al.*, 1987). In northern waters, sightings are infrequent above 62°N in the Bering Sea (Nishiwaki, 1967). In the western Pacific, these porpoises are also widely distributed in the Sea of Japan and the Okhotsk Sea (Kasuya, 1982; IWC, 1991c).

Based on the distribution of cow-calf pairs in August-September, colour pattern, body size, and geographical variation in parasite loads, the Scientific Committee proposed seven stocks of Dall's porpoises (IWC, 1991c). These are: (1) the central Bering Sea (*dalli*-type), (2) south of the Kamchatka Peninsula (*dalli*-type), (3) south of the Aleutian Islands (*dalli*-type), (4) central Gulf of Alaska (*dalli*-type), (5) northern Okhotsk Sea (*dalli*-type), (6) central Okhotsk Sea (*truei*-type) and (7) eastern North Pacific (*dalli*-type).

Understanding of the Okhotsk Sea stocks has since been refined (Miyashita, In press-b). During recent surveys the density of the *dalli*-type was low in the central Okhotsk Sea where the density of the *truei*-type (including cow-calf pairs) was high. Cow-calf pairs of *dalli*-type were concentrated to the north and south of this area of concentration of the *truei*-type in the central Okhotsk Sea (Miyashita, In press-b). The breeding ground (for the *truei*-type) south of the Kamchatka Peninsula (east of the Kuril Islands) was discontinuous with those in the Okhotsk Sea. Thus, Miyashita (In press-b) proposed three Dall's porpoise breeding stocks for the Okhotsk Sea (i.e. northern Okhotsk Sea – *dalli*-type; central Okhotsk Sea – *truei*-type; and southern Okhotsk Sea – *dalli*-type). This brought to eight the number of stocks known or postulated in the North Pacific.

PROBLEMS AND CATCH STATISTICS

This species has been hunted in Japanese waters since at least the early 1940s (Hirashima and Ohno, 1944). Porpoises are caught from two stocks (i.e. the *dalli*-type, southern Okhotsk Sea stock, and the *truei*-type, central Okhotsk Sea stock). During the 1960s and 1970s, the hand harpoon fishery in northern Japanese waters landed between 5,000 and 10,000 porpoises annually. In its early years, the hand harpoon fishery operated during winter off the Iwate coast (northern Honshu), but as the fishery started to expand, the season lengthened and the fishing ground moved into waters around Hokkaido. By 1988 the reported catch had increased to over 40,000 individuals. The Government of Japan established regulations for the hand harpoon fishery in early 1989, which resulted in a reduction of the annual catch to a total of 29,048 for that year. The estimated removals by the direct fishery from both stocks between 1986 and 1989 totalled 111,530 porpoises (IWC, 1991c). The large increases in take of this species since 1986 have been used to compensate for the shortage of whale meat due to the IWC moratorium on whaling. The increase has also been intended to compensate for the decrease in catches of striped dolphins in recent years. During the 1970s, Dall's porpoises were consumed largely in the Shizuoka area, but they are now shipped to Taiji as well. In addition to these high numbers caught and landed, other Dall's porpoises are struck and lost and therefore, probably die in this fishery. Struck and loss ratios in this fishery have been found to be highly variable by vessel, crew and area (Fujise, 1991).

The reported catches since 1963 are given Table 1. Recent catch statistics are reported as meat weight or whole animals, and the factor used to convert values for meat landed to whole animals taken is not consistent. Therefore, the Scientific Committee has expressed concern about the accuracy of the reported catches. It was also noted that meat products cannot accurately be attributed to stocks if the hunting operations are conducted in areas where both stocks occur.

Table 1

Reported landed catches of Dall's porpoises from the hand harpoon fishery in Japanese coastal waters (IWC, 1991c). Both *dalli* and *truei* types are included.

Year	Catch	Year	Catch	Year	Catch
1963	9,040	1972	5,190	1981	9,767
1964	9,440	1973	7,230	1982	12,833
1965	9,180	1974	6,470	1983	12,776
1966	7,980	1975	7,350	1984	9,764
1967	5,150	1976	9,899	1985	10,378
1968	6,020	1977	9,358	1986	16,515
1969	7,020	1978	8,426	1987	25,600
1970	8,060	1979	6,843	1988	40,367
1971	5,210	1980	6,920	1989	29,048
				1990	21,802

POPULATION ESTIMATED

Bouchet (1981) estimated that 920,000 Dall's porpoises occur in the North Pacific and Bering Sea portions of their range, excluding the Sea of Japan and Okhotsk Sea. This estimate was revised upwards to 953,000 (Turnock, 1987). The latter estimate included 212,000 porpoises in the Bering Sea stock and 741,000 porpoises in the western and central North Pacific between 150°E and 172°W. A large but unknown population(s) occurs in the eastern North Pacific.

Miyashita and Kasuya (1988) reported minimum estimates for the *dalli*-type stock in the southern Okhotsk Sea of 47,000 (plus an unknown number of animals in adjacent Soviet waters) and for the *truei*-type stock in Japanese and USSR waters of 58,000. Using porpoise sightings from 1990 surveys, Miyashita (Miyashita, In press-b) estimated the three stocks off Japan to be: 111,000 (CV=0.29), *dalli*-type, northern Okhotsk Sea stock; 226,000 (CV=0.15), *dalli*-type, southern Okhotsk stock; and 217,000 (CV=0.23), *truei*-type, central Okhotsk Sea stock.

These estimates are substantially different from the previous estimates for part of the area; so, with help from a review by Buckland the sub-committee examined the new results in some detail. The design was found to be acceptable. Although bad weather did prevent surveys from achieving uniform coverage, it did not significantly affect results. Buckland suggested that a more appropriate method of calculating variance would yield a higher variance. If the porpoises are attracted to vessels, as are Dall's porpoises in other areas, results will be biased upward; if they avoid vessels the results will be biased downward. This was not possible to assess with the data available.

ASSESSMENT AND STATUS

From data then available (catches through 1987, population estimates from Miyashita and Kasuya (1988)) the Scientific Committee concluded in 1989 that the take of Dall's porpoises in the Japanese hand harpoon fishery was clearly not sustainable (IWC, 1991b; c). In 1988 and 1989, respectively, totals of 40,367 and 29,048 porpoises were taken in this fishery. These represented 38% and 28%, respectively, of the minimum population estimates then available. Takes during the 1990 season were estimated to consist of 9,360 of the *dalli*-type and 12,442 of the *truei*-type (uncorrected for animals struck but lost). The Japanese statistics report the catch by colour type based on the area of operation for catches landed as meat (i.e. 100% *dalli*-type off Hokkaido and 90–95% *truei*-type off Sanriku). In 1990, then, the reported takes of Dall's porpoises in the Japanese harpoon fishery comprised 4.1% of the revised estimated population of *dalli*-type from the southern Okhotsk Sea stock and 5.7% of the estimated population of the *truei*-type from the central Sea of Okhotsk stock. These percentages must be increased by some amount to account for porpoises struck but lost. Estimates of the average struck-and-lost ratio ranged from 3.3% to 9.8% of those struck, depending on region (Fujise, 1991). Although some of these struck and lost animals may survive, applying the above range of struck and lost ratios suggests that 1990 takes accounted for 4.2–4.6% of the southern Okhotsk Sea stock and 5.9–6.3% of the central Okhotsk Sea stock. While these levels are very much lower than the catch rates reported for 1988 and 1989, it cannot necessarily be assumed that they are sustainable. The sub-committee in 1990 (IWC, 1991c) stated that it believed 'that allowable harvest and incidental take rates should be lower than half of the estimated value for r_{max}' and noted that 'all estimates of r_{max} presented in the submitted papers in 1990 are less than 0.10'. This implies that annual takes should be less than 5% of the estimated population size; how much less is still open to question. In addition, demographic implications of the sharp differences in age and sex structures of catches in different regions (Fujise *et al.*, 1991) must be taken into account in assessing impact.

RECOMMENDATIONS

In 1990 the highest priority recommendations of the Scientific Committee related to small cetaceans were that the planned Japanese sightings surveys be carried out and that new population estimates be developed for the stocks taken in the hand harpoon fishery (see new results in Miyashita, In press-b). It was also recommended that a plan for monitoring trends in the populations be developed. The sub-committee was pleased to receive the new estimates and **recommends** that surveys be continued as a basis for monitoring trends in population sizes for hunted stocks.

Additional recommendations in 1990 were that analyses of parasite loads in the eastern North Pacific and other areas be compared to those already studied (Walker, 1990) to help identify other possible stocks. Along these lines, it was also recommended that studies be continued or undertaken to differentiate stocks using a combination of techniques, such as differences in life-history parameters (e.g., asymptotic length), parasite and contaminant loads, reproductive seasonality, DNA and isozymes.

In 1989, the Scientific Committee recommended that catch statistics for this fishery be collected and reported on a stock-by-stock basis. Considering the possible take from the stocks off Japan, it was also recommended that the Republic of Korea be requested to report to the IWC by-catches of Dall's porpoises (and other cetaceans) in its squid driftnet fishery (IWC, 1990b).

In 1990, the Scientific Committee recommended that information on struck-and-lost rates be collected and analysed for each gear type in the Japanese harpoon fishery, to allow more accurate estimation of total mortality. It also recommended a clarification of the basis for revision of the 1986 and 1987 catch statistics (IWC, 1991c). The sub-committee was pleased to acknowledge the Japanese Government's quick response to these requests. Given that continuing problems have been identified, however, the sub-committee **advises** that there be increased effort in improving catch statistics for this fishery, and that this includes steps to distinguish the two colour types in landings of meat only. Noting the high variability in estimates currently available for struck-but-lost rates, the sub-committee **advises** that additional information be collected on these rates by area, season, vessel and other significant variables. Further, it **encourages** the continuation of steps taken to improve precision in estimates of take (Kasuya, 1991).

The sub-committee is pleased that catches have been reduced, perhaps to levels very near sustainable rates. However, given the uncertainty about the age and sex structure of catches, and pending a detailed age-structure assessment, it is again **reiterates** that catches in this fishery be further reduced.

5.1.1.2 *Globicephala macrorhynchus*

COMMON NAMES

Short-finned pilot whale, *tappa-naga* for the northern stock and *ma-gondo* for the southern stock (Japanese).

DISTRIBUTION

This species is found in tropical and warm temperate waters world wide. Short-finned pilot whales from at least two different stocks are hunted in Japanese waters (Kasuya *et al.*, 1988). The northern stock is found along the Pacific coast of northern Japan between 35°N and 43°N (IWC, 1987). Most sightings of whales in this stock during recent surveys were concentrated between 40°N and 43°N and west of 143°E (Kasuya *et al.*, 1986). Whales belonging to the southern stock were found during summer survey cruises in 1984 and 1985 in Japanese waters south of 37°N from the coast east to 125°E. No whales were seen south of 25°N or east of 152°E. This suggests that whales of the southern stock are restricted to this area off the Pacific coast of Japan. Wada (1988) reported, based on electrophoretic data, that the two stocks were genetically isolated.

PROBLEMS AND CATCH STATISTICS

Northern stock

The northern stock of pilot whales was exploited by Japanese small-type whaling vessels before World War II, but no statistics are available. During the late 1940s and early 1950s, the annual catches declined rapidly from 400 to less than 50 animals. In addition, the proportion of males in the catch declined. After a pause of about 25 years, small-type whaling on this stock resumed in 1982. Two to seven vessels have operated and landed their catch at three land stations in Ayukawa. The gunners select large whales. The total reported catch for eight seasons (1982–1990) was 700 whales (see Table 2).

Table 2

Catch statistics for northern stock of short-finned pilot whales taken by Japanese small-type whaling vessels, based on gunner's reports.

Year	No. of whales	No. of vessels	Operational-vessel days
1982	172	5	119
1983	125	7	100
1984	160	6	94
1985	62	7	77
1986	28	3	14
1987	0	0	0
1988	98	4	90
1989	50	2	78
1990	10	2	58

Since 1982, the regulations by the central government have changed several times: (1) no catch limit was set during the October-November 1982 season; (2) a quota of 175 was set for the 1983 and 1984 seasons; (3) a fixed fishing season of 255 vessel days was established for seven small-type whaling vessels during the 1985 season; (4) the government and industry decreased the fishing effort for the 1986 season to 40% of the previous season and set a quota of 50 whales from 5 October to 18 November for three vessels; (5) no whaling occurred during the 1987 season and the quota of 50 whales was carried over to the 1988 season; (6) four vessels were allowed to operate from 5 September to 30 November in 1988 with a two year quota of 100 whales; and (7) an annual quota of 50 whales was set for the 1989 and 1990 seasons and only two of the four vessels previously involved were allowed to operate from 1 September to 18 November each year.

Southern stock

In Japanese waters the southern stock has been exploited since before World War II by local fishermen in three isolated areas. Fishermen from various villages have operated a drive fishery for pilot whales along the Izu Peninsula since the early 1900s. Statistics are available since 1950. Annual catches ranged between 31 and 650 from 1950 to 1956. Statistics are incomplete between 1957 and 1971. From 1972 to the present, the annual catches have ranged from 0 to 80 whales. Today, only the fishermen from Futo (Izu Peninsula) still hunt pilot whales, but the last catch was 20 whales in 1981. Available catch records are summarised in Table 3. No catch limits are set for this fishery by the Shizuoka Prefectural government, but the Fisheries Agency requested a limit of 657 individuals of all dolphin species for the 1991 season.

Table 3

Drive fishery statistics for southern stock of short-finned pilot whales landed at Izu Peninsula, Japan.

Year	Catch	Year	Catch	Year	Catch	Year	Catch
1950	224	1958	---	1966	---	1974	0
1951	425	1959	---	1967	30	1975	0
1952	650	1960	---	1968	---	1976	0
1953	349	1961	---	1969	---	1977	73
1954	31	1962	---	1970	---	1978	80
1955	86	1963	---	1971	---	1979	0
1956	126	1964	---	1972	0	1980	0
1957	---	1965	33	1973	0	1981	20

Off Nago, Okinawa, the fishermen have hunted pilot whales in a drive fishery for a long time, but catch statistics are only available for years since 1960. Annual catches have varied from 0 to 500 animals per season (not calendar year). In 1975, the fishermen started to harpoon pilot whales from 5–7 fishing vessels. This method has replaced the traditional drive fishery in the area. The reported catches since 1960 are given in Table 4. This crossbow fishery came under regulation in 1989. A quota of 100 individuals (all species) was established for the Nago fishery with four vessels licensed for the 1991 season by the local governor.

The major pilot whale fishery is the one at Taiji (Kii Peninsula) that started in the 17th century (Kasuya and Marsh, 1984). Statistics are fragmentary for years before World War II. After the war, both small-type whaling and a drive fishery operated in the waters off Taiji. A total of 200–300 whales was taken annually between 1949 and 1951 by small-type whaling vessels. After 1951, lower catches were made and only a single small-type whaling vessel operated to meet local demand for pilot whale meat. The drive fishery started in 1969 and, since 1980, has been the only pilot whale fishery operating off Taiji. Annual catches ranged between 90 and 605 whales between 1975 and 1985. In 1982, the Japanese government placed all drive fishermen under the control of the relevant Prefectural governments (IWC, 1987). The Wakayama Prefecture (Taiji) has set an annual catch limit of 500 pilot whales since that time. Recent catch statistics are summarised in Table 5. Small-type whaling from Taiji started again on the southern stock of short-finned pilot whales in 1988 when 20 whales were caught (Kishiro and Kasuya, 1993); 3 vessels operated that year. An annual quota of 50 whales was set

Table 4

Drive and crossbow fishery for southern stock of short-finned pilot whales landed in Okinawan waters (Kasuya, In press).

Year	Catch	Year	Catch	Year	Catch
1960	243	1970	0	1980	80
1961	281	1971	165	1981	0
1962	0	1972	170	1982	5
1963	189	1973	87	1983	0
1964	318	1974	53	1984	88 *
1965	0	1975	49	1985	70 *
1966	0	1976	36	1986	82 *
1967	150	1977	301	1987	92 *
1968	150	1978	0	1988	116 *
1969	500	1979	0	1989	93 *
				1990	74 *

*Taken in crossbow fishery - crossbow and drive fisheries not seperated between 1975 and 1982.

Table 5

Catch statistics for southern stock of short-finned pilot whales taken by small-type whaling and drive fishery off Taiji, Japan, by calendar year (Kishiro and Kasuya, 1993).

Year	Harpoon	Drive	Year	Harpoon	Drive
1948	38	0	1970	108	0
1949	283	0	1971	111	24
1950	233	0	1972	60	30
1951	227	0	1973	66	52
1952	131	0	1974	65	94
1953	141	0	1975	53	410
1954	20	0	1976	14	370
1955	12	0	1977	6	170
1956	141	0	1978	13	309
1957	98	0	1979	3	87
1958	---	0	1980	0	605
1959	---	0	1981	0	476
1960	---	0	1982	0	305
1961	---	0	1983	0	378
1962	---	0	1984	0	424
1963	---	0	1985	0	589
1964	---	0	1986	0	264
1965	121	0	1987	0	294
1966	---	0	1988	20	327
1967	---	0	1989	5	71
1968	97	0	1990	8	75
1969	75	77			

for 1989 and 1990 but only 5 and 8 whales were taken, respectively. This quota was set by the Japanese Fisheries Agency.

ASSESSMENT AND STATUS

Northern stock

The provisional total estimated population size of the northern stock, based on summer surveys during 1984 and 1985, was 5,344. In 1986, the Scientific Committee expressed considerable concern that the available data suggested a decline in the northern stock (IWC, 1986b). Using data collected in September and October of 1982 through 1988, Miyashita (1993) re-estimated the population size of the northern stock to be 4,239 (CV=0.61). The annual catch of about 87 whales since 1982 represents more than 2% of the estimated present population size, but the current quota of 50 is about 1% of the estimate.

Southern stock

The estimated size of the southern population based on five cruises conducted during the summers of 1984 and 1985 was 53,000 (IWC, 1987). Based on new sighting data collected in 1986 through 1988, Miyashita (1993) revised the estimate for the southern stock of pilot whales down to 24,474 (CV=0.61). Recent total annual catches (uncorrected for any struck/lost whales) represent 1 to 2% of the estimated present population size of this stock.

RECOMMENDATIONS

In 1986, the Scientific Committee recommended that the biological monitoring programme be expanded on the northern stock and that additional vessel surveys be conducted to improve the population estimate and to collect data on the proportion of adult males present (IWC, 1986b). Additional sighting surveys were conducted by the Japanese and the results presented in Miyashita (1993). The sub-committee understands that biological materials have been collected routinely from whales landed in this fishery. It is requested that these materials be studied and reported on.

In 1986, the Committee also requested that fishing effort, sighting and catch data continue to be collected for the drive fishery along with the collection of biological materials from the catch. The Committee noted that no biological materials had been collected from the drive fishery since 1981. The Committee also suggested that investigations be initiated on stock identity of the whales taken in the three different southern fishing areas.

In 1986, the Scientific Committee felt it appropriate, from a biological point of view, that no animals be taken from the northern stock until a clearer understanding of the status of this population became available (IWC, 1986b). It recommended that if a pause in whaling was not possible, the catch should be reduced by significantly curtailing the total effort in the fishery. Japan reduced the annual catch limit from 175 whales in 1984 to 50 in 1987 and the number of vessels licenced to hunt pilot whales from the northern stock were reduced; from 6 vessels in 1984 to 2 vessels in 1989.

In 1986, the Committee also considered that the exploitation of the southern stock should not be intensified because of the recent catch levels and the fact that gross productivity of this species is low. However, effort on this stock has increased since small-type whaling on the southern stock started again in 1988. The sub-committee again **recommends** that catches from the southern stock not exceed levels prior to those in 1986.

5.1.1.3 *Berardius bairdii*

COMMON NAMES

Baird's beaked whale, *tsuchi kujira* (Japanese), *severnyi plavun* (Russian).

DISTRIBUTION

These whales are found only in the North Pacific Ocean and adjacent seas. Based on migration patterns, at least three stocks exist in the western Pacific around Japan: a western Pacific stock; a Sea of Japan stock; and an Okhotsk Sea stock (Kasuya and Miyashita, 1988).

PROBLEMS AND CATCH STATISTICS

Japanese fishermen have hunted Baird's beaked whales since at least the 17th century. Fishermen using hand harpoons from small boats operated out of Katsuyama in Chiba Prefecture (near Tokyo) until the start of the Meiji era (1867). The annual catch was only four or five whales. In 1908 *tsuchi-kujira* whaling resumed again off Chiba Prefecture from a small wooden boat with a Norwegian-type harpoon gun. After the end of World War II, coastal whaling increased, and by 1952 the Fisheries Agency of Japan had licensed 76 small-type whaling vessels. The largest catch was in 1952 when 322 Baird's beaked whales were landed (Omura *et al.*, 1955). Since 1952 the catches have declined. The Government of Japan established a national quota of 40 whales in 1983 (IWC, 1984b). The small-type whaling association divided this quota into 35 for the western Pacific and 5 for the Okhotsk Sea. In 1988 the national quota was increased 50% (from 40 to 60) as a one-year emergency increase for the small-type whaling vessels to partially replace the former catch of minke whales (IWC, 1980c). However, this higher quota was maintained in 1989 and 54 whales were landed. In 1989 one vessel with a quota of six whales did not operate in the fishery. During 1990 the quota was 54 whales and all were taken. Table 6 lists the catch of Baird's beaked whales between 1961 and 1990.

Soviet whaling operations were reported to have taken 143 whales between 1934 and 1964 off Kamchatka and the Kuril Islands. Small numbers were also taken in the eastern North Pacific and landed at various shore stations in the USA (14 whales) and Canada (135 whales) between 1934 and 1966.

A few Baird's beaked whales are known to have been caught incidentally in the Japanese salmon driftnet fishery (from both research and commercial vessels) (Ohsumi, 1975). None has been identified as incidentally taken in any of the high seas pelagic driftnet fisheries in the North Pacific (L. Jones, pers. comm.). A few have been taken in gillnets off California (California Department of Fish and Game records).

Table 6

Statistics for Baird's beaked whales taken in Japanese coastal waters.

Year	Catch	Year	Catch	Year	Catch
1961	133	1971	118	1981	39
1962	145	1972	86	1982	60
1963	160	1973	32	1983	37
1964	189	1974	32	1984	38
1965	172	1975	46	1985	40
1966	171	1976	13	1986	40
1967	107	1977	44	1987	40
1968	117	1978	36	1988	57
1969	138	1979	28	1989	54
1970	113	1980	31	1990	54

ASSESSMENT AND STATUS

Based on sightings data, Miyashita (1986) estimated that 4,220 Baird's beaked whales occurred in the western North Pacific. The most recent estimate of abundance for this species – 5,870 whales in the western North Pacific and adjacent seas (Miyashita, 1990), based on 11 surveys conducted between 1983 and 1989 (IWC, 1991c) was presented to the Committee in 1990. This new estimate included 3,950 (CV=0.28) for the Pacific coast, 1,260 (CV=0.45) for the Sea of Japan and 660 (CV=0.27) for the Okhotsk Sea. The Committee noted that the estimates of 3,950 and 4,220 whales were not statistically different from each other but that they did differ from the estimate of 2,500 from 1989 that was based on data from all months rather than just the survey data for the season of greatest abundance in coastal waters (August).

The CPUE data did not show a clear annual trend from 1947 to 1983 (Kasuya, 1984). It is not known if the population is declining or stable (IWC, 1989).

At the 1985 Scientific Committee meeting, it was noted that the national quota of 40 whales was approximately 1% of the population estimate of 4,220 (Miyashita, 1986). It is 2.4% of the 1989 estimate (2, 500). It was also noted that historically, approximately 70% of the annual catch has been males (Ohsumi, 1983). In the absence of an estimate of gross reproductive rate, the Committee did not know whether or not the population could sustain the present level of catch. During the past five years the average catch in the western Pacific by Japan has averaged about 41 whales. This is around 1% of the population size depending on the estimate used. The corresponding figures for the Okhotsk Sea stock are 8 whales and about 1.2%.

RECOMMENDATIONS

In 1990, the Committee recommended that monitoring of trends in these populations in Japanese waters continue, taking special notice about the complications to stock assessments introduced by migration of animals (IWC, 1991c).

In 1990, the Committee again noted that there was insufficient data to judge whether annual catches of approximately 60 whales are sustainable and recommended 'as in the past (IWC, 1989) that research to develop an understanding of the life history, behaviour and social system that will allow estimation of growth rate potential be continued.' It was also noted that 'this should include continued collection and analysis of data and samples from the catch'. The sub-committee noted that Japan had increased its biological sampling to 100% of the catches; the sub-committee **encourages** continuation of that level of sampling and prompt evaluation and publication of results.

5.1.1.4 *Stenella coeruleoalba*

COMMON NAMES

Striped dolphin, *suji-iruka* or *suzi-iruka* (Japanese).

DISTRIBUTION

This species is found in tropical and warm-temperate waters around the world. In Japanese waters it is associated with the advancing northern front of the warm Kuroshio Current (Miyazaki *et al.*, 1974). During the winter, the northern boundary is around 33°N; during the summer it extends to 46°N. Ohsumi (1972) and Miyazaki *et al.* (1974) suggested that all striped dolphins caught in Pacific Japanese waters belong to one stock. Recently, Kasuya and Miyashita (1989) suggested there were coastal and offshore stocks of striped dolphins off the Pacific coast of Japan.

PROBLEMS AND CATCH STATISTICS

Drive fisheries for small cetaceans have a long history in Japanese waters. The first known drive fishery operated during the Genroku Age (1688–1703), but the types of dolphins caught were not recorded. The first recorded drive fishery for striped dolphins was started by the Kawana fishermen on the Izu Peninsula on 17 December 1888 (Miyazaki, 1983). Ten villages are known to have operated the fishery in the early 1900s (Kasuya, 1985). The number has declined, and since 1984 only Futo has continued to operate. Catch statistics for the Izu area are found in Table 7.

Striped dolphins were also caught in the harpoon fishery off Taiji until 1972. Starting in 1973 a local group of fishermen formed a new drive fishery for these dolphins. Catches by this drive fishery at Taiji between 1963 and 1990 are given in Table 8. The highest catch was 11,017 in 1980. Beginning in 1982 a voluntary catch limit of 5,000 dolphins was set by the fishermen in Taiji based on advice provided by the prefectural government. In 1989 the 5,000 limit became a condition of the license. In addition, the Fisheries Agency of Japan has requested a voluntary limit of 3,100 for 1991. Striped dolphins have made up 15% – 67% of the catch at Taiji between 1982 and 1990. No catch limit has been set for the Izu Peninsula area, but the Fisheries Agency requested a limit of 657 for all species of dolphins for 1991.

Matsuoka stated that these catch limits can be achieved by adjusting the catch by releasing a certain proportion of schools driven into a bay. For example, in early 1991, when

Table 7

Catch statistics for striped dolphins landed along the Izu Peninsula. Statistics are incomplete before 1961. Data for 1942-81 from Miyazaki (1983) and 1982-1990 from Japanese Progress Reports to the IWC.

Year	Catch	Year	Catch	Year	Catch
1942	21,591	1959	21,953	1976	5,175
1943	7,763	1960	14,418	1977	4,020
1944	7,660	1961	10,569	1978	2,028
1945	7,319	1962	8,554	1979	1,300
1946	8,180	1963	8,509	1980	5,278
1947	395	1964	6,428	1981	73
1948	5,892	1965	9,696	1982	246
1949	13,441	1966	8,371	1983	40
1950	15,186	1967	3,664	1984	925
1951	11,899	1968	9,250	1985	578
1952	8,032	1969	3,130	1986	0
1953	4,028	1970	5,348	1987	0
1954	298	1971	3,315	1988	356
1955	2,552	1972	7,235	1989	102
1956	8,507	1973	6,799	1990	0
1957	2,751	1974	11,715		
1958	3,681	1975	5,996		

approximately 2,000 striped dolphins out of 7,000–12,000 sighted were driven into the bay of Taiji, only 600 of them were killed; the rest were released.

Striped dolphins have also been reported taken in gillnets and set nets in Japanese waters (Miyazaki, 1983). Between 1976 and 1981, a total of 772 striped dolphins was taken in fishing gear. Recent reports of incidental catches in various types of gear in Japanese waters are also available (Anonymous, 1990d). Watanabe (1994) has also reported catches in large-mesh drift nets during research cruises in the central North Pacific. Estimates of total catches of striped dolphins in this fishery are not yet available.

ASSESSMENT AND STATUS

The largest directed fishery (both drive and hand-harpoon) for small cetaceans in Japanese waters was that conducted on the striped dolphin, until the Dall's porpoise fishery expanded in the mid 1970s. Kasuya and Miyazaki (1982) estimated that the initial population of striped dolphins off Japan had been 320,000–340,000, but by the late 1970s it was down to between 130,000 and 180,000. At the 1982 Scientific Committee meeting, Kasuya reported that recent life-history and populations studies led him to believe that

Table 8

Catch statistics for striped dolphins landed at Taiji, Japan between 1963 and 1990. Data for 1963-1978 from Miyzaki (1980), 1979-1981 from Miyazaki (1983) and 1982-1990 from Japanese Progress Reports to the IWC.

Year	Catch	Year	Catch	Year	Catch
1963	331	1972	700	1981	4,710
1964	934	1973	727	1982	1,758
1965	642	1974	967	1983	2,179
1966	422	1975	759	1984	2,812
1967	819	1976	1,053	1985	2,639
1968	400	1977	562	1986	2,720
1969	499	1978	1,644	1987	358
1970	997	1979	2,397	1988	1,767
1971	1,717	1980	11,017	1989	1,000
				1990	682

these estimates were unreliable, for the reasons noted below.

The full statistics for the earlier years (before 1961) of the fishery on striped dolphins are not available, but in some years the catches exceeded 20,000 animals. Catch statistics from 1961 onward indicate a statistically significant downward trend in the total catches on the Izu Peninsula between 1961 and 1981, with a high of 11,715 landed in 1974 (Miyazaki, 1983). Catches of around 10,000 in the early 1960s declined to about 1,000 or less after 1980 using the same equipment (four vessels) and driving teams (Kawana and Futo). This decline occurred while the demand for dolphin meat remained high in the area. Kasuya and Miyashita (1989) reported that after the catch of striped dolphins decreased, the people in the Shizuoka area increased their use of Dall's porpoises. Kasuya (1976), Kasuya and Miyazaki (1982) and Kasuya (1985) noted that the striped dolphin population in Japanese waters has declined in abundance due to over-exploitation. Kasuya and Miyashita (1989) reported a hiatus in the density of sightings of this species at about 30°N during the summer, and suggested the possibility that there was another stock to the south of 30°N. They also identified a large number of striped dolphin sightings in the offshore water (145–160°E) between 33° and 40°N. During the same surveys, sightings of striped dolphin were scarce in the Japanese coastal waters. These data suggest that the stock of coastal striped dolphins is depleted and that the striped dolphins found offshore belong to another stock or stocks.

RECOMMENDATIONS

At the 1982 meeting, the Committee noted that the catches of these dolphins had declined over a long time period on the Izu Peninsula, that reproductive parameters had possibly changed in response to this heavy exploitation and that available analyses of CPUE were not adequate to determine the status of the stock (IWC, 1982b). Therefore, it recommended that Japan be urged to collect and analyse more detailed effort data and other relevant information on this species including:

(a) effort data in hours and days, by vessel, area, season and year;
(b) detailed oceanographic data;
(c) data on other major fisheries in the area, especially for squid, and;
(d) information on yearly changes in seasonal abundance, effort and catch.

Noting that catch limits are now voluntary, the sub-committee **advises** the establishment of mandatory catch limits on a species and stock basis, according to the status of the population.

Noting that the fisheries department has not sampled the catch of striped dolphins in ten years, the sub-committee **recommends** that Japan be encouraged to undertake a study of the age and sex composition of the catch and of reproductive parameters of the affected population.

Given reports that there have been changes in drive procedures, and total effort, the sub-committee **requests** an updated description of the drive fishery's current methods and procedure.

5.1.1.5 *Other species*

Several additional species are taken in Japanese direct fisheries (see past Japanese progress reports to the Committee, e.g. Anonymous, 1985a; 1986; 1987b; 1990d).

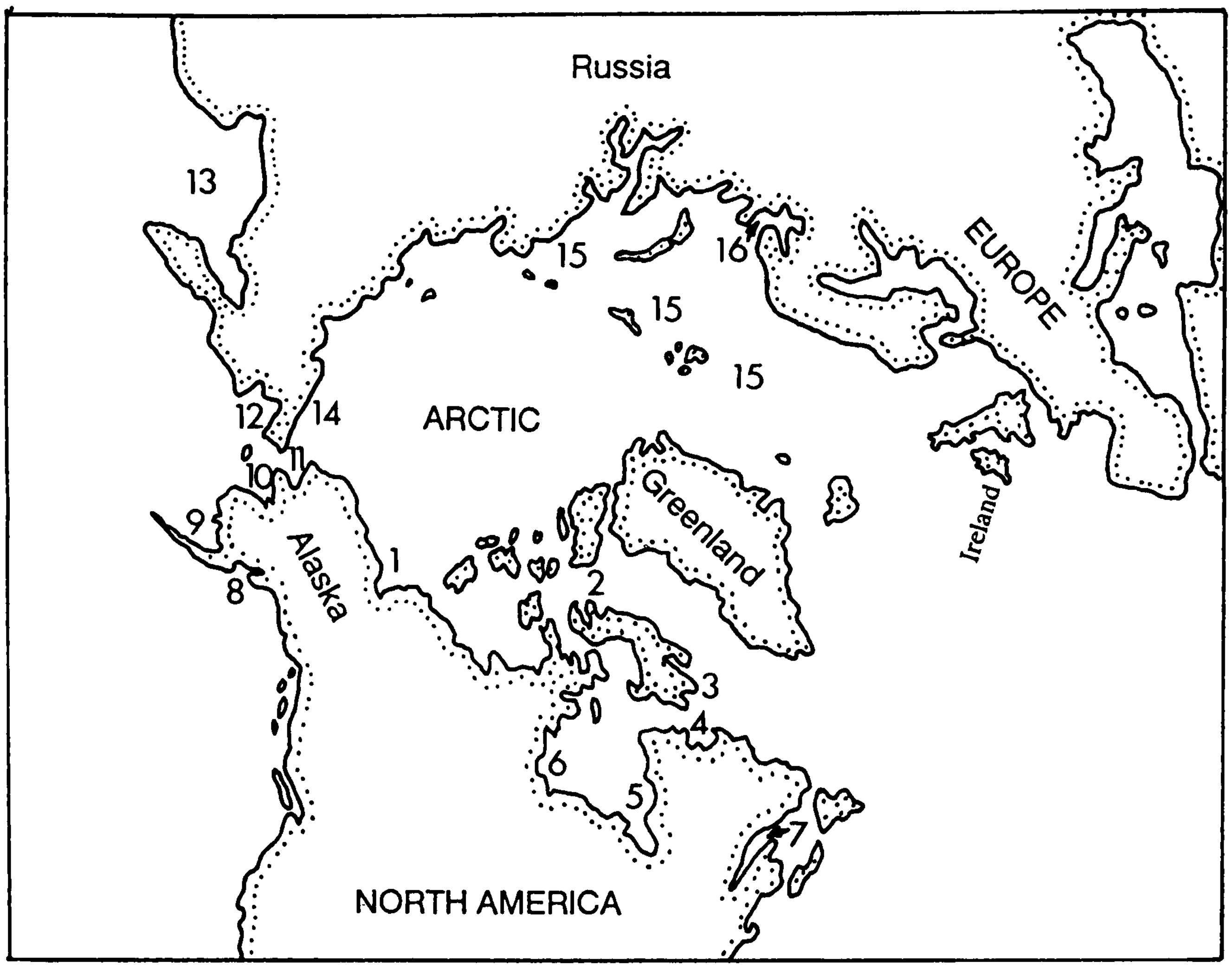

Fig. 1. White whales. Numbers refer to those in Table 9.

For example, 1,274 bottlenose dolphins were taken in drive fisheries in 1990 (SC/43/ProgRep Japan). The impacts of these takes on the populations are unknown.

5.1.2 Direct fisheries for small cetaceans in the Arctic[2]

Two species of small cetacean – the white whale and the narwhal – have distributions centred in the Arctic, and both have been exploited for centuries. In the past, commercial operations took thousands of white whales and hundreds of narwhals in some years. In recent years, most of the hunting for both species has been done by aboriginal peoples for domestic subsistence use and for the sale of muktuk and ivory. This section reviews recent developments in the exploitation of white whales and narwhals throughout their ranges, with emphasis on those areas where an immediate conservation problem is recognised or suspected.

5.1.2.1 *Delphinapterus leucas*

COMMON NAMES

White whale, beluga, belukha (Alaska and USSR), *qilaluaq* or *qaqortoq* (Greenlandic), *qilalugaq* (Inuktitut), *hvidhval* or *hvidfisk* (Denmark), *situaq* (Bering Strait Inupiat), *sisuaq* (Northern Alaskan Inupiat), *cetuaq* (Alaska mainland Yupik).

DISTRIBUTION

The white whale has a circumpolar distribution in the Arctic and subarctic, mainly north of 55°N. The world population is subdivided into at least 16 stocks that are isolated from one another to varying degrees (see Fig. 1 and Table 9). White whales tend to congregate in estuaries in summer, and the resulting aggregations have provided the basis for defining some of the stocks. Most populations are migratory, and their distribution is partly shaped by seasonal changes in ice conditions. Several stocks may mix during winter when they are excluded from the summering areas by ice (IWC, 1980c). For analytical convenience, distribution and other topics are discussed below by country. It is important to bear in mind that some of the stocks occur within the coastal jurisdictions of more than one country.

[2] Initial draft by R.R. Reeves.

Greenland

White whales occur infrequently in East Greenland coastal waters, and those that do occur there are considered wanderers from the Svalbard area (i.e., the Barents Sea) (Dietz *et al.*, 1985).

The white whales off the west coast of Greenland belong to a stock probably shared with Canada. They ranged historically all along the coast to at least as far south as Qaqortoq (Julianehaab, *ca* 61°N), where they were hunted in winter (Winge, 1902; Degerboel and Nielsen, 1930). They now occur as far south as Nuuk (Godthaab, *ca* 64°N) only infrequently but are still abundant in outer Disko Bay and in the open pack ice along the Greenland coast south to approximately Sisimiut (Holsteinsborg, *ca* 67°N) in winter (McLaren and Davis, 1981; 1982). Surveys in 1990 and 1991 confirmed that this is the core area for white whales in winter; most animals were observed within 50km of the coast (M.P. Heide-Jørgensen, pers. comm. to Reeves, 30 April 1991).

Canada

Seven white whale stocks are provisionally recognised in Canada, based on varying degrees of difference in body sizes, catch histories and hiatuses in distribution. These are Beaufort Sea-Mackenzie Delta, High Arctic (Lancaster Sound region), Southeast Baffin (Cumberland Sound, Frobisher Bay and Lake Harbour area in Hudson Strait – see Richard and Orr, 1986), Ungava Bay, East Hudson Bay-James Bay, West-South-North Hudson Bay (=West

Table 9

Status of world white whale stocks (modified from Braham, 1984). Fig. 1 shows the stock areas. Status: (A) large (3000+) and lightly or sustainably exploited; (B) large and exploited at rates that give cause for concern; (C) medium (500-3,000) and lightly or sustainably exploited; (D) medium and exploited at rates that give cause for concern; (E) small (500 or less) and vulnerable to hunting or habitat deterioration.

	Est. abundance		Est. ann. removal rate			
Centre of Summer distribution	Init.[1]	Current	Kill	(% stock size)	Refs	Status
Canada						
1. Beaufort Sea/Mackenzie Delta	--	11,500	232[2]	2.0	1,2	A
2. High Arctic/West Greenland	12,000	6,300-18,600	1,200[3]	6.5-19.0	3,4,5	B
3. SE Baffin	5,000	500	92-119	18-24	6,7	E
4. Ungava Bay	1,000	low	50+	high	8,9	E
5. E Hudson Bay/James Bay	6,600	1,864-3,874	199-203[4]	5.1-10.9	9,10	D
6. W, S and N Hudson Bay	--	25,000[5]	431-9[6]	1.7	11	A
7. St. Lawrence R.	5,000	500	0	0	12,13	E
Alaska (USA)						
8. Cook Inlet	--	300-400	10-15[7]	2.5-5.0	14	E
9. Bristol Bay	--	1,000-1,500	7-9[8]	0.5-1.0	2,15,16	C
10. Norton Sound/Yukon Delta	--	2,000[9]	155-181[8]	?	2,15,16	?
11. E Chukchi Sea	--	2,500-3,000	91-94[8]	3.0-3.8	2,15,16	?
USSR						
12. Anadyr Gulf (Bering Sea)	--	2,000-3,000	low	low	17	C
13. Sea of Okhotsk	--	25,000-30,000	low	low	18	A
14. E Siberian (W Chukchi and E Siberian Seas)	--	2,000-3,000	150[10]	5-7.5	19,20	?
15. W Siberian (Barents, Kara and Laptev Seas)	--	7,000-10,000	?	?	17	?
16. White Sea	--	500-1,000	?	?	17	?

[1]Based on cumulative catches, to be regarded as minimum estimates of pre-exploitation population size.
[2]Assumes an average catch of 123 per year in Mackenzie Delta, 1985-89, corrected on the basis of 1 killed and lost for 4 landed (ref. 21), giving an estimated total kill (ETK) of 151. Assumes an average catch of 43 (40-46) in Alaskan waters, 1987-90 (Table 4), corrected on the same basis as in Ref. 2:table 5, giving an ETK of 81.
[3]Assumes an average catch of 813 per year in West Greenland (Table 2, 1975-85); corrected on the basis of a 25% loss rate (1 killed and lost for 3 landed) (ref. 5), giving an ETK of 1084. Assumes an average catch of 87 per year in Canada, 1974-87 (Table 3); corrected on the basis of a 25% loss rate, giving an ETK of 116.
[4]Assumes that 40% of the catch in Hudson Strait and 100% of the catch on the east side of Hudson Bay is from this stock (Table 3). A loss rate of 30% of the total kill is applied arbitrarily.
[5]Combines estimates for west, south and north Hudson Bay (ref. 11).
[6]Assumes that 60% of the catch in Hudson Strait and 100% of the catch in western and northern Hudson Bay is from this stock (Table 3; and see text). A loss rate of 30% of the total kill is applied arbitrarily.
[7]Based on total kill estimate of 10 (ref. 14) and secured catch estimate 10-12 (ref. 15).
[8]Catches from Table 4, corrected for hunting loss by ETL:ETK ratio of Ref. 2:Table 5. Norton Sound loss rate may have declined in recent years with the use of aeroplanes to locate animals that sink during the hunt (ref. 21).
[9]Considered to include Kuskokwim Delta. Population estimate is not based on survey data; a single sighting of more than 2000 white whales was made near the mouth of the Yukon River in 1956 (ref. 21)
[10]Based on a guesstimate for the total annual kill at or near Sireniki in the mid-1980s (ref. 20).

References: 1. Davis and Evans (1982), 2. Lowry *et al.* (1989), 3. Reeves and Mitchell (1987c), 4. Smith *et al.* (1985), 5. Heide-Jørgensen (1990), 6. Mitchell and Reeves (1981), 7. Richard (1991), 8. Reeves and Mitchell (1987b) and Anonymous (1987), 9. Smith and Hammill (1986), 10. Reeves and Mitchell (1987a), 11. Richard *et al.* (1990), 12. Reeves and Mitchell (1984), 13. Sergeant and Hoek (1988), 14. Hazard (1988), 15. K.J. Frost (*in litt.* to Reeves, 1 April 1991), 16. Frost and Lowry (1990), 17. Yablokov (1979), 18. Ivashin (1990), 19. Ivashin (1988), 20. Burns and Seaman (1985), 21. K.J. Frost (*in litt.* to Reeves, 1 May 1991).

Hudson Bay in previous IWC reports) and St. Lawrence River. There is considerable uncertainty about the relations among the groups of whales in Hudson Bay and adjacent waters (Richard *et al.*, 1990). The delineation of stocks based on body size differences (Sergeant and Brodie, 1969) has been found by Doidge (1990) to be less useful for some stocks than was thought previously. However, white whales in Hudson Bay are consistently smaller than those in other areas studied. Preliminary attempts to use mitochondrial DNA markers to distinguish white whale stocks suggested that white whales in eastern Hudson Bay are distinct from those in the Mackenzie Delta, western Hudson Bay, Cumberland Sound and Jones Sound (Helbig *et al.*, 1989). The Beaufort Sea-Mackenzie Delta stock is shared with Alaska (USA) and possibly the USSR; the High Arctic stock probably with Greenland.

The winter and spring distribution of the Hudson Bay, Ungava Bay and SE Baffin populations is centred in Hudson Strait, the Labrador Sea and Davis Strait (Boles, 1980; Finley *et al.*, 1982; Richard and Orr, 1986), although some white whales overwinter in Hudson and James bays (Reeves and Mitchell, 1989a). Whales from several stocks may have a common wintering area. Those that summer in the Canadian High Arctic and off northwest Greenland probably winter primarily along the east side of Baffin Bay and Davis Strait in open water or unconsolidated pack ice. Some winter in the Baffin Bay North Water (Vibe, 1950; Freeman, 1968; Finley and Renaud, 1980).

Alaska (USA)

Four provisional management stocks are recognised in Alaskan waters, in addition to the Beaufort Sea-Mackenzie Delta stock shared with Canada. These are the Cook Inlet, Bristol Bay, Norton Sound-Yukon Delta and eastern Chukchi Sea stocks (Hazard, 1988; Lowry *et al.*, 1989). All the populations except the one in Cook Inlet are believed to winter mainly in the Bering Sea. The evidence for stock differences is mainly the discontinuity of summer distributions (Lowry *et al.*, 1989; Frost and Lowry, 1990). Burns and Seaman (1985) have argued that all the 'stocks' that winter in the Bering Sea comprise a single genetic population, although no direct genetic evidence is available to evaluate this argument.

USSR

White whales are widely distributed along the Soviet Arctic coast, and they have been exploited intensively in many areas (Ivashin and Mineev, 1981; Ognetov and Potelov, 1984). The estuaries of all the major rivers along the coast of Siberia are said to be visited by white whales in summer. Yablokov (1979) proposed eight stocks in Soviet waters, as follows: White Sea (2), West Siberian (Barents-Kara-Laptev seas) (2, possibly 3), East Siberian (Chukchi-East Siberian seas), Anadyr Bay (Bering Sea) and Sea of Okhotsk (2). Berzin *et al.* (1986) showed major concentrations in three areas of the Okhotsk Sea: Sakhalin-Amur, Shantar and the northern bays (Gizhiginskaya and Penzhinskaya). Five stocks are provisionally listed in Table 9, pending a more detailed justification for subdividing them.

The East Siberian and Anadyr Bay stocks probably winter mainly in the Bering Sea, where they could mix with whales belonging to the Alaskan stocks (Burns, 1984; Burns and Seaman, 1985; Hazard, 1988). Some white whales overwinter in offshore areas of the Barents, Chukchi and probably Kara seas (Belikov *et al.*, 1990).

PROBLEMS AND CATCH STATISTICS

Greenland

Preliminary summaries of white whale catch statistics for Greenland have been published by Kapel (1977; also see Kapel *in* Reeves and Mitchell, 1987b). Reported secured catches for 1975–87 are summarised in Table 10. These are consistent with the estimate of recent annual catches of 500–1,000 by Heide-Jørgensen (1990). The completeness and reliability of the Greenland catch statistics has declined in recent years as fewer hunters have participated in the reporting scheme (E.W. Born, *in litt.* to Reeves, 3 October 1985; Heide-Jørgensen,MP, 1990). The reporting system is no longer functioning reliably. High catches have been made in some years at *savssats* (ice entrapments) in Disko Bay (e.g. about 500 in February 1990 – M.P. Heide-Jørgensen, pers. comm. to Reeves, 30 April 1991). Most of the Greenlandic catch of white whales (except for *savssats*) is made in the drive fishery in Upernavik district (Heide-Jørgensen, 1990).

The demand for white whale muktuk and meat in Greenland is strong and likely to grow along with the human population. Although much of it is consumed in the villages after being shared according to local customs, some is also sold for resale in urban centres (Dahl, 1989). There are no catch limits. Local regulations and customary rules govern some aspects of the hunting (Dahl, 1990; Qujaakitsoq, 1990), but these may not be adequate in the light of changing hunt technology and consumption patterns (Dahl, 1990; Heide-Jørgensen, 1990).

Canada

White whales are protected from commercial hunting under the Beluga Protection Regulations (Fisheries Act) introduced initially in 1949 and amended many times since (Reeves and Mitchell, 1989b; Department of Fisheries and Oceans, 1990a). The St. Lawrence stock was given full protection from exploitation in 1979 and a quota of 40 whales per year (secured catch; no allowance for hunting loss) was set for Pangnirtung in Cumberland Sound in 1980. The reported catch since 1980 at Pangnirtung has exceeded the quota in some years (Richard and Orr, 1986; Cosens *et al.*, 1990). White whale products cannot be exported from the Northwest Territories (NWT) but are traded or sold within the NWT. Some is shipped to urban centres where it is sold (Reeves, unpubl. data).

Prior to 1975, there was no monitoring or reporting of catches in northern Quebec (primarily East Hudson Bay – James Bay, West-North and South Hudson Bay and Ungava Bay stocks in Tables 9 and 11). Estimates of secured catches in 13 northern Quebec communities were derived from 'harvester recall' surveys and a self-monitoring programme begun in 1975 (Boulva, 1981; Usher and Wenzel, 1987). The introduction of regular reporting from northern Quebec in the mid-1970s may give the impression of a dramatic increase in the total Canadian white whale catch, but there is no reason to believe that

Table 10

Reported white whale catches in Greenland, 1975-87, from IWC Denmark progress reports. For previous years, see Kapel (1977). Note that figures listed for 1983-85 are estimates which include an allowance for unreported catches (but not for hunting loss). The figures for 1986 and 1987 are incomplete and preliminary.

	Year												
Area[1]	75	76	77	78	79	80	81	82	83	84	85	86	87
West Greenland													
N Greenland	-	50/yr[2]	-	20	25	30	76	127	53	21	190	?	?
NW Greenland	169	89	289	148	272	291	438	346	252	348	194	244	563
CWe Greenland	105	154	108	231	195	210	198	200	100	158	50	?	?
CWw Greenland	163	799	271	221	184	202	142	113	94	194	127	114	29
SW+S Greenland	167	120	122	99	65	156	163	108	102	42	50	2	14
Total	654	1212	840	719	741	889	1017	894	601	763	611	378	606
East Greenland													
Ammassalik	2	1	1	0	0	0	0	5	0	0	0	15	76
Scoresbysund	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	2	1	1	0	0	0	0	5	0	0	0	15	76

[1]For communities assigned to each area, see Kapel (1977). [2]Annual estimate - Kapel (1983).

Note: The relatively large catches assigned to Ammassalik in 1986-87 are in error. (M.P. Heide-Jørgensen, pers. comm. to Reeves, 30 April 1991). West Greenland catches for 1988-90, as estimated by the Greenland Fisheries Research Institute, are: West Greenland - 275 in 1988, 457 in 1989 and 1,000 in 1990.

catches in northern Quebec were much different immediately before 1973–74 than since then.

A confounding aspect of the catch statistics for settlements along the coasts of northern Hudson Bay and Hudson Strait is that more than one management stock uses these areas (Finley *et al.*, 1982; Anonymous, 1987a; Richard *et al.*, 1990). Attempts to prorate catches and assign them to the different stocks are made difficult by the lack of an easily applied genetic, morphometric, behavioural or other marker.

Statistics on catches of white whales in Canada before 1972 are imprecise and incomplete. In 1972 the federal Department of Fisheries and Oceans assumed responsibility for compiling information on white whale catches (Kemper, 1980; Usher and Wenzel, 1987). Before then, the compilation of such data was idiosyncratic or unreliable. The pre-1972 data (e.g. as reported in *International Whaling Statistics* – see Reeves and Mitchell, 1987b; Strong, 1989) should be discounted or interpreted cautiously, particularly in evaluating year-to-year variability or trends through time. Although a more systematic effort has been made since 1972 to document the white whale harvest (Table 11; Strong, 1989), the problem of incomplete reporting of landed catches remains in some areas (Usher and Wenzel, 1987).

Before Canada's withdrawal from the IWC, catches of white whales and other whales were reported and published annually in the Canadian progress reports. Although a progress report has continued to be compiled and submitted annually to the IWC (Department of Fisheries and Oceans, 1990b) the most recent published report was in 1984 (Goodman, 1984). Catches are included in the Tables of reported catches worldwide published each year as part of the report of the sub-committee on small cetaceans (e.g. IWC, 1989).

Alaska (USA)

The quality and regularity of Alaskan catch statistics have improved over the past 15 years (see Seaman and Burns, 1981; Feldman, 1986; Hazard, 1988; Lowry *et al.*, 1989). K.J. Frost (*in litt.* to Reeves, 1 April 1991) reports good cooperation with hunters in obtaining accurate catch statistics for recent years (Table 12). Because of the improved reporting, comparisons of catch levels through time should be made with caution.

USSR

Catch figures provided by the USSR are difficult to interpret because little information is available concerning the hunting methods, effort, product utilisation etc. The official catch totals (e.g., Ivashin and Mineev, 1981; IWC progress reports e.g. Ivashin, 1986) presumably reflect mostly or entirely commercial catches. The totals given by Ivashin and Mineev (1981) are separated into a vessel catch in the western areas and a shore-based catch in all areas. Catches by aborigines and others for subsistence, if they occur (cf. Ivashin and Shevlyagin, 1987), may be under-reported or unreported. Burns and Seaman (1985) referred to a report received in 1985 that 25–30 white whales were taken annually at Sireniki, on the southeast coast of Chukotka. The same source confirmed that although white whales are occasionally hunted at other localities in the Bering and Chukchi seas, the average number taken is very low. The opportunistic hunt at a *savssat* in the Bering Strait region in winter 1984–85 resulted in a catch of 506 whales and an estimated 500 more dead due to 'hunger, lack of air and injuries' (Ivashin and Shevlyagin, 1987). After reviewing available information, Burns and Seaman (1985) concluded that the Soviet harvest in the Bering and Chukchi seas was on the order of 60 white whales per year in the mid-1980s. They considered it likely that 60% of the whales killed were lost (see below), indicating a total kill of about 150 per year.

Berzin (1981) implied that commercial hunting for white whales ended in the Soviet Bering and Okhotsk seas in 1963. However, the table of catches published by Ivashin and Mineev (1981) shows no catch for the Bering Sea from 1960 to 1972, then a total catch of 160 between 1973 and 1980. For the Okhotsk Sea, it shows no catch from 1960 to 1963, then a total catch of 293 between 1964 and 1969 and no catch from 1970 to 1980. Commercial catching apparently continued in the White and Kara seas through the mid 1980s (Table 13). Yablokov's (1979) summary of annual catches in Soviet waters, apparently referring to the

Table 11

Reported catches of white whales in Canada, 1974-87. See note for communities included within each statistical area.

	Year													
Area	74	75	76	77	78	79	80	81	82	83	84	85	86	87
W Arctic[1] (Beaufort Sea/ Mackenzie Delta)	128	154	154	148	129	144	85	155	126	86	142	129	157	144
E High Arctic[1]	144	60	58	61	48	86	16	158	101	106	123	121	75	58
SE Baffin[1]	200	80	171	204	93	107	74	105	66	44	51	72	65	110
Hudson Strait[2]	277	327-429	229	314	158	153	195	158	216	228	170	142	74	
Ungava[2]	92	130-163	184	194	37-38	78	60	79	58	43-45	29	32	42-44	
E Hudson Bay[2]	119	126-139	143	181	118-124	211	220	61	73	69	97	62	32-33	
W+N Hudson Bay[1]	164	94	152	191	112	105	137	211	158	196	324	263	238	238

Note: W Arctic - Aklavik, Inuvik, Tuktoyaktuk, Paulatuk, Holman; E High Arctic - Clyde River, Coppermine, Pond Inlet, Arctic Bay, Grise Fiord, Resolute, Creswell Bay, Spence Bay, Hall Beach, Igloolik, Pelly Bay; SE Baffin - Pangnirtung, Iqaluit, Lake Harbour, Broughton Island; Hudson Strait - Cape Dorset, Ivujivik, Salluit, Kangiqsujuaq, Quaqtaq; Ungava - Kangirsuk, Aupaluk, Tasiujaq, Kuujjuaq, Kangirsualujjuaq, Killiniq; E Hudson Bay - Sanikiluaq, Kuujjuarapik, Umiujaq, Inukjuak, Povungnituk, Akulivik; W and N Hudson Bay - Churchill, Eskimo Point, Whale Cove, Rankin Inlet, Chesterfield Inlet, Repulse Bay, Coral Harbour.

[1]Strong (1989), [2]Reeves and Mitchell (1989b)

1970s, indicated: 100–300 along Kanin Peninsula in trap nets; 10–15 in Onega Bay and other parts of the White and Barents seas by rifle; 200–400 in trap and gillnets and 20–50 by rifle in the Kara and Barents Seas (Yenisey and Pyasina bays); 100 or less in the Laptev, East Siberian and Chukchi seas by rifle; 20–50 in the Bering Sea by rifle; and 100 or less in the Sea of Okhotsk in seines. The total annual catch in all areas of the USSR, according to Yablokov (1979), was 550–1,015.

Table 12

Recent landed catches of white whales in Alaska (AIBWC via K.J. Frost, in litt. to Reeves, 1 April 1991). For data from earlier years, see Seaman and Burns (1981) and Lowry *et al.* (1989). Frost (in litt. to Reeves, 1 April 1991) considers the data for 1987-90 the most complete ever available for Alaska.

Year	Beaufort[1]	E Chukchi	Norton Sd/ Yukon Del.	Kusko-kwim Del.[2]	Bristol Bay	Cook Inlet
1987	31-52	78	60-68	3-5	6	8-10
1988	67	69	200-223	13-20	5-10	12-13
1989	26-30	48-53	141-169	12	6	11-13
1990	34-35	99	85-101	0	4	10-12
4/yr ave.:	40-46	74-75	122-140	7-9	5-7	10-12

[1]Taken from the same stock as those reported for Canadian Western Arctic (Table 11).
[2]Could belong to either Norton Sound/Yukon Delta or Bristol Bay stock.

Table 13

Reported white whale catches in the USSR, 1960-88, from Ivashin and Mineev (1981) and IWC USSR progress reports. WBK - White, Barents and Kara Seas (vessel fishery); Yen - Yenisey Gulf (Kara Sea); White - White Sea; Bar - Barents Sea; Ch - Chukchi Sea; Bering - Bering Sea; Okhotsk - Okhotsk Sea; B + K - Barents and Kara Seas; Kara - Kara Sea.

	Area								
Year	WBK	Yen	White	Ch	Bering	Okhotsk	Bar	B+K	Totals
1960	2,382	324	840						3,546
1961	1,732	319	18						2,069
1962	1,143	314	21						1,478
1963	1,030	254	223						1,507
1964	2,322	253	662			94			3,331
1965	1,510	929	297			6			2,742
1966	905	35	609			35			1,584
1967		608	166						774
1968		56	30			101			187
1969		43	167			57			267
1970		67	850						917
1971		53	458						511
1972		36	518						554
1973		42	155	4	15		197		413
1974		24	146	2	17		9		198
1975		74	91						165
1976		170	302		21		38		531
1977	457	64	215		29				765
1978		19			32				51
1979		74	179		26				279
1980	60	81	75		20				236
1981									-
1982			139		53		13	73 *	278
1983			24		12		2	183 *	221
1984					33		1	300 *	334
1985			110		506	29		74 **	719
1986			172		3		3		178
1987			27		3		4		34
1988			3		5				8
	11,541	3,839	6,497	6	775	322	267	640	23,877

* Barents + Kara; ** Kara only.

According to Ivashin and Mineev (1981), the commercial exploitation of white whales is regulated by catch limits, although for unstated reasons the quotas have almost always been higher than the actual catches.

Hunting loss in all areas

Estimated loss rates for white whale hunting in Greenland ranged from 14 – 19% in West Greenland south of Thule and were less than 10% for the Thule district (IWC, 1980c:appendix 4). Set nets used in Upernavik for catching white whales (Kapel, 1985) presumably cause few losses. Communal hunts using boats to drive whales or trap them in shallow water before killing them with rifles (as described by Oldendow [1935] and Dahl [1990] for the Disko Bay area and by Heide-Jørgensen [1990] for Upernavik district) also may result in relatively small losses. On the other hand, the winter and spring hunting over deep water (at *savssats* or along an ice edge) results in substantial hunting loss (Kapel, 1977). 'As a preliminary figure an overall loss rate of 25% seems reasonable for white whales' (Heide-Jørgensen, 1990).

Seaman and Burns (1981; also see IWC, 1980c, Appendix 5) reported much higher losses for white whales killed in deep water, such as when they are hunted by seal or bowhead hunters during spring, than for those killed in shallow coastal water during open-water hunts. They estimated loss rates of 60% for deep-water hunting and 20% for shallow water hunting. Their estimated total kills were based on the assumption that for all parts of Alaska, one-fourth to one-third of the white whales are taken in deep water and two-thirds to three-fourths in shallow water. Lowry *et al.* (1989) provided estimates of loss rates on a finer scale than that of Seaman and Burns (1981). They considered losses in nets (some set deliberately to catch white whales, others intended mainly to catch fish, with white whales being caught incidentally) to be negligible. Also, they estimated the loss rate for open-water hunting from boats in areas with deep, muddy water (e.g., the Yukon-Kuskokwim Delta and Bristol Bay) to be 40%. In estimating catches throughout Alaska, Lowry *et al.* (1989) applied appropriate loss rates to each harvesting situation. However, it should be noted that the loss rates applied by Burns and Seaman (1981) and Lowry *et al.* (1989) were somewhat subjective.

According to K.J. Frost (*in litt.* to Reeves, 1 May 1991) the loss rate of 20% for shallow-water hunting in parts of the eastern Chukchi Sea and Northern Sound is probably too high, particularly since small aeroplanes have been used in recent years to search these areas after the hunt to find any animals that were killed but not secured. She suggests 10% as a more appropriate estimate.

For the Mackenzie Delta, Fraker (1980) reported estimates by hunters of loss rates (percentage of killed whales that were not secured) of 32% (1973) and 27% (1977). Fraker suggested that Hunt's (1979) estimate of a 40% loss rate in the Mackenzie Delta hunt included an allowance for injured animals that escaped but eventually died from their wounds (c.f. Brodie, 1981). Fraker considered a loss rate of 33% appropriate for correcting catch statistics for this area. More recent monitoring of the Mackenzie Delta hunt has resulted in loss rate estimates of 20 to 38% of the landed catch (Strong, 1990; Weaver, 1991). Weaver (1991) attempted to account for orphaned calves by noting the number of lactating females taken, then counting their calves part of hunting mortality. The

Fisheries Joint Management Committee has funded systematic collection of data on harvest and loss in recent years. For 1985–89 the average catch was 123 (116–133) and the average number struck and lost was 28 (17–38); this would suggest 1 whale lost for every 4 landed (Alaska and Inuvialuit Beluga Whale Committee, via K.J. Frost, *in litt.* to Reeves, 1 May 1991).

For the SE Baffin region, during hunts monitored both in and outside Clearwater Fiord, the main hunting area, in 1982–84, only one instance was reported of a white whale being killed but lost (by sinking) (Orr and Richard, 1985). Most killed whales floated and thus were relatively easy to secure (c.f. Brodie, 1981). Burns and Seaman (1985) queried Orr and Richard's conclusion, noting

'In our experience, whales that sink before being harpooned or speared, would not be seen unless they were subsequently grappled, or floated to the surface, usually a day or more after death.'

Richard and Orr (1986) noted that losses were higher in hunts conducted in and near Cumberland Sound outside Clearwater Fiord. The overall loss rate for this stock may be in the order of 10–30% of the total kill (Richard, 1991a).

No data are available for the USSR. In areas where trap and gillnets have been used to capture white whales (e.g., White, Barents, and Kara seas – Yablokov, 1974; 1979; Mitchell, 1975a), the loss rate presumably has been low. However, in those areas where the whales are hunted with rifles, hunting loss must be significant (cf. Burns and Seaman, 1985; see above).

POPULATION ESTIMATES

Greenland

No independent estimate of population size for white whales in Greenlandic waters is available. Heide-Jørgensen (1990) considered the estimate by Smith *et al.* (1985) for the Canadian High Arctic stock as applicable to West and North Greenland, on the still unproven assumption that the whales found as far west as Peel Sound and Barrow Strait in summer migrate east and south in the fall to winter off West Greenland. McLaren and Davis (1981; 1982) surveyed a large area of northern Davis Strait and southern Baffin Bay in March 1981. They estimated that about 2,400 white whales were present in waters south of 70°N, north of 66°N and east of 55°30′W; their estimate made no allowance for animals that were submerged or under the ice. Surveys in 1990 and 1991 of the same area using similar methods revealed an approximately 40% decline in the number of white whales present (M.P. Heide-Jørgensen, pers. comm. to Reeves, 30 April 1991).

Canada

The stock summering in the Mackenzie Delta and eastern Beaufort Sea has been estimated recently at 11,500 (Davis and Evans, 1982).

A detailed reconstruction of the catch history in western Hudson Bay and Foxe Basin revealed no pattern of intensive exploitation and depletion that could be used for a cumulative catch estimate (Reeves and Mitchell, 1989a). The highest documented kill for any decade before 1949, when the commercial white whale processing plant at Churchill began operations, was somewhat less than 1,600 whales taken at York and Churchill, combined, in the 1880s. Richard *et al.* (1990) estimated the white whale population in western Hudson Bay as more than 23,000 in 1987. They also estimated summering populations in northern Hudson Bay of more than 700 and southern Hudson Bay of more than 1,300. These three areas have been treated as a single stock area in Table 9.

Cumulative catches indicate a minimum population in southeastern Hudson Bay (mainly summering in the Great Whale and Little Whale river estuaries) of 6,600 in the 1850s (Reeves and Mitchell, 1987c). Aerial surveys in summer 1985 produced current estimates of 1,123 (95% confidence limits 740–1,970) in James Bay and 1,124–1,904 (offshore estimate plus estuarine count) in eastern Hudson Bay south of 59°N (Smith and Hammill, 1986). The totals for southeastern Hudson Bay and James Bay are combined for an estimate of the East Hudson Bay – James Bay stock (Table 9).

At least 800–1,000 white whales summered in southern Ungava Bay during the 1870s (Reeves and Mitchell, 1987a). Systematic and coastal reconnaissance aerial surveys of Ungava Bay in the late 1970s and early 1980s suggested a remnant population of less than 50 (Finley *et al.*, 1982; Smith and Hammill, 1986).

At least 5,000 white whales summered in Cumberland Sound (SE Baffin stock) in the early 20th century, judging by the catches made in this area (Reeves and Mitchell, 1981). The most recent estimate of population size, based on aerial photographic surveys in 1985–86, is less than 500 (Richard *et al.*, 1990).

Alaska (USA)

Population estimates for all Alaskan coastal stocks were provided by Hazard (1988) and Lowry *et al.* (1989) (see Table 9). Additional surveys summarised by Frost and Lowry (1990) and Frost *et al.* (1991) gave no reason to change the earlier estimates. Surveys planned for 1991 should provide additional data for Cook Inlet and the eastern Chukchi Sea. It should be noted that there is no recent basis for the Norton Sound/Yukon Delta stock estimate; this area has never been properly surveyed for white whales (K.J. Frost, *in litt.* to Reeves, 1 May 1991).

USSR

Yablokov (1979) stated that there were no good census data from Soviet Arctic waters. He guessed that some 1,000–2,000 white whales summered in the East Siberian and western Chukchi Seas and some 2,000–3,000 in the Soviet Bering Sea. Burns (1984) assumed that at least 3,000–4,000 white whales were present in summer in offshore waters of the western Beaufort, northern Chukchi and East Siberian seas and that another 6,000-8,000 were present in coastal waters along the Asian sides of the Chukchi Sea, Bering Strait and Bering Sea, including Wrangel Island (Burns and Seaman, 1985). Gaev *et al.* (1987), as summarised by Ivashin (1990) claimed that white whales were rare in coastal waters around Wrangel Island, although Berzin (1981) cited reports of migrating herds of up to 500 white whales seen southeast of Wrangel Island in October 1960. An estimated 2,500–3,000 white whales became trapped in ice in Senjavin Strait along the eastern coast of Chukotka in December 1984 (Ivashin and Shevlyagin, 1987)

Results of aerial surveys in 1987 suggested a Sakhalin-Amur population of not more than 7,000–10,000 white whales (Popov, 1990). In addition, it was estimated that there were 3,000–5,000 white whales in the Shantar Islands area in 1987 and roughly 15,000 in the northern Sea of Okhotsk. Thus, the total estimated current population in the Okhotsk Sea is 25,000–30,000. However, the reliability of this estimate is uncertain.

Ognetov and Potelov (1984) referred to observations of a few hundred to several thousand white whales in different areas of the Kara Sea at different times, but they gave no recent population estimate for the Kara Sea stock. Judging by the large commercial catches summarised by Kleinenberg *et al.* (1968) for the Kara Sea in the 1930s (1,922 in Yenisei and Pyasina bays from 1930 to 1936; 2,092 in the Gulf of Ob from 1931 to 1935) and 1950s (743 near Dickson Island from 1953 to 1958), the Kara and Barents seas combined in the 1950s (3,664 from 1953 to 1959 by vessels of the Arkhangel'sk and Tyumen Sovnarkhozes) and near Svalbard by Norwegian vessels after World War II (3,407 from 1945 to 1960 [Lønø and Øynes, 1961]), the West Siberian stock must have been very large historically. Yablokov (1979) estimated current stock sizes of 500–1,000 for the White Sea and 7,000–10,000 for the Barents-Kara-Laptev Seas.

ASSESSMENT AND STATUS

In general, white whale stocks can be assigned to five categories: (A) large (3,000+) and lightly or sustainably exploited; (B) large and exploited at rates that give cause for concern; (C) medium (500–3,000) and lightly or sustainably exploited; (D) medium and exploited at rates that give cause for concern; (E) small (500 or less) and vulnerable to hunting or habitat deterioration. Of the 16 stocks tentatively identified (Table 9), at least 3 are in category A, 1 in B, 2 in C, 2 in D and 4 in E.

Greenland

Using annual estimates of 875–1,500 whales killed from a population of 6,300–18,600 whales (Smith *et al.*, 1985), and citing estimates of permissible exploitation rates of 2% for white whales (IWC, 1984b) and 3–4% for narwhals (Kingsley, 1989), Heide-Jørgensen (1990) concluded that the Canadian High Arctic-West Greenland white whale population is being exploited at a level above sustainable yield. White whales have virtually disappeared from the southern districts of West Greenland where large catches were made in the 19th and early 20th centuries (Kapel *in* Reeves and Mitchell, 1987b). Catches listed for South and Southwest Greenland in recent years (Table 10) indicate mainly catches made by hunters who travelled to the more northern districts for hunting (M.P. Heide-Jørgensen, pers. comm. to Reeves, 30 April 1991).

Three factors that may cause white whale catches in Greenland to increase are: the high and increasing price of muktuk, the improved technology for hunting white whales and transporting muktuk, and the expansion of freezer facilities allowing preservation of muktuk in most settlements (M.P. Heide-Jørgensen, pers. comm. to Reeves, 30 April 1991).

Alaska

Major reviews of the status of white whales in Alaskan waters have been published recently (Seaman and Burns, 1981; Hazard, 1988; Lowry *et al.*, 1989; Frost and Lowry, 1990). The Beaufort Sea/Mackenzie Delta stock shared with Canada is not considered to be in jeopardy at present (see below). Of the other four provisional stocks in Alaska, the Norton Sound-Yukon Delta stock is of greatest concern because there is no reliable stock estimate and there are substantial removals. For the other three, the stock estimates are far more current and reliable and harvest levels have been relatively stable in recent years (Lowry *et al.*, 1989; Frost and Lowry, 1990)

Aerial survey results, hunter information and reduced catch levels have been interpreted to indicate a decline in the use of southeastern Kotzebue Sound by white whales (eastern Chukchi Sea stock) (Lowry *et al.*, 1989; Frost and Lowry, 1990). Local informants have suggested that boat traffic, noise and other disturbances (Burns and Seaman, 1985; Frost and Lowry, 1990) have contributed to this decline in local availability of white whales. When this migratory stock has been surveyed farther north off Point Lay, there has been no indication of a substantial change in numbers between 1979 and 1990 (Frost and Lowry, 1990; Frost *et al.*, 1991).

Frost and Lowry (1990) concluded that the Bristol Bay stock is stable at or near its historical size. The Cook Inlet stock has been small (a few hundred) for a considerable time (at least 25 years) (Hazard, 1988).

The Alaska and Inuvialuit Beluga Whale Committee (AIBWC) was established in 1988 with the objectives of conserving white whales and their habitat and preserving traditional white whale hunting in Alaska and the western Canadian Arctic. A draft management plan has been published (Anonymous, 1990b). This plan includes provisions for ensuring full reporting of catches (including struck but lost whales), reduction of hunting loss and monitoring of populations. Harvest levels are to be based on 'the number of animals in the populations and cultural and nutritional needs.'

Canada

Exploitation of the Beaufort Sea stock within Canadian waters is managed under the Inuvialuit Final Agreement of 1984, which entrenches the preferential rights of the Inuvialuit to harvest white whales and to sell or barter the products of the harvest to other beneficiaries of the claim, and commits the Canadian federal government to a process of joint management with the Inuvialuit (Anonymous, 1984). The Inuvialuit are also represented in the AIBWC (see above). Recent reviews have concluded that this stock is large and healthy and that its rate of exploitation is within sustainable limits (Fraker, 1980; Finley *et al.*, 1987; Lowry *et al.*, 1989).

The relatively large Canadian High Arctic population is thought to be shared with Greenland (see Greenland section above). It is expected that problems associated with the management of this stock's exploitation will be a principal concern of the Greenland-Canada Joint Commission on Conservation and Management of Narwhal and Beluga (Lemche, 1991).

A scientific advisory committee within the Canadian Department of Fisheries and Oceans (DFO) stated in its prognosis for the SE Baffin stock:

> 'Pre-exploited' stock size is irrelevant to the current management decisions because unknown ecosystem changes may have altered carrying capacity, and 'historical' levels may no longer be attainable (Cosens *et al.*, 1990).

Rather than using a target level related explicitly to the minimum estimated pre-exploitation population size of 5,000, the committee recommended a target level of 'a few thousand (e.g. 3,000), to provide an adequate buffer from ... natural hazards.' To achieve the objective of allowing this limited recovery, the committee recommended complete closure of the white whale hunt in Pangnirtung and Iqaluit and a closed season from June to October in Lake Harbour. In addition, it recommended that the stock not be allowed to fall below its current level of 400–500 in the late 1980s. Richard (1991a) has predicted that continued hunting could extirpate the stock in less than a decade. However, the expected decline in the population due to hunting removals of around 100 per year during the 1980s apparently did not occur. Results of aerial photographic surveys in August 1990 were similar to those of surveys conducted in 1979–82 (Richard and Orr, 1986; P. Richard, pers. comm., 22 April 1991). In 1990, following a decision of the Nunavut Wildlife Management Board, DFO introduced annual quotas of 5 white whales each for Iqaluit and Lake Harbour and reduced the quota for Pangnirtung from 40 to 5 whales (Department of Fisheries and Oceans, 1990a; Richard, 1991a). This change provoked much controversy (e.g., Amagoalik, 1990; Anonymous, 1990b; Tinling, 1990), and the hunters in Iqaluit claimed to have taken about 60 and those in Pangnirtung more than 40 white whales in the 1990 season (Smellie, 1990a; b). The matter of SE Baffin white whale stock assessment has been referred within Canada to an independent committee for re-evaluation.

The Ungava Bay stock is severely depleted, and its conservation and recovery are a high priority (Anonymous, 1987a; Reeves and Mitchell, 1989b). Exploitation has continued in recent years (Table 11; Department of Fisheries and Oceans, 1990b), regulated at least to some degree by an informal cooperative agreement between the responsible federal agency and local or regional Inuit groups (Osherenko, 1988). It is unclear whether the community quotas and hunting ban for the Mucalic River (S. Ungava Bay) agreed in 1987 have been effective in reducing the hunting pressure on this stock.

The Eastern Hudson Bay stock is listed as 'threatened' by the Committee on the Status of Endangered Wildlife in Canada (Campbell, 1989; Reeves and Mitchell, 1989b). It continues to be hunted at levels that may exceed replacement yield (Anonymous, 1987a). An important further concern is that major hydroelectric damming and diversion projects are planned for several of the rivers used by white whales in summer (e.g. Great Whale and Nastapoka), and other large-scale industrial developments, including the impoundment of James Bay to supply fresh water to southern states and provinces, is being considered.

With respect to the Western, Northern and Southern Hudson Bay 'stocks'; the question of whether more than one stock should be recognised for the western half of Hudson Bay remains open (Richard *et al.*, 1990). If the whales summering from the Southampton Island area in the north to James Bay in the south are treated as a single population, they comprise a stock of more than 25,000. Approximately 185 white whales were taken per year by hunters in western and northern Hudson Bay (average for 1974–87 - Table 3). Whales from these areas are also hunted in Hudson Strait during autumn, winter and spring (possibly also in Foxe Basin). Arbitrarily attributing 60% of the reported or estimated catch in Hudson Strait to this stock increases the yearly average (1974–86 - Table 11) to 302–07. Applying a loss rate of 30% of the total kill, annual hunting removals in the order of 431 from this 'stock' are suggested. These calculations are necessarily very crude, but it seems safe to conclude that this stock (or these stocks) are in relatively good shape.

USSR

Without better information on population sizes and recent removals, it is impossible to make useful assessments of stocks in the Eurasian Arctic. However, despite considerable variation in the population estimates for the Sea of Okhotsk, the stock or stocks there apparently remain large (certainly in thousands or low tens of thousands). If commercial exploitation has stopped and the subsistence catch is low as implied by available information, there should be no acute conservation problem for white whales in the USSR.

RECOMMENDATIONS

The Scientific Committee (IWC, 1980a) reviewed the status of white whale stocks in 1979 and made the following recommendations as a result.

(1) That the Cumberland Sound (=SE Baffin) stock be given complete protection, that it be censused regularly to estimate population size and gross recruitment, that its relations with 'stocks' in Hudson Strait be examined and that any whales taken (should there be a hunt) be examined and sampled. As demonstrated by the work cited above, considerable effort has been devoted to stock assessment since 1979, and the catch limit has been reduced.

(2) That Canada initiate research on the stock identity and size of white whale populations hunted along the Quebec coasts of Hudson Strait and northeast Hudson Bay. Finley *et al.* (1982), Smith and Hammill (1986), Helbig *et al.* (1989) and Doidge (1990) have reported some of the relevant work conducted since 1979.

(3) That the Canadian High Arctic (summer) and West Greenland (winter) populations of white whales be provisionally managed as one stock and that Canada and Denmark (Greenland) initiate a joint research programme on this stock. Particularly, the Committee called for censuses of white whales summering in Melville Bay-Thule district and Canadian and Greenland waters of Smith Sound and Kane Basin and for analysis of the stock affinities of these whales. The Greenland-Canada Joint Commission on Conservation and Management of Narwhal and Beluga has initiated a research programme on this stock. However, no census of the specified areas has been made.

(4) That more accurate estimates be made of struck-but-lost rates in the white whale hunts of Greenland and Canada. No new data on loss rates in Greenland are available. For Canada, considerable effort has been directed at estimating loss rates in the Mackenzie Delta (Strong, 1990; Weaver, 1991; K. Frost, *in litt.* to Reeves, 1 May 1991).

(5) That the USSR provide all available data on the white whales in the Barents, White, Kara and Laptev Seas and include 'a study of the components of the Barents Sea wintering group and an assessment of the stock or stocks involved.' Some information has become available since 1979 (e.g. Berzin, 1981; Ivashin and Mineev, 1981; Ognetov and Potelov, 1982; 1984; Berzin and Vladimirov, 1986).

(6) That national research programmes on the white whales thought to winter in the Bering Sea be expanded and that a cooperative research programme be instituted by the USA, USSR and Canada. It was expected that such programmes would include documentation of catch statistics, loss rates and characteristics of the hunt and collection of biological samples for determination of vital parameters. Also, 'the temporal and spatial components of the populations should be determined, the populations censused and the inter-relationships among them identified.' No cooperative programme has been

established with the USSR to date. Several cooperative efforts between Canada and Alaska have been initiated and include sharing of harvest information, collection of samples for stock identification and vital parameters and planning further census efforts. Surveys will be conducted of the Cook Inlet and eastern Chukchi Sea stocks in 1991.

(7) That the white whale be defined as a 'whale' and listed in the IWC schedule 'so that appropriate management procedures may be discussed and implemented in the future.' No action has been taken with respect to the later part of this recommendation.

(8) That Canada provide complete catch statistics for Manitoba, Ontario and Quebec. Reporting for Quebec (mainly East Hudson Bay – James Bay, West-South-North Hudson Bay and Ungava Bay stocks) and Manitoba (West-South-North Hudson Bay stock(s)) has improved substantially over the past decade (e.g., Boulva, 1981; Gamble, 1987a; b; Reeves and Mitchell, 1989b; Strong, 1990). The white whale harvest in Ontario (southern Hudson Bay and James Bay) is negligible.

The substance of these same recommendations was reiterated in 1980 (IWC, 1981). It was noted with reference to No. 1 that a catch limit of 40 had been introduced for the Cumberland Sound stock. However, the Committee recommended that this be reduced to zero. It was noted with reference to No. 3 that the current rate of removals from the Canadian High Arctic-West Greenland stock could be 'too high for the overall population,' and this demonstrated the need for better data on population size, stock relations and removals. With reference to No. 5, it was noted that either the reported catch levels for white whales in the Barents, White, Kara and Laptev Seas (c.f. Ivashin and Mineev, 1981) were substantially above annual gross production or the current population estimates were too low. This problem highlighted the need for abundance estimates for this area.

The Scientific Committee carried out another review of white whale stocks in 1981 (IWC, 1982a, pp. 60, 121–2). The 'responsive and considerable expansion' of studies in Greenland and Canada was noted, and both governments were encouraged to continue this work, giving particular attention to stock identity, migration, abundance, calf production, collection of complete and accurate catch statistics and full collection of age and reproductive samples from the catch. Noting the 'seriously depleted status' of the Cumberland Sound, Ungava Bay and eastern Hudson Bay stocks (Finley *et al.*, 1982) and the importance to the species of 'estuarine calf-rearing grounds', the Committee recommended that all three stocks and their critical habitat be fully protected. The USA and USSR were again urged to initiate field studies to evaluate the stock structure, abundance and status of white whales summering in their waters. With respect to No. 7, the question of adding the white whale to the IWC Schedule, the Committee report noted that most members supported the earlier recommendation.

In 1982, the Scientific Committee noted that the research recommendations made in previous years had been acted upon by the USSR and Canada and that the results of research on population size, productivity and exploitation in the USSR and population size, discreteness, exploitation history and loss rates in Quebec, Hudson Strait, northeast Hudson Bay, the Canadian High Arctic and West Greenland had been reported in progress reports and the SM series (IWC, 1983a, p.161). The Committee reiterated its recommendation that the summer populations in Cumberland Sound, eastern Hudson Bay and Ungava Bay be completely protected. It also called for catch statistics and population assessment from the USA and more nearly complete catch statistics from Canada.

The Scientific Committee made three recommendations in 1982 (IWC, 1983a, p.61):

(1) that white whale catches in Alaska be 'minimised' until the uncertainty about stock identity, stock size, net recruitment and removal rates was removed;
(2) that the three depleted stocks in eastern Canada be given complete protection;
(3) that the USSR make available catch information for its white whale fishery.

In 1984, it was recommended again that the USA collect and report data on catches and loss rates (IWC, 1985, p.136). The AIBWC has been doing this since 1988 and the data are improving each year (K.J. Frost, *in litt.* to Reeves, 2 May 1991). The Alaska Department of Fish and Game reported catch figures for 1980–86 (Lowry *et al.*, 1989).

The sub-committee makes the following new **recommendations**:

(1) that the USA obtain more accurate estimates of stock size for white whales in Alaska, particularly the Norton Sound/Yukon Delta stock for which there is no reliable estimate;
(2) that more accurate and complete information be obtained on struck-and-lost rates for all areas where white whales are hunted and that methods for reducing the number of whales that are struck-but-lost be developed and implemented;
(3) that the USA, USSR, Canada and Greenland conduct genetic studies to determine the stock identity of white whales;
(4) that Greenland conduct an assessment of white whale stocks to serve as a basis for management, and that Greenland report data on white whale catches and loss rates.

The sub-committee welcomed the formation of the Canada-Greenland Joint Commission on Conservation and Management of Narwhal and Beluga and of the Alaska and Inuvialuit Beluga Whale Committee as bilateral initiatives that promise to provide intensified and coordinated research and management of shared stocks.

The sub-committee noted its continuing concern about white whale stocks in Canada that are harvested at rates above their estimated sustainable yield levels.

5.1.2.2 *Monodon monoceros*[3]

COMMON NAMES

Narwhal, *narhval* (Denmark), *killalugaq* (Inuktitut, Baffin Island), *tugalik* (Inuktitut, West Greenland), *qilaluaq qernertaq* (Greenlandic).

DISTRIBUTION

The narwhal's distribution is circumpolar north of about 65°N, but it occurs in much higher densities in Arctic waters adjoining the North Atlantic basin than in those adjoining the North Pacific. Three high-density summering areas have been identified in the eastern Canadian Arctic and off northwest Greenland: Repulse Bay and Frozen Strait, the Lancaster Sound region, and Inglefield Bay (Born, 1986; Strong, 1988). Small groups of narwhals

[3] Initial draft from R. Reeves dissertation in preparation.

summer in many other areas, including Jones Sound, Smith Sound, Melville Bay, western Baffin Bay and Davis Strait, and northern Foxe Basin. Narwhals winter mainly in the open and close pack ice of Baffin Bay and Davis Strait as far south as *ca* 64°N and in the Labrador Sea and Hudson Strait (Kapel, 1977; McLaren and Davis, 1981; 1982; Mitchell and Reeves, 1981; Turl, 1987; Richard, 1991). They rarely occur in the main body of Hudson Bay south of Southampton Island. There are few definite records from eastern Hudson Bay, but narwhals are killed occasionally on the west side of the bay as far south as Whale Cove (*ca* 62°N).

Narwhals occur in many fiords along the east coast of Greenland north from Ammassalik (Dietz *et al.*, 1985). Two offshore areas have been identified in the Greenland Sea where 19th-century whalers consistently observed narwhals, on some occasions in large numbers. These areas are centred west of Spitsbergen at 78–81°N, 05°W-10°E, and off the Greenland coast between latitudes 72–76°N (Dietz *et al.*, 1985). A possible third concentration area was identified off the northeast coast of Greenland at 79–81°N. There is no direct evidence that the narwhals in the Greenland Sea belong to a separate stock from those in Davis Strait, Baffin Bay and Smith Sound.

PROBLEMS AND CATCH STATISTICS

Greenland Sea

The narwhals in the Greenland, Barents and Kara Seas, and in the Arctic basin north of these, were exploited to some degree by European commercial whalers during the bowhead whaling era and by the Inuit of east Greenland. However, this exploitation is believed to have been light in terms of the numbers of animals killed relative to the population size.

Tomilin (1957) estimated the annual catch in Scoresby Sound as 20. Incomplete statistics for east Greenland from 1954–75 indicate annual catches ranging from 2 to 65, with a mean of about 21 (Kapel, 1977). The total reported catch in Ammassalik district during the 1970s was 141 (Dietz *et al.*, 1985). Reported catches increased during the 1980s, averaging 87 per year for Scoresbysund and Ammassalik districts, combined, from 1980 to 1987 (Table 14).

West and North Greenland

Catch statistics are provided through the Greenland Hunters' Lists of Game (Kapel, 1977; 1978; Born and Olesen, 1986; Table 14). Participation in the reporting scheme has declined during recent decades, and this has meant that a higher proportion of the reported catch is estimated rather than being an actual count (E.W. Born, *in litt.* to Reeves, 3 October 1985; Heide-Jørgensen,MP, 1990). An important shortcoming of the statistics has been the lack of reporting for Thule district (North Greenland) and in recent years the entire system of reporting catch statistics for small cetaceans in Greenland has deteriorated. Thule provided reliable estimates of the narwhal catch for only three years in the early 1960s (M.P. Heide-Jørgensen, pers. comm. to Reeves, 30 April 1991). Heide-Jørgensen (1990) estimated the recent annual catch for all of West Greenland, including Thule district, as 200–600. The Greenland Fisheries Research Institute estimated the total catch for West Greenland as 600 in 1989 and 1,200 in 1990.

Canada

Narwhal catches in Canada are underreported for a number of reasons (Finley *et al.*, 1980; Finley and Miller, 1982; IWC, 1982a; Gamble, 1987a). The tag system used to implement the national quota is most effective for monitoring the number of large, unbroken tusks that are sold. It is considerably less effective for ensuring that kills of untusked whales (females, calves and juveniles) and whales with short or significantly damaged tusks are reported. Reported catches during the 1970s and 1980s show no clear trend of increase or decrease (Table 15). The total reported catch in all years has been below the total national quota of 525 (Strong, 1989). The catch in Arctic Bay (as observed by and reported to fisheries field personnel) is strongly biased toward males (Roberge and Dunn, 1990). This bias appears to be less consistent and strong at Pond Inlet (Weaver and Walker, 1988). Discussion of the trade in tusks and other products is given in Appendix 3.

Loss rates

Acknowledging that there are no data for estimating the loss rate directly in Greenland south of Thule district, Born and Olesen (1986) assumed that it was *ca* 20%, similar to the open-water loss rate in Canada. [Born and Olesen cited as their source for the 20% figure an unpublished report by Strong *et al.* (1985) which was published in abbreviated form as Strong (1988).] Most of the hunting south of Thule is done in open water, by shooting first and then

Table 14

Narwhal catches reported in IWC Denmark progress reports. For previous years, see Kapel (1977). Note that figures listed for 1983-85 are estimates which include an allowance for unreported catches (but not for hunting loss).

	Year												
Area[1]	75	76	77	78	79	80	81	82	83	84	85	86	87
West Greenland													
N Greenland	-	150/yr[2]		-	110	120	130	118	164	135	274	115	150/yr[2]
NW Greenland	65	49	175	239	154	207	223	221	236	325	73	178	479
CWe Greenland	0	12	6	100	36	10	10	19	10	10	0	?	?
CWw Greenland	44	45	47	162	64	110	239	57	58	56	67	23	25
SW + S Greenland	7	0	9	1	3	5	19	0	0	1	1	36	1
Total	266	256	387	612	377	462	609	461	439	666	256	387	655
East Greenland													
Ammassalik	10	8	17	1	8	48	128	84	12	15	21	140	42
Scoresbysund	2	16	4	2	10	10	15	15	41	50	28	28	16
Total	12	24	21	3	18	58	143	99	53	65	49	168	58

[1] For communities assigned to each area, see Kapel (1977).

[2] Annual estimate - Kapel (1983).

Table 15

Reported narwhal catches (uncorrected for under-reporting and hunting loss) in Canada, 1974-87 (from Strong, 1989). See note for communities included within each statistical area.

	Year													
Area	74	75	76	77	78	79	80	81	82*	83	84	85	86*	87*
High Arctic	152	266	281	217	233	260	256	272	283	310	189	231	218	110
SE Baffin	-	5	16	38	28	28	68	94	99	23	69	67	38	47
N Hudson Bay/ Hudson Strait	-	-	8	-	6	31	26	40	22	11	27	16	7	24
Totals	152	271	305	255	267	319	350	406	404	344	285	314	263	181

*Strong (1989) considered the data for these years complete.

Note: High Arctic - Clyde River, Pond Inlet, Arctic Bay, Grise Fiord, Resolute, Creswell Bay, Spence Bay, Gjoa Haven, Hall Beach, Igloolik, Pelly Bay; SE Baffin - Broughton Island, Pangnirtung, Iqaluit; N Hudson Bay/Hudson Strait - Lake Harbour, Cape Dorset, Whale Cove, Rankin Inlet, Repulse Bay, Coral Harbour.

harpooning. Losses are low in Thule district, where most of the hunting is done from kayaks in open water, using a harpoon first and then killing with a rifle shot. Approximately 1 whale is lost for 20 landed in the summer hunt in Thule district (IWC, 1980b). Loss rates for hunting at *savssats* are much higher, on the order of 1 whale lost for every 2 landed (IWC, 1980b). Winter-spring hunting in Greenland generally is assumed to involve the loss of approximately 1 whale for every 4 landed (IWC, 1980b).

Nets are set for narwhals in Thule district beginning on 1 September each year. This net fishery apparently began about nine years ago after hunters noted that narwhals frequently entangled in seal nets (M.-P. Heide-Jørgensen, pers. comm. to Reeves, August 1990). The number of narwhals that are netted is unknown, except that it is small, probably less than 20 per year; the loss rate from netting is probably close to nil.

Direct observations of narwhal hunting in Canada have revealed significant hunting loss (Land, 1977; Finley *et al.*, 1980; Finley and Miller, 1982; Weaver and Walker, 1988; Roberge and Dunn, 1990). Cosens *et al.* (1990) cited a range in estimated loss rates (percentage lost of total killed) of 42–56%; thus, the estimated total of removals by hunting would be 1.72–2.27 times the landed catch. The range of 42–56% apparently is based mainly or entirely on data from Pond Inlet, which may not be representative for all catch areas. For example, at Arctic Bay, the estimated loss rates for five years with data (1983, 1986–89) ranged from 20% to 34% (Weaver and Walker, 1988). The secured catch at Arctic Bay is often as high as or higher than that at Pond Inlet (Strong, 1989). In the absence of data on loss rates from other settlements that hunt narwhals, it is impossible to decide which of the two ranges of estimates is more representative. In general, losses are highest during the ice-edge and ice-crack phases of the hunt and lowest during the open-water phase.

MANAGEMENT

In Greenland, the hunting of narwhals is regulated mainly by local legislation (Born, 1986; Qujaakitsoq, 1990).

In Canada, narwhal hunting is regulated under the Narwhal Protection Regulations (Fisheries Act) introduced in 1971 (Strong, 1988). In addition to specifying that females with calves not be hunted, waste be minimised and only high-power ammunition be used, these regulations include a national quota, allocated by community primarily on the basis of historic catch levels. The total quota is 525.

The Canada-Greenland Joint Commission on Conservation and Management of Narwhal and Beluga met for the first time in January 1991 (Lemche, 1991). This commission was established under the terms of a Memorandum of Understanding between the responsible Canadian and Greenlandic government agencies. No decisions on management were made at this session. A Scientific Working Group was charged with reviewing information on potentially shared stocks and providing advice on research and management needs. It was specified in the report that the scientific advisory group should consider knowledge from hunters in the development of its advice to the Joint Commission.

POPULATION SIZE

Greenland Sea

The only estimate is for a small part of the summer range. Larsen (1930) estimated that there were at least 176 narwhals in Scoresby Sound in September 1983, based on an aerial line-transect survey. No correction was made for animals below the surface.

Inglefield Bay

In mid-August 1984, Born (1986) counted 4,043 narwhals passing a clifftop observation site at the head of Inglefield Bay. This provides a minimum estimate for the number of narwhals summering off northwest Greenland. Additional animals apparently summer in Melville Bay (Meldgaard and Kapel, 1981) and in Smith Sound and other areas north of Inglefield Bay (Vibe, 1950).

Baffin Bay and Davis Strait

McLaren and Davis (1981; 1982) estimated that a minimum of 5,000 narwhals were present in the pack ice of northern Davis Strait and southern Baffin Bay in March 1981. This was considered an underestimate because many animals were thought to be submerged or under the ice and missed by the surveys. These wintering narwhals are considered part of the Inglefield Bay and/or the Canadian High Arctic stocks (see below).

Canadian High Arctic Stock

Smith *et al.* (1985) estimated that 13,200–18,000 narwhals summered in Lancaster Sound and adjoining waterways in 1981. This estimate was based on the results of a stratified strip-transect survey of Lancaster Sound, Barrow Strait and Prince Regent Inlet in August, and it included estimates of 2,000 and 2,117 to account for whales in two unsurveyed areas (Peel Sound and Admiralty Inlet, respectively; the former based on Smith *et al.*'s own observation of 2,022 in July 1980, the latter on Fallis *et al.* [1983]). No allowance was made for whales summering in the Pond Inlet-Eclipse Sound-Navy Board Inlet complex or along the east coast of Baffin Island. Smith *et al.* (1985) considered the estimate by Davis *et al.* (1978) of 20,000 to 30,000 narwhals in the Lancaster Sound region in 1976 to be an overestimate caused by 'the inappropriate combination of shorebased counts (Greendale and Brousseau-Greendale, 1976) with their aerial surveys.' Aerial photographic surveys of Eclipse Sound, Admiralty Inlet, Prince Regent Inlet and Peel Sound in August 1984 resulted in an estimate of 17,900 narwhals, uncorrected to account for submerged animals or for those in unsurveyed areas (Strong, 1988). Confidence limits for this estimate are 13,100–21,400 (Cosens *et al.*, 1990). It should be noted that Born (1986) and Born and Olesen (1986), citing an earlier unpublished report by Strong *et al.*, referred to an estimate of 23,700 (95% CI 18,100–29,500) for the Canadian High Arctic stock. Combining his own count with the estimate from Strong et al., Born (1986) suggested a combined Canada–Greenland High Arctic population size of at least 28,000, with confidence limits of about 22,000 to 33,500. According to J.T. Strong (pers. comm. to Reeves, 15 April 1991), the high estimate of 23,700 for the Canadian sector was released prematurely and should be ignored. A reanalysis of the 1984 aerial photographic survey data is planned (J.T. Strong, pers. comm. to Reeves, 15 April 1991).

Northern Hudson Bay Stock

Systematic photographic surveys centred in Repulse Bay and Frozen Strait in July 1982, 1983 and 1984 provided estimates ranging between 1,038 and 1,517 narwhals, with varying degrees of precision (Richard, 1991). Richard (1991) suggested that the narwhals in this area be managed as an isolated stock of about 1,300 animals.

ASSESSMENT AND STATUS

Table 16 summarises the current status of the world's narwhal stocks.

Barents and Kara Seas

The comments by Tomilin (1957) about narwhal abundance in the areas around Franz Josef Land and Novaya Zemlya are problematical. His account suggests a significant decrease in abundance post-1930, but no basis for this impression is offered nor is any possible reason given for such a decrease. Yablokov and Bel'kovich (1974) claimed that chronicles and the discovery of bones on beaches 'testify to the former greater distribution of narwhal in the seas of the European North (White and Kara seas).' However, they did not elaborate. The statement that the narwhal 'is thought to have disappeared from the northeastern part of its range (Novaya Zemlya and Franz Josef Land), presumably because of hunting' (Anonymous, 1978) apparently is based on the reports cited above. Yablokov (1979) indicated that observations of narwhals in Soviet waters were 'rare' but speculated that there could be several thousand animals in two populations in the Soviet High Arctic. Apart from occasional kills by commercial whalers hunting bowheads in the Barents Sea during the 19th century and kills by aborigines along the Yamal Peninsula during at least the 17th century (MacRitchie, 1909), no regular hunt for narwhals in the Eurasian Arctic is documented. Their offshore, high-latitude distribution in this sector may explain, at least partially, the absence of a more detailed record. The continuing presence of small numbers of narwhals in the Barents and Kara seas (as well as in the western part of the East Siberian Sea) was noted by Belikov *et al.* (1990).

Table 16

Status of world narwhal stocks (modified from Braham, 1984).

Centre of summer distribution	Est. abundance	Est. annual kill	Removal rate (% stock size)	Refs
Barents & Kara Seas (Arctic Basin)	no estimate	none known	-	-
Greenland Sea	no estimate[1]	89[2]	unknown	-
Canadian High Arctic (Lancaster Sound region)	17,900[3]	397-568[4]	2.2-3.2	1,2
NW Greenland (Inglefield Bay)	4,043+[5]	616[6]	15[7]	-
N Hudson Bay	1,300	29-41[8]	2.2-3.2	3

[1]Larsen (1985) gave conservative estimate of 176 in Scoresby Sound, September 1983.
[2]Based on average reported catch 1978-87 (Table 1), corrected assuming 1 whale killed and lost for 4 secured (see text).
[3]The data from the 1984 survey are being reanalysed.
[4] Secured catch 290/yr (average 1976-87; Cosens *et al.*, 1990), corrected using loss rates from pooled Pond Inlet data 1982-3 (Weaver and Walker, 1988), 49%, and from pooled Arctic Bay data 1983, 1986-89 (Roberge and Dunn, 1990), 27%, as a range.
[5]Number counted in one day from a shore observation site in Inglefield Bay (Born, 1986).
[6]Based on average reported catch 1978-87 (Table 1), corrected assuming 1 whale killed and lost for 4 secured (see text).
[7]Probably an overestimate since the population estimate is an underestimate of the stock(s) hunted.
[8]Based on average reported catch 1978-87 (Table 1), corrected using the same procedures as described in footnote 3 for Canadian High Arctic stock. Note that the catches included are those from Hudson Bay and Hudson Strait only; Foxe Basin catches are assumed to be from the High Arctic stock.

References: (1) Strong, 1988; (2) Cosens *et al.*, 1990; (3) Richard, 1991.

Greenland Sea

The basis for the statement that this stock was historically much larger and more widely distributed than currently (Anonymous, 1990c, p.136) is uncertain. Too little information is available about the past or present population size for narwhals in this region. Substantial recent catches, particularly in Ammassalik district (Table 14), demonstrate the need for better information on the stock(s) off east Greenland.

Canadian High Arctic

Although Cosens *et al.* (1990) indicated in their Introduction that there was no evidence of Canadian narwhal stocks being harvested at levels that could not be sustained, they concluded in their assessment of the High Arctic stock that harvests have exceeded the estimated net recruitment rate of 2–3% and that if the stock size is 17,900 as estimated, the population must be declining. Strong (1988), using similar estimates of population size and calf production, but a lower estimate of the annual kill rate, concluded that the stock was stable and that the current level of harvest could be sustained. Better information is needed about stock relations and removal rates.

Cosens *et al.* (1990) apparently did not include the two Foxe Basin communities' harvests (Igloolik and Hall Beach) in their assessment of removals from the High Arctic stock. Neither Smith *et al.* (1985) nor Richard (1991) covered Foxe Basin in their population assessment surveys. The stock affinities of narwhals hunted in northern Foxe Basin are unknown, but there is circumstantial evidence from local people suggesting that they come from the High Arctic, passing through Gulf of Boothia and Fury and Hecla Strait in late summer (P. Richard, pers. comm. to Reeves, 1 May 1991).

West and North Greenland

Annual catches of about 450 (the 1975–87 average from Table 14) would represent more than 10% of an estimated minimum stock size of 4043. However, both the catch level (incomplete reporting, no allowance for hunting loss) and the population size (based on a one-day count at a fixed location in Inglefield Bay – Born, 1986) are likely underestimates. Without improved census data and better information on stock relations of narwhals hunted in the Canadian Arctic and West Greenland, it is impossible to make a useful assessment. However, the available data are sufficient to warrant concern about the status of the stock.

Northern Hudson Bay

The combined quotas for communities in northern Hudson Bay (summering area) and Hudson Strait (wintering area) is 70, or 5.4% of the estimated stock size. Reported landed catches in most communities have been below the quota in most years (Strong, 1989), but since reporting is incomplete (Gamble, 1987a) and the quotas make no allowance for struck whales that are not secured, there is reason for concern about the impact of hunting on this stock.

RECOMMENDATIONS

The IWC Scientific Committee has made few recommendations concerning narwhals, apart from calling for their inclusion in the IWC Schedule (IWC, 1980b, p.124). In 1981, Canada and Denmark were encouraged to continue and expand research on stock identity, migration, abundance and calf production; to collect complete and accurate catch statistics; and to sample catches fully for studies of age estimation and reproduction (IWC, 1982a, p.121). Some effort toward achieving these objectives has been made by Denmark and Greenland (e.g. Born, 1986). In Canada, comprehensive research programmes have been implemented to address many of these concerns (e.g. Smith *et al.*, 1985; Gamble, 1987a; Strong, 1988; Weaver and Walker, 1988; Kingsley, 1989; Roberge and Dunn, 1990; Richard, 1991).

The sub-committee remains concerned about catch levels and loss rates in the Canadian and Greenlandic fisheries. It **recommends** particularly that more effort be made to assess stock size and removal rates for the narwhal population in the High Arctic, Baffin Bay and Davis Strait. In this regard, the sub-committee welcomes the formation of the Greenland-Canada Joint Commission on Conservation and Management of Narwhal and white whale, which is expected to implement a joint programme of research and management. The sub-committee notes with concern that the system for reporting catch statistics in Greenland has deteriorated, and recommends that such record keeping and reporting be made a high priority. In view of the substantial catches in some years in east Greenland, the sub-committee also recommends that some attention be given to stock assessment in the Greenland Sea.

(Low, 1906; Bruemmer, 1966; Hansen, 1970; Hay and Sergeant, 1976; Riewe, 1977; Treude, 1977; Durham, 1978; Kapel, 1983; Anonymous, 1985b; Ivashin, 1988; Sergeant and Hoek, 1988)

5.1.3 Direct fisheries for Globicephala melas, *in the North Atlantic*[4]

COMMON NAMES

Long finned pilot whale. Faroe Islands: *grindahvalur*; *nydingur* (large pilot whale); *leiftur* (newborn). Iceland: *marsvín*. Greenland: *nisarnaq*. Newfoundland: pilot whale; blackfish; pothead; roundhead. Norway: *grindehval*. Shetland Isles: pilot whale; blackfish; caa'ing whale. Britain: long-finned pilot whale. Sweden: *grindval*. Finland: *pallopää*; *grindvalas*. Denmark: *grindehval*. Holland and Belgium: *griend*. Germany: *grindwal*. France: *globicéphale noir*; *dauphin pilote*. Spain: *calderòn*; *caldeirò* (Galician); *cap d'olla* (Catalan). Portugal: *boca de panela*. Italy: *globicefalo*. Greece: *mavrodelphini*.

DISTRIBUTION

In the North Atlantic, the long-finned pilot whale lives in cold temperate and subarctic waters. Its general distribution is from Northwest Africa, including the Mediterranean, to the Norwegian-Barents Sea in the east and from Bermuda and Cape Hatteras at the coast of North Carolina to central parts of Greenland in the west. The North Atlantic Sightings Surveys (NASS) in 1987 and 1989 have improved our knowledge of the abundance inside the northeast Atlantic distribution area. Concentrations of pilot whales were observed especially from 2–40°W and 45–65°N, (Lens *et al.*, 1989; Bloch *et al.*, 1989; Buckland *et al.*, 1993). There is some overlap in distribution of the northerly range of the short-finned pilot whale, *Globicephala macrorhynchus*, and southerly limit of the long-finned pilot whale.

Although the pilot whale occurs north to the Barents Sea (Mitchell, 1975b), the only record from the Norwegian coast from NASS surveys was a single observation off southwestern Norway (Øritsland *et al.*, 1989; Bloch *et al.*, 1989), although they occasionally beach on the Norwegian coast (Griffiths and Øen, 1990). Elsewhere the pilot whale is commonly distributed in the western basin of the Mediterranean (Gannier and Gannier, 1990), in the Gibraltar Strait (Hashmi, 1990) and off Spain (Lens *et al.*, 1989).

Pilot whales appear to move into coastal areas following their squid prey in the summer and are more concentrated offshore in deep waters in winter (Evans, 1987). Brown's (1961) summary of observations made from ocean weather ships, merchant vessels and other ships, provides information on the oceanic range of this species as far south as 45°N in the central area of the North Atlantic, suggesting occurrence throughout the year in oceanic waters between 45°N and 50°N and probably in all longitudes from the Bay of Biscay to Newfoundland. Observations during the NASS studies tend to confirm this, indicating a greater abundance of whales, including pilot whales, in the central parts of the North Atlantic.

[4] Initial draft by D. Bloch and C. Lockyer

PROBLEMS AND CATCH STATISTICS

There is not enough information to separate North Atlantic pilot whales into discrete stocks. Previously, pilot whales were taken in the old Norse areas, including Norway, Iceland, Shetland, Orkney and Hebrides (Williamson, 1970; Joensen, 1976). Until 1972, the pilot whale was still taken in Newfoundland and until 1973 in Norway. Today, the pilot whale is only taken in the Faroe Islands and Greenland.

Between 1975 and 1987, a total catch of 487 pilot whales has been taken by small type whalers off Greenland (Table 17). The largest catch was 136 in 1977.

In the Faroe Islands, the fishery (*grind*) is opportunistic. Whales are observed either from land or from boat, and are driven on shore and killed, with entire schools taken usually. Between 1986 and 1988, 47 sightings of pods occurred (one third from land), followed by landings of 43 pods. The distance from the school to the shore ranged between 0.1 to 3.3 n.miles (Bloch *et al.*, 1990a). Traditional Faroese fishing boats are used (specialised boats or whalers have never been used). The whales are driven into suitable bays. Since November 1989, the Faroe Islands Government has restricted the use to 21 bays only.

The whales are hunted communally for food and are utilised non-commercially – the catch is shared free among the local inhabitants. Complex laws and regulations exist for the control of the catch and its utilisation. The first regulations, covering the total course of events from the initial sighting of a pod until the animals have been flensed and the beach cleaned, appeared in 1832. These have been updated several times, but the original regulations still form the backbone of today's laws (Bjørk, 1956–63).

Pilot whales have been harvested in the Faroe Islands since the Norse settlement in the 9th Century (Thorsteinsson, 1986). Hunting statistics exist back to 1584, and unbroken records exist from 1709 to the present (Joensen and Zachariassen, 1982; Bloch *et al.*, 1990b). During the period 1709–1990, 1,646 pods (235,630 whales) were harvested. The statistics show a peak periodical occurrence of whales every 110–120 years (Joensen, 1962; Joensen and Zachariassen, 1982).

In the period 1709–1990, a range of 0–4,360 whales (0–23 pods) per year were harvested, averaging 990 (6.9 pods). The maximum harvest occurred in 1941 (23 pods and 4,325 whales). In three years, 1844, 1939 and 1941, the harvest exceeded 3,000 whales; in 25 years, more than 2,000 whales were landed, while in over 95 years (a third of the time period), the annual catch exceeded 1,000 whales.

By contrast, the period 1750–1795 showed poor harvests with a total of only 13 pods comprising 2,459 whales, averaging 55 whales per year. During the years around 1900, there were occasional years with no pods landed (1890–1, 1901, 1924 and 1927). Although pods were seen during those years, attempts to beach them met with no success. In all, there were 44 years when no pods were taken (Bloch *et al.*, 1990b).

The fishery has never been managed by quota limitation. However, since 1982, a district or a whaling bay can be closed by an executive order issued by the Faroe Islands Government whenever the area in question is considered to already have an adequate supply of meat. Between 1986–1988, restrictions occurred in 4 (1986), 5 (1987) and 3 (1988) districts out of 9, and lasted for 0.5–3.5 months. So long as the pilot whale meat and blubber is used non-commercially, and only by Faroese people for local consumption, there will be an upper limit on the catch, regulated by demand.

In recent years, the Faroese Government has made limitations of the use of the gaff and spear in the fishery, in response to international concerns.

The complete pilot whale catch information is held at the Faroese Museum of Natural History in Tórshavn. There are other species taken by drive fisheries in the Faroes, including *Lagenorhynchus acutus* in some years. Catch statistics for some species are available for the past five years.

POPULATION ESTIMATE

The NASS-87 (June-August) survey of the Faroese-Icelandic area covered an area bounded by Spitzbergen and the Barents Sea in the north, the Spanish coast in the south, West Greenland in the west and the Norwegian coast in the east (Sigurjónsson *et al.*, 1989). A total of 109 sightings of approximately 4,413 animals were made onboard the four survey vessels. The sightings were concentrated southwest and west of the Faroe Islands, off the southeast coast of Iceland and in deep waters southwest and west of Iceland in the Denmark Strait; although some sightings were made west of the British Isles and Ireland, and along the East Greenland coast.

The resultant population estimates were 72,000 (CV 0.4) for the area covered by the Faroese vessel; partial population estimates for closing and passing mode are 18,950 (CV 0.5) and 12,945 (CV 0.25) whales respectively, for the areas covered by the Icelandic vessels. This gives a total 'best' estimate of close to 100,000 animals; it does not include a correction for submerged animals and assumes that all schools close to the trackline were sighted (Bloch *et al.*, 1989). When reviewing these estimates, the sub-committee discussed several factors that could bias the estimates, and noted that due to these factors, there was a greater uncertainty in the estimate than indicated by the calculated CVs (IWC, 1990b).

The area between 50–65°N and 06–45°W was covered by Iceland and the Faroe Islands during the NASS-89 survey, and a similar number of sightings of pilot whales was recorded but the data are still not fully analysed. There are no updated estimates from the other areas in the North Atlantic. However, there is an estimate of about 60,000 whales as the initial population in Newfoundland waters (Mercer, 1975), and about 13,000 whales from an aerial line-transect of a portion of the Newfoundland-Labrador area (Hay, 1982).

ASSESSMENT AND STATUS

There is no detectable evidence that the stock size of pilot whales appearing in the Faroese area has been affected by the drive fishery. The observed periodicity in the

Table 17

Catches of pilot whales in Greenland 1975-87 (Total=487). Data from Danish Progress Reports.

Year	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Catch	106	51	136	101	50	6	1	1	-	-	26	9	-

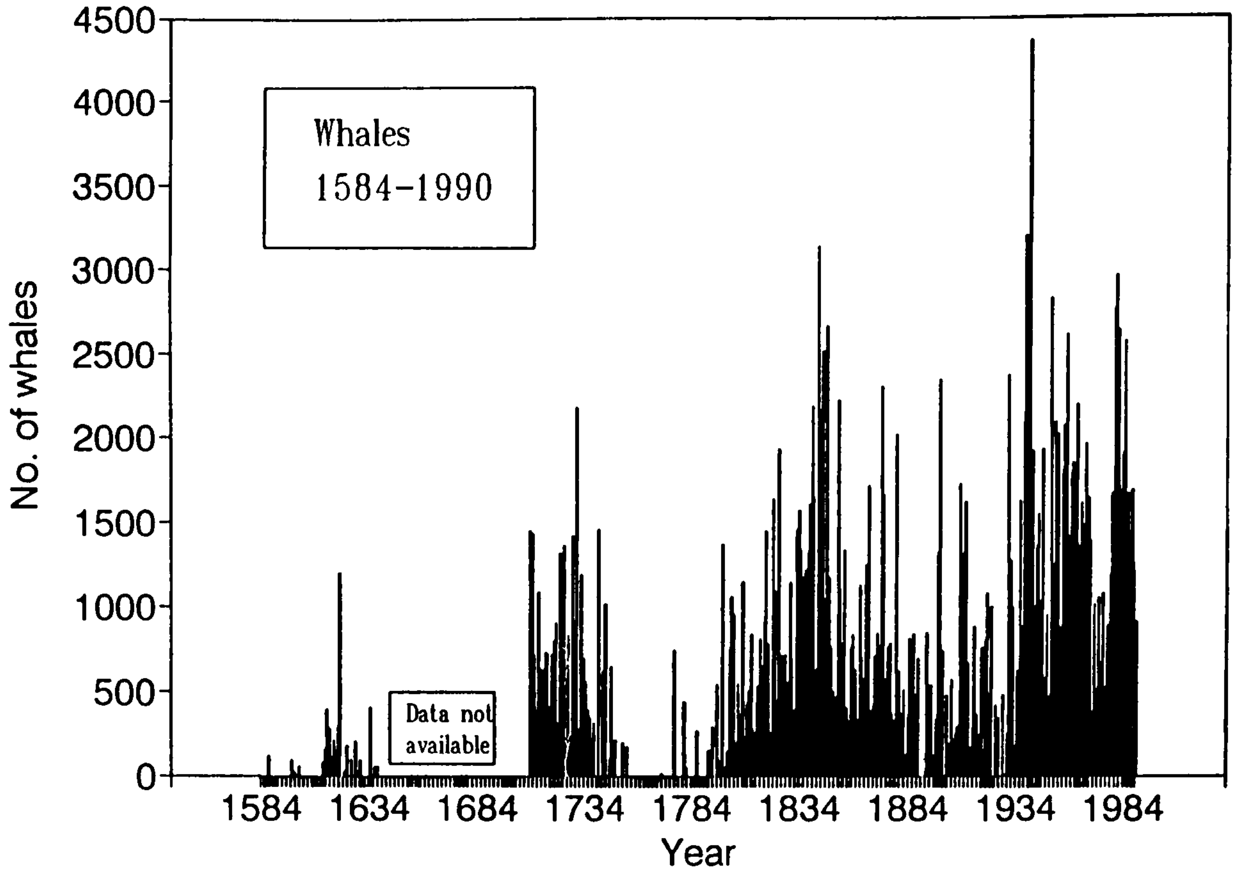

Fig. 2. Catches of pilot whales at the Faroe Islands.

occurrence of whales in the Faroese area (Fig. 2) is significantly correlated with the occurrence of the squid prey, *Todarodes sagittatus*, the presence of which is also correlated with the periodicity in the sea surface temperature (Hoydal, 1986). Any connection between the pilot whales occurring around Newfoundland in summertime and the all year round occurrence in the Faroes (Sergeant, 1986) is still not proven.

RECOMMENDATIONS

In 1985, the Scientific Committee recommended the funding of a proposal to examine the ecology of Faroese pilot whales (IWC, 1986a, p.52). Although IWC funding was not forthcoming, between July 1986 and July 1988, a comprehensive examination was undertaken of the ecology and status of the pilot whale in the Faroe Islands, under the auspices of the IWC and the United Nations Environment Programme (UNEP). The content of these examinations is outlined by Desportes (1990), and most of the results are published in Donovan *et al.* (1993).

In 1987 (IWC, 1988, p.51), the Scientific Committee noted that material being collected from the Faroese pilot whale fishery was particularly valuable for investigating the factors which determined the concentrations of organochlorine pollutants in whale tissue. These compounds are known to affect reproduction in other marine mammals. It therefore recommended that this opportunity should be brought to the attention of laboratories capable of performing standardised analyses for organochlorines and particularly for individual PCB congenors. Studies on these matters were instigated and the results are published in Donovan *et al.* (1993).

In 1989 (IWC, 1990a), the Scientific Committee made several recommendations. Concerns about past fisheries and by-catches were expressed, and in view of the fact that in the western North Atlantic the by-catch of pilot whales by foreign flag mackerel vessels in the US EEZ jumped sharply in 1988 to 140 and may have been larger in earlier years when the then larger mackerel fishery was unmonitored, it was recommended that the historical data for this fishery be examined to estimate earlier removals of pilot whales.

The existence of a past Icelandic drive fishery was confirmed (Anonymous, 1990c) and the Committee recommended that the historical data for that fishery and for strandings be obtained and reported.

Information on these matters was published in Donovan *et al.* (1993).

Several recommendations specific to the Faroese drive fishery were also made. At that time, no new information was available on population dynamics, but it was recommended that attention be given to research on this topic using the Faroese frequency-at-age data. Extensive demographic information which has been, and will be, generated by the Faroese research programme could form the basis for a valuable mathematical model of the population dynamics of pilot whales, and possibly other odontocetes. The Committee therefore recommended that such an integrated model should be developed.

The Committee recommended that stock identity be addressed by genetic comparisons being carried out between pilot whales from the Faroes and from other regions in the North Atlantic using both analyses of isoenzyme allelic frequencies and appropriate analyses of DNA. Results of such studies were presented in Donovan *et al.* (1993).

Because of the importance of information about migration to questions of stock identity and status and because the pilot whale is a species particularly suitable for radio-telemetry studies, the Committee recommended that the proposed project using satellite-linked transmitters at the Faroes to study movements, described at an earlier meeting two years previously be undertaken. This particular project, while attempted, has not met with success. No further attempts have been made or are planned.

In teeth and hard tissues, depositional anomalies may be related to stress or other external factors and it was recommended that incidence of marker lines and other anomalies in teeth of pilot whales be examined in more detail to determine possible links with oceanographic conditions, food availability and life history events. Research on this matter is continuing.

5.1.4 The Black Sea dolphin and porpoise fishery[5]

Three species of small cetacean were killed by fishermen from the four countries surrounding the Black Sea between 1870 and 1983. The common dolphin (*Delphinus delphis*) was historically the species caught in the largest numbers by the USSR, and although the limited catch statistics have generally been reported for all three species combined, it appears that the harbour porpoise (*Phocoena phocoena*) became the numerically dominant species in the catch from 1964 to the time the fishery ended in 1966 (except Turkey). The bottlenose dolphin (*Tursiops truncatus*) was of intermediate importance in the harvest. The Turkish catch reportedly consisted of 80% *Phocoena*, 15–16% *Delphinus* and 2–3% *Tursiops* in the early 1980s (Klinowska, 1991). No information is available on the composition of the earlier Turkish catches or on the Bulgarian and Romanian catches for any period. The abundance of all three species was greatly reduced by the fisheries (Zemsky and Yablokov, 1974; Smith, 1982).

DISTRIBUTION

The three species involved in the Black Sea fisheries are distributed widely, in disjunct populations, in temperate regions of the Northern Hemisphere (*Phocoena*) or the world (*Delphinus* and *Tursiops*). They are found throughout the Black Sea, reportedly moving seasonally to follow concentrations of various small pelagic fishes. For example, in the autumn they follow such prey fishes northward along the eastern Black Sea. The cetaceans formerly entered the Azov Sea, in the northeast corner of the Black Sea, along with the prey species. However, they no longer occur in that shallow sea, reportedly because it has become heavily polluted. The common dolphin historically occurred primarily in the central Black Sea, harbour porpoises and bottlenose dolphins primarily in the more coastal regions. However, sightings data suggest that there were shifts in ranges of the species in later years as the numbers of common dolphins declined. The animals in the Black Sea could move into the Mediterranean Sea, and bottlenose dolphins have been reported moving through the Bosphorous Straits. The extent of such movement is unknown, however. Tomilin (1957) presented evidence that all three cetacean species in the Black Sea differ morphologically from those elsewhere. Harbour porpoises do not occur in the eastern Mediterranean Sea at present, so those in the Black Sea are definitely an isolated stock. There is no information on the existence of separate breeding stocks within the Black Sea for any of the species. The genetics of the Black Sea dolphins and porpoise have not been studied. However, DNA-sequence comparisons with samples from other regions are presently being carried out for the common dolphin and the harbour porpoise (W. Perrin, pers. comm.).

PROBLEMS AND CATCH STATISTICS

Although the three species were harvested for many years at high levels, catch statistics are sketchy, being reported only irregularly and in total weight of the catch for all three species combined, as summarised up to 1974 by Smith (1982). The USSR catches apparently reached their maximum of 135,000 to 140,000 animals in 1938, after which they declined. The average reported catches before World War II were roughly double those for later years, despite increasing fishing effort including the use of spotting aeroplanes. During the entire fishery, catches were made by both netting (mainly USSR) and shooting (mainly Turkey), with unknown loss rates in the latter. Smith reported that during a June 1981 joint USSR-US dolphin sighting survey, there was a decreasing rate of encounter of floating harbour porpoise carcasses with increasing distance from the Turkish coast (IWC, 1983b), suggesting the continuation of a harvest by shooting in the early 1980s and an apparently high struck-and-lost rate. The decline in catches of all three species to a few thousand per year by 1964–66 prompted first seasonal restriction, then a total moratorium in the USSR, Bulgaria and Romania from 1966. Little information has been reported for years since 1974 although it is known that the harvest continued in Turkey until it was banned in 1983.

Çelikkale *et al.* (1989) and Çelikkale (1990) described recent developments in the fishery, noting especially concern within Turkey that the dolphins and porpoises posed a serious threat to the continued success of local net fisheries for the European anchovy.

Recently, illegal takes of at least two of the three species have been reported in Turkey. The causes are not known but are variously described in newspaper accounts in March and April 1991 as incidental entanglement in net fisheries, directed take to reduce competition for the European anchovy, directed take to reduce the damage to fishing nets, utilisation of an incidental catch, and directed takes for commercial marketing of fertiliser, animal feed, and oil, perhaps for cosmetics. Catches are reportedly being made in 'turbot nets', and carcasses seen on the docks are being processed by boiling in vats. There have been no official estimates of the magnitude of this recent harvest, and no confirmation of their purpose; given the lack of systematic reporting in the years before the harvesting became illegal and the illegal nature of present harvests, accurate statistical reporting should not be expected.

POPULATION ESTIMATES

Following the 1966 moratorium on industrial Black Sea dolphin/porpoise hunting in the USSR, Bulgaria and Romania, a series of aerial sighting surveys was begun by the USSR, continuing at least through the early 1980s. The methods and some of the resulting data are described in Zemsky and Yablokov (1974), and analyses of the annual variability of estimates based on these data through 1973 are presented in Smith (1982). The abundance of all three species together was estimated to be 1.5 to 2.0 million animals in the 1930s, but only 250,000 over the period 1967 to 1974. There was no apparent trend in abundance in the latter period, but variability in the estimates between years was far greater than anything reasonably compatible with the biology of the species. The largest estimates in the later period were for the common dolphin (average roughly 150,000), while the smallest estimates were for harbour porpoise (average roughly 22,000), with bottlenose dolphins intermediate (averaging roughly 85,000). These estimates are based on expanding the numbers of animals sighted assuming an effective track width of three km in which 50% of the animals present were seen. The survey tracks covered most of the Black Sea, although certain areas were missed, including that within 12 miles of the Turkish coast.

[5] Initial draft by T.D. Smith.

New surveys were conducted by Turkey in April and July of 1987 using standard line transect methods aboard four ships (Çelikkale *et al.*, 1989), and estimates for the three species combined of more than 450,000 animals obtained. The surveys were conducted seaward to 60 km, over roughly 1/6th the total area of the Black Sea, primarily along the southern coastlines. The estimates are based on assuming an effective track width of 5 km (2.5 km on each side of the vessel) and that the animals are distributed over the unsurveyed areas of the Black Sea at the same density as observed in the surveyed areas. Buckland *et al.* (1992) reviewed the statistical basis of these estimates, however, and suggested that they may be seriously biased by the use of the 'maximum effective sighting distance' as the 'effective search width', by size-biased sampling because the school sizes varied between several tens and several thousands of animals, and by extrapolating to unsurveyed areas. For example, they suggest that an estimate of just the surveyed area would be on the order of 76,000 animals, and that 'the true abundance might be substantially below the estimate of 454,440 animals, and may be well below half that estimate'. New estimates of 96,000 ±30,000, 10,000 ±3,000 and 7,000 ±3,000 for common dolphins, harbour porpoise and bottlenose dolphin, respectively, were reported in SC/43/Prog Rep USSR, but these estimates were not reviewed by the sub-committee.

ASSESSMENT AND STATUS

The populations of the three species in the Black Sea had clearly been greatly reduced by the time the fisheries closed between 1966 and 1983. While all three species continue to exist in the Black Sea, the degree of their recovery from previous depletion is not known with any precision. Based on the generally low rates of increase of cetacean populations, however, it is unlikely that they have increased to any substantial fraction of their pre-exploitation abundance in the few years that they have been protected. Further, given the reported declines in the fishery for at least one of their prey items, the recovery of the cetaceans may have been inhibited by reduced food resources. The reported Turkish takes, therefore, are of great concern, whatever their purpose.

RECOMMENDATIONS

The Scientific Committee made five recommendations concerning Black Sea dolphins in 1982 (IWC, 1983a, p.60):

(1) that better information on catch levels and species composition be made available;
(2) that the data from aerial surveys by the USSR be made available for analysis and evaluation;
(3) that a Turkish scientist familiar with the fishery be invited to participate in the next meeting;
(4) that the history of the anchovy fisheries in the Black Sea be reviewed; and
(5) that Turkey and FAO be approached concerning the sampling of the Turkish fishery to obtain biological data of various sorts.

The Scientific Committee reviewed the above recommendations in 1983 (IWC, 1984a, pp.58–9) and noted that a general FAO fishery mission to Turkey had obtained some new data on the harvest of small cetaceans. However, the requested USSR sightings data had not been obtained, nor was the invitation for a Turkish scientist to attend the Scientific Committee meeting accepted. In view of the ban on the hunting of dolphins and porpoises announced by the Turkish Government, effective mid-April 1983, the recommended sampling programme was no longer required. The Scientific Committee re-stated recommendations 2, 3 and 4.

No new data were available in 1984, and the Scientific Committee requested information from IUCN and UNEP and again expressed the desire to have a Turkish scientist attend the Scientific Committee meeting (IWC, 1985, p.53).

The paper on the anchovy fishery provided to the 1990 Scientific Committee meeting (Çelikkale, 1990) was welcomed as a partial response to recommendation 4, as was the participation of Çelikkale.

The Committee in 1990 recommended (1) that the current abundance estimates not be used as a basis for management and that they be reviewed independently; (2) that further population surveys be carried out, preferably involving at least the four nations bordering the Black Sea, and (3) that, because of the perception by fishermen in Turkey of competition by dolphins for fish, studies of feeding ecology of the small cetaceans be carried out.

The sub-committee makes two further **recommendations** below.

(1) An evaluation of alternate possible causes for the declines in the anchovy fishery in Turkey should be made, including fishery resource surveys to monitor abundance and collection of specific catch and fishing effort statistics. The seasonal distribution of the anchovy population and the small cetaceans should be more fully described. Because the fish populations migrate throughout the Black Sea, similar information should be obtained in all countries surrounding the Black Sea, including information on possible incidental take or directed take of cetaceans.
(2) The actual reasons for the reported takes of dolphins and porpoises in Turkey should be determined, and accurate statistics should be collected. Steps should be taken to ensure that these takes are reduced given the poor present understanding of the status of these populations. If the takes are motivated by perceived threats to the anchovy fishery, these threats should be further evaluated. If the takes are motivated by the commercial value of the products, these markets should be documented, and the existence of alternate sources of raw materials investigated. If the takes are incidental to commercial fishing operations, the causes of the entanglements should be determined, and steps taken to reduce the incidental take through education and possible changes to gear and fishing practices. Bulgaria, Romania and the USSR should also be encouraged to provide similar information.

5.1.5 The Peruvian small cetacean fishery[6]

Several species of small cetacean are taken by a variety of artisanal fisheries in Peruvian coastal waters and used for human consumption (Read *et al.*, 1988; Van Waerebeek and Reyes, 1990a). In Peru, the distinction between directed and incidental catches is blurred because small cetaceans possess commercial value, so all catches of dolphins and porpoises have been retained. Three species are commonly taken by these fisheries: dusky dolphin (*Lagenorhynchus obscurus*), Burmeister's porpoise (*Phocoena spinipinnis*), and common dolphin (*Delphinus delphis*).

[6] Initial draft by A. Read.

DISTRIBUTION

The dusky dolphin occurs in cold-temperate waters along both coasts of South America and in presumably separate populations off southern Africa and New Zealand. On the Pacific coast of south America, it is distributed in coastal waters from Huacho, Peru (11°S) to southern Chile (Gaskin *et al.*, 1987). Burmeister's porpoises also occur in the cool waters of the coastal upwelling zone in Peru, extending from Paita (5°S) to the Beagle Channel in Chile and in the coastal waters of the Atlantic into southern Brazil (IWC, 1991c). Their entire range appears to be limited to coastal waters of South America. Common dolphins are widely distributed in pelagic and coastal waters throughout the world oceans, extending south in the Pacific to at least 40°S (Aguayo, 1975). Nothing is known about seasonal movements or stock structure of these three species in Peruvian waters.

PROBLEMS AND CATCH STATISTICS

Two sets of catch statistics describe the numbers of dolphins and porpoises captured in Peruvian waters. Official government statistics, compiled by the Ministerio de Pesqueria (MIPE), report the weight of all small cetaceans landed annually in Peruvian ports from 1966 to the present. Reported landings were at fairly low levels until the early 1970s, when catches rose dramatically (Read *et al.*, 1988). Recent annual landings have decreased from a peak of 1,408 tonnes in 1979 to 426 tonnes in 1989 (Van Waerebeek and Reyes, 1990b). Unfortunately these data are not collected on a species-by-species basis, so it is difficult to estimate the total number of individuals taken.

Estimates have also been made of the actual number of small cetaceans landed at several ports in central Peru since 1985 (Read *et al.*, 1988; Van Waerebeek and Reyes, 1990a; b). In the small port of Pucusana (12°S), the estimated total kill of small cetaceans has increased from 175 in 1985 to 2,320 in 1989 (Van Waerebeek and Reyes, 1990b). The majority of this catch is comprised of dusky dolphins, captured intentionally in a drift net fishery during the winter months (Read *et al.*, 1988). Comparison of these estimates with the published statistics show that the MIPE data are accurate for Pucusana, where small cetacean carcasses are weighed, but highly inaccurate for other ports where weights are estimated by port officials (Van Waerebeek and Reyes, 1990b).

Read *et al.* (1988) estimated the total number of dolphins and porpoises captured in Peruvian waters by combining official MIPE statistics on landed weights with data on species composition and mean weight of each species collected at Pucusana. These authors reported an approximate catch of 10,000 dolphins and porpoises during 1985, although they cautioned that this estimate depended on the accuracy of MIPE records and the extrapolation of species composition from central Peru to the remainder of the coastline.

A particularly troubling aspect of the situation in Peru is the recent development of the directed fishery for small cetaceans. Early reports of utilisation of small cetaceans in Peru (Mitchell, 1975a) indicated that the capture of these animals occurred incidentally to other fishing operations. In recent years, the majority of landed dolphins and porpoises have been deliberately captured, mostly in the directed net fishery for dusky dolphins (Read *et al.*, 1988), although a large catch of common dolphins was taken by harpoon in 1987 (Van Waerebeek and Reyes, 1990b). It has been suggested that this direct exploitation was initiated in the early 1970s following the collapse of the industrial anchoveta fishery in 1972 (Read *et al.*, 1988). The commercial value of incidentally captured dolphins and porpoises presumably stimulated deliberate catches of these animals, particularly after the demise of the lucrative anchoveta fishery.

POPULATION ESTIMATES

There are no population estimates for any species of small cetacean in Peruvian waters.

ASSESSMENT AND STATUS

It is not possible to assess the status of small cetaceans in Peru, because estimates of total kill and abundance are lacking. The catch of dusky dolphins is known to be large, however, numbering in the thousands, and is thus cause for concern. In 1990, the IWC Workshop on Mortality of Cetaceans in Passive Fishing Nets and Traps expressed concern for this population of dusky dolphins (IWC, 1994). Notwithstanding the increase in catches at Pucusana, Van Waerebeek and Reyes (1990b) noted a negative trend in MIPE national landing statistics between 1979 and 1990, and suggested that this reduction in catches might indicate an unsustainable exploitation of declining populations. The Peruvian government reportedly closed the directed fishery for small cetaceans in November 1990, but the Scientific Committee had no detailed information about this closure and its effects.

RECOMMENDATIONS

Research is required to provide reliable estimates of total fishing mortality for each species in Peruvian waters. The sub-committee **recommends** that this be achieved by modifying existing MIPE data collection procedures to record the number of individuals of each species landed rather than total weight. Estimates of abundance of affected species and elucidation of stock structure are also urgently required to assess the impact of directed and incidental takes on affected populations, and the sub-committee **recommends** such studies to be undertaken.

The IWC Workshop (IWC, 1994) recommended that the Government of Peru collect and report catches of cetaceans at all ports, by species and number as well as weight. It also recommended that alternative fishing methods be sought to reduce marine mammal mortality without affecting fishery yields and that technological programmes to this end be established. If the incidental and directed kills continue, it is vital that an effort be made to assess the dolphin population(s), to at least obtain a minimum estimate of abundance.

5.1.6 The Sri Lankan small cetacean fishery[7]

Large catches of small cetaceans have been reported around Sri Lanka. Although some dolphins may have been harpooned by Sri Lankan fishermen at least as long ago as the late nineteenth century (Leatherwood and Reeves, 1989), the current situation appears to have developed along with the rapid expansion of use of synthetic gillnets, which were introduced in the 1950s and are now the fishing method of choice in most fishing areas of the country. Initially, incidentally gillnetted cetaceans may have been discarded by most fishermen, or retained for personal use by only a few. However, as uses were identified and markets established for flesh of small cetaceans, those animals incidentally caught began to be retained and practices were gradually expanded to include deliberate

[7] Initial draft by R. Reeves.

taking (Leatherwood and Reeves, 1989). These developments may well have been fuelled by rapidly increasing human populations and declining availability of some other traditionally sought marine resources (Amarisiri and Joseph, 1985; Joseph, 1985). At present, dolphins are taken mostly in gillnets and by hand harpoons and are used for human consumption and as bait in longline fisheries. The taking of dolphins in Sri Lanka is now widespread and apparently growing (Leatherwood and Reeves, 1989).

SPECIES INVOLVED

The following species of small cetaceans, in approximately descending order of importance (i.e. numbers landed), have been identified in Sri Lanka since 1982: *Stenella longirostris*, *Grampus griseus*, *S. attenuata*, *S. coeruleoalba*, *Tursiops truncatus*, *Kogia simus*, *Feresa attenuata*, *Pseudorca crassidens*, *Globicephala macrorhynchus*, *Peponocehala electra*, *Lagenodelphis hosei*, *K. breviceps*, *Steno bredanensis*, *Orcinus orca*, *Mesoplodon sp.*, *Delphinus delphis* and *Ziphius cavirostris* (Leatherwood and Reeves, 1989). Catches also include a few large cetaceans (*Physeter catodon, Balaenoptera physalus and Megaptera novaeangliae)* and dugongs (*Dugong dugon*) (Leatherwood and Reeves, 1989). Most of the species involved in the Sri Lankan fisheries have pantropical or cosmopolitan distributions.

ESTIMATED CATCHES

The Sri Lankan National Aquatic Resources Agency (NARA) recently estimated that approximately 12,950 small cetaceans are caught in gillnets and others (no estimate) are harpooned annually in Sri Lanka (Dayaratne and de Silva, 1990). Methods used to estimate mortality were not presented in sufficient detail to warrant critical evaluation. Leatherwood (1994) reexamined data on fishing effort and dolphin catches in Sri Lanka from 1984–1986 originally presented in Leatherwood and Reeves (1989), and estimated that at least 8,042–11,821 small cetaceans were taken annually, depending on the assumptions used; he regarded even the highest of these figures as a substantial underestimate. In fact, data do show clearly that takes of small cetaceans are very large in Sri Lanka but are inadequate to permit calculation of reliable estimates with appropriate measures of confidence. With the kind and quality of data currently available

'All attempts to estimate mortality of cetaceans in Sri Lankan fisheries ... are compromised in significant ways ... The best (one) could do was to calculate a series of estimates using conservative assumptions and present the basis and details for those estimates in sufficient detail that they can be recalculated as more information becomes available' (Leatherwood and Reeves, 1989,p.47).

POPULATION STATUS

Although small-scale aerial and vessel surveys have helped describe distribution, relative abundance and behaviour of cetaceans in some areas of Sri Lanka (e.g. Alling, 1986; Leatherwood and Reeves, 1989), there is virtually no information available on stock identity, size or status for any species. Even if there were, data on fishing effort and catches of small cetaceans are inadequate to reliably define any trends in catches of small cetaceans. Therefore, it is not possible to assess effects of removals on the populations involved.

RECOMMENDATIONS

A well-established system for collecting statistics on fish catches exists in Sri Lanka. Observers in fish-landing sites record fishing effort and catches daily or weekly; these data are regularly compiled for each of the 14 fish-landing districts and reported to a national data centre. Catches of cetaceans are not routinely included in catch reports; they are available for only a few sites regularly visited by officials. By training local fisheries officers in identification of cetaceans and making reporting of cetacean catches a routine part of their duties, Sri Lankan authorities could use the existing fisheries reporting system to assess magnitude of catches. Biological studies of caught specimens, as have been initiated by NARA, combined with extensive surveys of the fishing grounds and adjacent EEZ, are then needed to assess effects of catches on affected populations.

It is already illegal to take cetaceans in Sri Lanka (Leatherwood and Reeves, 1989). However, pressures from increasing human populations and economic problems in the country are defining government policies favouring expansion of resource harvesting. As favoured status, and thus full protection, for cetaceans is unlikely, a conservative management programme is needed. To succeed, this programme must educate fishermen and field workers about differences between reproductive potentials of fishes and marine mammals, and thus consequences of overfishing the latter, and provide for careful monitoring and regulation of takes.

The IWC Workshop (IWC, 1994), in addition to a variety of recommendations applicable to Sri Lanka as one of many nations with large cetacean by-catches, recommended that new fisheries not be initiated and that existing fisheries not be expanded until after evaluation of their effects on non-target species.

5.1.7 Platanista minor[8]

COMMON NAMES

Indus susu, Indus river dolphin, *bhulan* (Pakistan)

DISTRIBUTION

This dolphin formerly inhabited the Indus River system, from upstream as far as Attock to downstream below Hyderabad. The historic distribution included the major tributaries of the main channel: Ravi, Sutlej, Chenab and Jhelum (Reeves, 1991). The present distribution is much less extensive (Fig. 3). A few dolphins may survive upstream of Chashma Barrage and below Sukkur Barrage, but most of the population is downstream of Chashma Barrage and upstream of Sukkur Barrage. They are now absent from the tributaries above Panjnad Barrage (Khan and Niazi, 1989).

Upstream movement through barrages is very unlikely to occur, and downstream movement, while possible, is probably only sporadic (Reeves *et al.*, 1991). The extant population is divided into five isolated subpopulations (Khan and Niazi, 1989).

PROBLEMS AND CATCH STATISTICS

No official statistics of any kind appear ever to have been kept on dolphin catches in the Indus system. Information about takes is limited to what can be learned from the literature on scientific collections and live captures, totalling at least 6 and 11, respectively, since 1968 (Herald *et al.*, 1969; Pilleri, 1970a; b; 1972; Pilleri *et al.*, 1976).

[8] Initial draft by R.R. Reeves and R.L. Brownell, Jr.

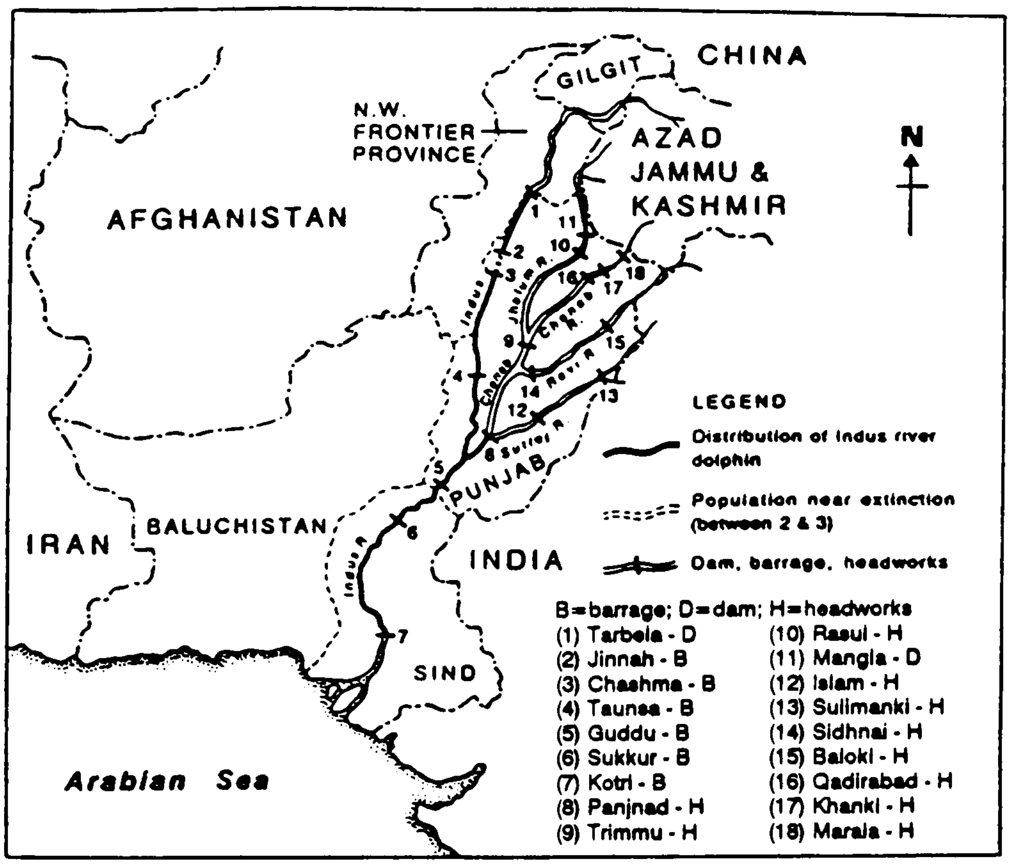

Fig. 3. Distribution of the Indus river dolphin.

Although the river dolphin has been legally protected in Sind province since 1972, the Punjab province since 1974 and the Northwest Frontier province since 1975 (Atkins, 1989), there have been reports of continued killing (Pilleri and Zbinden, 1974; Pilleri and Bhatti, 1978; Reeves, 1991). There is no reported regular incidental mortality in fishing gear or from boat collisions. However, fishing with gillnets, throw nets and various other gears takes place, and some motor traffic occurs, throughout much of the area inhabited by the dolphins.

The most serious conservation problem for this species is the loss of suitable habitat, including the partitioning of the metapopulation by barrages. All the barrages are being considered for retrofitting to produce hydroelectric power. The pressure is strong in Pakistan for intensified agricultural and industrial development, and the demand for water will certainly continue to grow.

POPULATION ESTIMATE

Counts of dolphins in the Sind Dolphin Reserve between Sukkur and Guddu barrages, carried out by the Sind Wild Life Management Board since the late 1970s, suggest a stable or increasing subpopulation there (Khan and Niazi, 1989). The most recent counts suggest a population size on the order of 400–450 dolphins. Because the details of survey methodology are unavailable, however, it is difficult to judge the validity of this estimate.

In the Punjab, counts by the Punjab Wildlife Research Centre between 1987 and 1990 indicate a subpopulation of about 100–110 in waters below Taunsa and Panjnad barrages and above Guddu Barrage (Chaudhry and Chaudhry, 1988; Chaudhry and Khalid, 1989; A.A. Chaudhry and U. Khalid, pers. comm. to Reeves, May 1990). The subpopulations in the Punjab and Northwest Frontier province upstream of Chashma Barrage and in Sind downstream of Sukkur Barrage range from a few to 10–20 individuals (Khan and Niazi, 1989; Chaudhry and Khalid, In press). Although the counts for the Punjab reported by Chaudhry and colleagues are substantially higher than those reported by Khan and Niazi (1989), there is no reason to suppose that the population has increased. Khan and Niazi's counts were made in discrete portions of the area (see Niazi and Azam, 1988), whereas Chaudhry *et al.* attempted 100% coverage.

ASSESSMENT AND STATUS

The Indus River dolphin is critically endangered because of its restricted distribution and low population size. The subpopulation between Sukkur and Guddu barrages receives some protection, and its distribution and population size are monitored regularly by the Sind wildlife authorities. The same is true of the subpopulation between Taunsa, Panjnad and Guddu barrages, although since this area lacks explicit status as a dolphin reserve, policing efforts may be less effective. Even if protection from direct exploitation were complete, which it probably is not (Reeves, 1991), the deterioration of habitat is likely to continue.

RECOMMENDATIONS

International support is urgently needed for developing a programme of field research that addresses immediate management problems. Research should include (1) continued regular monitoring of population size and distribution, (2) noninvasive efforts to identify and track the movements and activities of individual dolphins, (3) estimating calf production and calf mortality, (4) identifying limiting habitat parameters, (5) precisely mapping and monitoring existing utilised and vacant habitat along the full length of the river, (6) determining and quantifying the cause(s) of mortality generally, determining whether the subpopulations are increasing or decreasing and projecting future trends in the subpopulations. Potential reserve areas need to be surveyed and appropriate reports and recommendations prepared. The advisability and feasibility of creating ways to allow mixing of the artificial subpopulations should be studied, perhaps as a component of the hydroelectric development work being supported with foreign capital (Reeves *et al.*, 1991).

Enforcement and strengthening of existing protective laws and creation of additional reserves should be high priorities. International support may be needed to ensure adequate staffing, training and equipping of wardens. Further withdrawals of water from the main river channels for irrigation, power plant cooling or any other domestic or industrial use should be minimised. The Government of Pakistan and the international aid agencies involved in supporting development projects in the Indus basin should be made aware of the river dolphin's precarious status, required to assess the likely impact of the projects on dolphins and dolphin habitat, and encouraged to make every effort to reduce or eliminate any deleterious effects.

5.2 Incidental catches

5.2.1 Phocoena sinus[9]

COMMON NAMES

Vaquita, Gulf of California harbour porpoise

DISTRIBUTION

This porpoise is endemic to the warm-temperate waters of the upper Gulf of California. It has the smallest geographic range of any marine cetacean. A few sightings from farther south in the Gulf have not been confirmed. (Silber, 1990; Vidal, In press).

PROBLEMS AND CATCH STATISTICS

The vaquita has been incidentally caught in the gillnet fishery for totoaba (the large sciaenid fish *Totoaba macdonaldi*) since the mid-1920s (Vidal, In press). The fishery peaked in the 1940s and declined as the totoaba was depleted. The totoaba became fully protected in 1975, but the fishery has continued at lower levels, both as a legal experimental fishery and illegally. In addition, the vaquita is taken incidentally in gillnets in a growing shark fishery and a fishery for sierra (*Scomberomorus* sp.) and in shrimp trawls. The historical levels of incidental catches are impossible to reconstruct because of lack of information on fishing effort and vaquita catch rates. Records are available for 85 vaquitas taken incidentally since 1985 (Vidal, In press). This undoubtedly represents a very small proportion of the total mortality from fishing operations. The available information suggests that 30–40 vaquitas are killed each year (IWC, 1991c). Most recently, 13 vaquitas have been caught in the totoaba fishery during February and March this year (O. Vidal, pers. comm., 1991; not included in Vidal, In press).

POPULATION ESTIMATE

The size and status of the vaquita population are unknown. Extensive surveys by Silber (1990) and co-workers 1986–89 resulted in sightings of only 110 individuals in all surveys combined. Considering the scarcity of sightings relative to survey effort, the few individuals per sighting, and the very limited geographic range of the species, there can be no doubt that the population is very small, perhaps in the low hundreds (IWC, 1991c).

ASSESSMENT AND STATUS

The vaquita is the most endangered marine cetacean. The relatively high incidental catches and the difficulties and costs of enforcing long-term conservation measures quickly lead to the conclusion that the vaquita is in immediate danger of extinction (IWC, 1991c).

RECOMMENDATIONS

Because of the precarious status of the single population of this species, the Scientific Committee in 1990 (IWC, 1991b) recommended that further action be taken to stop the major cause of entanglement by fully enforcing the closure of the totoaba fishery and reconsidering the issuance of future permits for experimental totoaba fishing, that immediate action be taken to stop the illegal shipment of totoaba (also and endangered species) across the US border, and that a management plan for the long-term protection of this species and its habitat be developed and implemented. The plan should include: (1) an evaluation of other fisheries that take or may take vaquitas; (2) investigation and implementation of alternative methods of fishing or other economically viable activities to prevent further incidental mortality; (3) education of the local fishermen and general public to increase awareness of the vaquita's dangerous situation; (4) monitoring of the status of the population of vaquitas; and (5) studies of the population biology of the species.

5.2.2 Lipotes vexillifer[10]

COMMON NAMES

Baiji, Chinese river dolphin

DISTRIBUTION

The species is presently restricted to the lower and middle Yangtze River, from the mouth to Yichang below the Three Gorges, where it occurs in small scattered groups over a distance of more than 1,000 km (Ridgway, 1966). It formerly occurred in other rivers and in the lakes feeding into the Yangtze.

PROBLEMS AND CATCH STATISTICS

The decline of the baiji is due to several causes: (1) habitat degradation (through depletion of fish stocks, development for water conservation and irrigation, and riverbank development, including explosion during construction), (2) increased river traffic resulting in deaths due to collisions with vessels, and (3) harmful fishing practices (Peixun and Yuanyu, 1989). The harmful fishing practices include the use of illegal bottom snaglines ('rolling hooks') and electrofishing. In 1984, in the section of the river from Honghu to Wuhu, 7 baiji were killed in explosions, 10 in illegal fisheries and one in electrofishing. Incidental kill data are not available for the entire length of the range of the species or for more recent years.

POPULATION ESTIMATE

The total number of baiji is estimated at 300 (Peixun and Yuanyu, 1989). This estimate is based on surveys conducted in 1985 and 1986. The density of dolphins per km of river searched ranged from 0.09 to 0.39. Further population surveys are planned.

ASSESSMENT AND STATUS

There is no estimate of original population size, but the range has contracted in historical times. The decline is thought to have been particularly steep during the last 35 years, as the Yangtze Valley has become industrialised and the river itself more heavily used (Perrin and Brownell, 1989).

RECOMMENDATIONS

The Workshop on Biology and Conservation of the Platanistoid Dolphins at Wuhan, People's Republic of China, in 1986 made a series of recommendations concerning conservation and management (Perrin and Brownell, 1989).

[9] Initial draft by W.F. Perrin.

[10] Initial draft by W.F. Perrin.

(1) Further efforts should be made to eliminate or reduce the use of the 'rolling hook' fishing gear in the regions of high dolphin density.
(2) Procedures should be developed to ensure that dolphins are absent or removed from the area before explosives are used in river-bank construction.
(3) All the proposed and additional natural reserve areas should be established along the river, with commitment of sufficient resources for effective enforcement of protective regulations.
(4) The two proposed semi-natural reserves at Shishou and Tongling should be constructed and the health of the captured dolphins placed in them monitored closely. Hydrologic surveys of the probable effects of high-dam construction on both sites should be carried out. Before dolphins are placed in the reserves, thorough studies of levels of contaminants in the water, bottom sediments and food fish should be completed. Seasonal change in the quantity and nutritive quality of the food fish should also be analysed. Finless porpoise should not be placed in the reserves; they may compete with the baiji for food in the situation of decreased species diversity of food fishes.

Since the workshop, several of these recommendations have been acted on. A patrol vessel has been put in service to enforce the ban on the use of 'rolling hooks'. An additional natural reserve has been established, and construction of the semi-natural reserve at Tangling has nearly been completed. An environmental study of the site of the proposed semi-natural reserve at Shishou has been carried out.

In addition the sub-committee **recommends** that monitoring of the population status should be continued.

5.2.3 Tursiops truncatus *on the Natal South Coast of South Africa*

COMMON NAMES

Bottlenose dolphin, *stumpneusdolfyn* (Afrikaans)

DISTRIBUTION

The bottlenose dolphin is found in tropical and temperate coastal waters around the world and in offshore waters in some regions (e. g. the eastern tropical Pacific: Scott and Chivers, 1990). In South African waters, the South Natal Coast population is apparently resident in a range approximately 30–40 km long (Ross *et al.*, 1989). Roughly 80–90% of dolphins seen in aerial surveys were within one km of the shore.

PROBLEMS AND CATCH STATISTICS

Approximately 20 dolphins die annually in anti-shark gillnets (Cockcroft, 1990; IWC, 1994). Most of the kill is made up of lactating females and their calves.

POPULATION ESTIMATE

Ross *et al.* (1989) estimated the population at 219–249, although some assumptions and factors in the assessment probably cause this to be an underestimate. They suggested a need for offshore aerial surveys, more detailed data on home range and daily movement patterns to assist in assessing the reliability of the aerial survey estimates, a means for estimating percentage of schools missed on the trackline, and mark-resighting studies of individual schools. Some of these problems were addressed in a series of surveys flown along the north coast of Natal in 1989 (Cockcroft *et al.*, 1991), from which it was estimated that the probability of seeing a dolphin group was 0.31 (approximate confidence limits 0.15, 0.46).

ASSESSMENT AND STATUS

The population may have been under pressure from the shark nets since 1952 (Ross *et al.*, 1989). The original size of the population is unknown. Although population size has been estimated as 219–249, the results of Cockcroft *et al.* (1991) suggest that this might be a substantial underestimate. Even so, the annual take of about 20 may be more than can be sustained, and it is likely that the population is declining (IWC, 1994).

RECOMMENDATIONS

Research needed to improve the population estimate is described above. The IWC Workshop (IWC, 1994) recommended that the killing of bottlenose dolphins in Natal waters be reduced immediately and that an immediate reassessment of deployment of the anti-shark nets be carried out. Information is also needed on relationships among contiguous stocks or herds of bottlenose dolphins.

5.2.4 Stenella coeruleoalba *in the Mediterranean Sea*[11]

COMMON NAMES

Striped dolphin (English), *delfin listado* (Spanish), *dauphin bleu et blanc* (French).

DISTRIBUTION

The striped dolphin is found in tropical and temperate waters worldwide. It is one of the most abundant cetacean species in Mediterranean waters. Its distribution extends over both the eastern and the western basins, although it appears to reach higher densities in the latter. It prefers deep waters and is usually found beyond at least 5–10 miles of the coast with the highest densities being probably reached in open waters.

PROBLEMS AND CATCH STATISTICS

Because of their pelagic habits, striped dolphins do not usually interact with coastal and artisanal fisheries. The major problems appear to be pollution, incidental catches in offshore drift nets.

(i) Pollution

This is probably the most acute long term problem for the population. Western Mediterranean striped dolphins are amongst those mammals in which the highest concentrations of organochlorine pollutants have ever been detected. The blubber of specimens stranded on the Mediterranean coast of France showed concentrations averaging 267 ppm for PCBs and 344 ppm for DDTs (Alzieu and Duguy, 1979) and free-ranging striped dolphins off Spain carried levels averaging 326 ppm of PCBs and 165 ppm of DDTs (Aguilar and Perrin, 1988). Concentrations of heavy metals, especially mercury, are also known to be extremely high (Viale, 1978; 1981; Sanpera *et al.*, unpub. data). Although no studies to establish the impact of these pollutant levels on the population have been carried out, it is well documented that some pollutants, especially organochlorines, depress reproductive rates, produce alterations in skeletal development, and depress the immune system of mammals (Luster and Faith, 1979; Nicholson and Moore, 1979).

[11] Initial draft by A. Aguilar.

In 1990 an epizootic process broke out in the western Mediterranean and produced thousands of deaths of striped dolphins. The ultimate cause was found to be a morbillivirus infection, although levels of PCBs in diseased dolphins were found to be higher than in the healthy population, suggesting that individuals carrying high pollution loads were more susceptible to the disease. Also, abnormal weather conditions that decreased water productivity in the region (and subsequent lack of food for the dolphins) may have also played a role by weakening the dolphins and facilitating the infection and spreading of the disease (Aguilar and Raga, 1990).

(ii) Catches

The striped dolphin is seldom caught in coastal gillnets, bottom trawlers or long-line fishing (Duguy *et al.*, 1983). However, the recent development of pelagic gillnet fisheries in Italian, Spanish and African Mediterranean waters produced considerable by-catches of this species in the late 1980s (Magnaghi and Podesta, 1987; di Natale, 1990; di Natale and di Sciara, 1990). Large-scale drift nets were temporarily banned in 1990 in Italy and strictly regulated in Spain in 1991. However, some limited drift net operations by foreign flag vessels in the southern Mediterranean still remain totally unregulated. The Government of Italy is reportedly considering whether the temporary ban instituted last year will be continued. Very recent, and as yet unconfirmed, information indicates that Italian vessels may be permitted to restart driftnetting in 1991 [*The ban was lifted – Ed*]. Reliable quantification of past and current incidental kills of striped dolphins in the Mediterranean is not available. Illegal directed kills of striped dolphins also occur in France, Italy, southern Spain and northern Morocco at least (Duguy *et al.*, 1983; Aguilar, unpub. data; di Natale, 1990).

POPULATION ESTIMATE

The Mediterranean population of striped dolphins appears to be independent of that inhabiting North Atlantic waters, although some limited mixing through the Gibraltar Straits probably exists (Aguilar and Perrin, 1988). No reliable population estimate for the Mediterranean population of striped dolphins is available. In the western basin it has been suggested that the species may have expanded in the last decades to occupy the ecological niche of the common dolphin, a species in clear recession (due to unknown causes), at least in the northern fringe of the western Mediterranean (Viale, 1985).

ASSESSMENT AND STATUS

Because of lack of reliable information of population abundance, population trends and biological parameters, the status of the species in the Mediterranean can not be assessed. However, the pressure of human activities, especially through pollution, incidental catches and decrease of prey abundance is undoubtedly adversely affecting the population.

RECOMMENDATIONS

IWC (1994) recommended that actions similar to the ban instituted by Italy should be encouraged elsewhere in the Mediterranean, and that international co-operation and action by the General Fisheries Council for the Mediterranean (GFCM) are required to ensure that large scale driftnet fisheries do not restart from other nations, or that reflagging for the purpose of continuing the fishery does not occur. A second recommendation was that wherever possible the consequences of banning drift nets for the fishermen involved should be studied, the economic impacts on the fishing community appraised and the subsequent development of alternative fishing methods monitored.

The sub-committee **recommends** that research efforts should be devoted to:

(i) monitoring pollutant levels, especially organochlorines and heavy metals, and assessing their effect on population parameters such as reproductive rates, body and skeletal growth, and immunological strength;
(ii) monitoring incidental and direct catches and identifying the fishing gear and areas in which the highest mortality occur;
(iii) determining population size, structure and stock identity, and estimating local abundance, especially in the regions affected by the 1990 epizootic;
(iv) monitoring fishing and anomalous natural mortality through examination of stranded animals. This will also permit continued monitoring of the health status of the population through necropsy.

The sub-committee also **recommends** that management measures should be adopted to ensure the enforcement of existing laws to restrict harmful fishing operations, and the reduction of pollutant shedding into Mediterranean waters.

5.2.5 Phocoena phocoena *in the western North Atlantic*[12]

COMMON NAMES

Harbour porpoise, common porpoise, *marsouin commun, pourcil*, (French); puffin' pig.

DISTRIBUTION

Distributed primarily in temperate and subarctic waters of the Northern Hemisphere, in the western North Atlantic, the distributional limits of this species are Upernavik (72°N) and northern Florida (28°N) (Gaskin, 1984; Polacheck *et al.*, In press). The vast majority of sightings have been made over the continental shelf, although harbour porpoises are occasionally found in deep waters further offshore (Stenson and Reddin, 1990). Gaskin (1984) suggested the existence of four stocks in the western North Atlantic based on indirect evidence from patterns of distribution and seasonal movements. From north to south, these proposed stocks are: (1) western Greenland, (2) eastern Newfoundland and Labrador, (3) Gulf of St. Lawrence, and (4) Bay of Fundy, Gulf of Maine and southwestern Scotian Shelf. Porpoises in all four stocks exhibit seasonal migrations and are common in inshore waters only during the summer months (Gaskin, 1984).

PROBLEMS AND CATCH STATISTICS

Harbour porpoises have been subjected to both directed hunting and incidental catches in commercial fisheries throughout their range. Aboriginal hunters in western Greenland took between 400 and 900 porpoises per year between 1900–50 and between 600 and 1,200 from 1950–87 except for the period 1968–71 when the catch was between

[12] Initial draft by A. Read.

1,300 and 1,500 (Kapel, 1977 and Danish Progress Reports to the IWC). It should be noted, however, that the reliability of the Greenlandic hunting statistics has been deteriorating during recent years. Harbour porpoises were also hunted in the Gulf of St. Lawrence (Laurin, 1976) and Bay of Fundy (Leighton, 1937; Prescott and Fiorelli, 1980) until recently (Gaskin, 1984). There are no reliable records of direct exploitation of this species in the waters of Newfoundland and Labrador.

Large numbers of harbour porpoises have been killed in salmon gillnets off the western coast of Greenland for several decades (Lear and Christensen, 1975). Foreign vessels were estimated to have taken approximately 1,500 porpoises in 1972 (Lear and Christensen, 1975) and the catch of the domestic fleet may have been almost as large (Kapel, 1977). No recent data exist on the numbers of porpoises killed in this fishery, although foreign vessels have been excluded since 1976 (Kapel, 1977). There is, however, reason to believe that the number of porpoises killed in this fishery has decreased since 1975 as the salmon quota has gone down from 2,000 tonnes in 1972 to around 800 tonnes in the most recent years (Lear and Christensen, 1975; Larsen, pers. comm.).

In Newfoundland and Labrador, harbour porpoises are killed in salmon gillnets, cod traps and groundfish gillnets. In 1980, 100 fishermen in Newfoundland reported taking 243 harbour porpoises in gillnets (Lien *et al.*, 1987). It is not possible to extrapolate a total catch from these data, because sampling was not proportional to fishing effort and no estimates of total effort are available. Nevertheless, the total annual incidental catch of harbour porpoises in this region probably numbers in the low thousands (Lien *et al.*, 1987).

Fontaine *et al.* (1992) sent questionnaires to 968 coastal fishermen in the Gulf of St. Lawrence and asked them how many porpoises they encountered in their nets during 1988. One-third of the fishermen responded, reporting that they caught 623 porpoises, mostly in groundfish gillnets. It is not known whether or not the respondents were representative of the entire fishing community, but it is clear that the incidental catch of harbour porpoises in the Gulf of St. Lawrence is substantial.

Harbour porpoises are also captured by bottom tending gillnets and herring weirs in the Bay of Fundy and Gulf of Maine (Smith *et al.*, 1983; Read and Gaskin, 1988). The largest incidental catches in this area are recorded by the groundfish gillnet fisheries. Reported kills by fishermen from the western Bay of Fundy and data on observed kill rates in the Gulf of Maine, combined with information on gillnet effort, suggest that the incidental catches are substantial, and it is has been suggested that recent takes are on the order of 300 to 800 animals per year (IWC, In press). However it is not currently possible to extrapolate observed kill rates for the Gulf of Maine to obtain an accurate estimate of total takes for this area because of the non-representative sample of vessels from which kill rate data were obtained and problems with spatial/temporal resolution in the gill net effort data (Smith *et al.*, 1990). In addition, no information is available on possible kills in the eastern Bay of Fundy and the western Scotian Shelf. There are a few confirmed reports of incidental catches from fixed gear in waters south of Cape Cod during winter months (Polacheck *et al.*, In press). Current efforts by the US National Marine Fisheries Services (NMFS) are directed at improving estimates of incidental catches by placing observers aboard gillnet vessels in the Gulf of Maine (Payne *et al.*, In press).

POPULATION ESTIMATES

No reliable population estimates are available for harbour porpoise stocks in Greenland, Newfoundland and Labrador, or the Gulf of St. Lawrence. Aerial surveys in the Gulf of Maine resulted in a minimum abundance estimate of 3,541 ±1,486 (Winn, 1982). Kraus *et al.* (1983b) performed a shipboard survey of the inshore waters of the Gulf of Maine and estimated harbour porpoise abundance at 7,956 ±1,327. The results of an experiment on census techniques indicated that aerial and shipboard surveys both under-estimate actual harbour porpoise density because only a small proportion of individuals are at the surface when the survey vessel passes (Kraus *et al.*, 1983a). Application of *ad hoc* correction factors derived from this experiment suggests that actual abundance was at least 15,000 when these surveys were performed. It was noted that these surveys may have missed a substantial proportion of the range of the population in this area, so that this may still be a considerable underestimate of the true population size (IWC, 1991c). A comprehensive census of harbour porpoises in the Bay of Fundy and Gulf of Maine is planned by NMFS during the summer of 1991.

ASSESSMENT AND STATUS

A lack of accurate data on the magnitude of directed and incidental mortality prevents definitive assessments of the status of harbour porpoises in Greenland, Newfoundland and Labrador, and the Gulf of St. Lawrence. Preliminary evidence, however, suggests that incidental catches are large in these areas and are thus cause for concern. Two recent reviews (IWC, 1991c; 1994) have concluded that the incidental catch of harbour porpoises in the Bay of Fundy and Gulf of Maine is unlikely to be sustainable. These reviews both recommended that steps be taken immediately to reduce the incidental mortality of harbour porpoises in this region. At the present time, harbour porpoises are listed as 'threatened' in eastern Canada by the Committee on the Status of Endangered Wildlife in Canada (Gaskin, 1989). A status review of this species in the United States is currently being performed by NMFS.

RECOMMENDATIONS

In 1990, the Scientific Committee (IWC, 1991c) recommended that research be undertaken to (1) improve understanding of harbour porpoise stock identity, (2) estimate abundance for all stocks, and (3) refine estimates of the magnitude of directed catches and incidental mortality for all stocks. Also to, (4) conduct a joint US-Canada comprehensive sighting survey in the Bay of Fundy, Gulf of Maine and adjacent waters. Each of these research initiatives will require a substantial investment of time and resources. In addition, research should address degradation of the coastal habitat of this species and the effects of contaminants on the condition of particular stocks. Research is underway for these recommendations in the Bay of Fundy and Gulf of Maine. Further, more general, recommendations on harbour porpoise research were made by the Scientific Committee in 1990. These are summarised in Item 5.2.7 below.

The large kills of harbour porpoises in commercial fisheries, combined with substantial uncertainty regarding many aspects of the biology of this species, led the Scientific Committee to recommend that levels of incidental mortality be reduced throughout the range of the species.

5.2.6 *Phocoena phocoena in the eastern North Atlantic*[13]

COMMON NAMES

Harbour porpoise (English), *bruinvis* (Dutch), *Schweinswal* (German), *marsvin* (Danish), *tumlare* (Swedish), *nise* (Norwegian and Faroese), *muc mhara* (Irish), *Marsouin* (French), *Marsopa* (Spanish).

DISTRIBUTION

Although recent surveys show an offshore, oceanic occurrence of the harbour porpoise, this species is primarily distributed in coastal waters of the temperate and subarctic zone throughout the Northern Hemisphere, with a population occurring as far south as Senegal in the East Atlantic (IWC, 1991c). The extensive shallow waters of the North Sea are probably the most important habitat for harbour porpoises in the Northeast Atlantic.

PROBLEMS AND CATCH STATISTICS

The sub-committee on small cetaceans expressed concern for the status of the stock when it reviewed available information in 1990, and listed incidental catches, depletion of prey populations, pollution and human disturbances as possible threats to porpoise populations in these areas (IWC, 1991c).

Most countries in the region have legislation protecting the harbour porpoise. The only reported directed catches of harbour porpoises are small takes in the Faroe Islands, and these takes are likely to have a negligible effect on the stock. Habitat degradation and incidental catches in fishing gear have been proposed as more significant threats to harbour porpoises in this region.

The seasonal migration of porpoises through the Danish Belt Seas into the Baltic is well known (Möhl-Hansen, 1954). This migration through shallow and narrow waters gave rise to the long history of the Danish harvest of porpoises. This historical hunt is described by Kinze (in prep), who mentions six major catching sites. The most important site was the northern Little Belt, which was operative in the period from 1357 to 1892 and in the years 1916–19 and 1941–44. The overall annual take for this site may have been about 1,000 animals, with a minimum total take of 47,432 animals from 1827 to 1892. According to Kinze, this hunt continued for about five centuries. However, in the 1880s the annual catches increased and may have initiated the decline of the 'Baltic population' of porpoises. The relative importance of these takes compared with other negative influences on the Baltic population is unknown.

Clausen and Andersen (1988) collected 149 porpoises mainly from coastal gillnet fisheries in Danish waters during 1980 and 1981. They also noted the existence of further catches in wreck nets worked further offshore in the southern North Sea. They proposed a total catch of several thousand by Danish vessels in the North Sea. Kinze (1990a) reported the capture of 152 porpoises in Danish fisheries, mainly in the Skagerrak, between 1986 and 1989. One vessel, from a fleet of 15 similar vessels at Hantsholm, was monitored individually in 1988 and 1989. An annual catch rate of 30 porpoises was recorded, which lead Kinze to speculate that this fleet may take around 450 per year. Further catches are reported in gillnets in Danish waters.

Further incidental takes in the order of tens to a few hundreds are reported from most other countries in the region (e.g. Northridge, 1988; Kremer and Schulze, 1990; Northridge and Lankester, 1990; Benke *et al.*, 1991). About 100 porpoises were recorded incidentally caught in a six-week period in 1988 by a drift net fishery for salmon in Norwegian coastal waters. The use of salmon drift nets was prohibited in Norway after the 1988 fishing season. Other Norwegian gillnet fisheries are known to catch porpoises, but less so than the former drift net fishery for salmon (Bjørge and Øien, 1990). Since the summer of 1988, a systematic scheme for collecting incidentally caught porpoises in Sweden has resulted in the collection of 178 individuals to December 1990, most of which came from gillnets in the Kattegat and Skagerrak (Lindstedt, 1990).

POPULATION ESTIMATES

The only estimates of population size based on survey results, are those of Bjørge and Øien (1990), who reported an estimated abundance of harbour porpoises in the Lofoten-Barents Sea area of 10,994 (CV 0.2381), and in the northern North Sea of 82,619 (CV 0.2165). There is little information on population trends in this area. In the Baltic Sea it is clear that harbour porpoise abundance has declined during this century (Andersen, 1982; Skora *et al.*, 1988; Määttänen, 1990). In the North Sea the situation is far from clear. The relatively large number of porpoises found in the central and northwestern North Sea gives no reason to neglect the possibility of a depletion of porpoise populations in neighbouring areas. Evans (1990) has reported declines in porpoise abundance in three separate areas in the Shetland Islands on the basis of boat surveys carried out locally in the early and late 1980s. Such results are difficult to interpret when so little is known of population distribution.

The stock identity of porpoises in the eastern North Atlantic is not well understood. A non-metric analysis of a large series of harbour porpoise skulls suggested the existence of several population units in this region (Kinze, 1990b), and a study based on isoenzyme electrophoresis indicated distinct Dutch and North Sea populations (Andersen, 1990).

ASSESSMENT AND STATUS

Although no single fishery is known to have a dramatically high incidental catch of porpoises (except for the possible large take in some Danish fisheries reported by Clausen and Andersen (1988)), the species is taken incidentally throughout the region, and there is a fear that the overall incidental catches could be above the sustainable level for the total population in the area. Although no reliable information is available at present on the population structure in the North and Baltic Seas, indications of distinct sub-populations exist. Taking into account the uneven distribution of fisheries, the impact of bycatches on any distinct sub-population may be more significant than overall takes on the total population in the northeast Atlantic region.

RECOMMENDATIONS

At its 1990 meeting, the Scientific Committee recommended, as a high priority, that incidental kills of harbour porpoises in gillnets should be reduced throughout their range (IWC, 1991c). Possible ways to reduce incidental kills include gear modifications, gear conversions, area or season closures and other restrictions in the fisheries.

The importance of determining harbour porpoise stock identities was also highlighted by the Scientific Committee in 1990 and it recommended that studies on stock identity should be undertaken through an integrated approach that

[13] Initial draft by A. Bjørge.

includes a combination of pollutant levels, calving areas, non-metric variation, DNA allozymes and other types of research that may contribute to stock discrimination.

The Committee also recommended:

(1) that the methodology for these different approaches be standardised so that results are comparable;
(2) that where distribution extends beyond the boundaries of a single country, available samples and data should be pooled from as many potential sub-populations as possible, across national boundaries, and be analysed together;
(3) that for the northeastern Atlantic the information on potential stocks, distribution, and other relevant data be synthesised in an attempt to produce a clearer picture of the stock identities in that region;
(4) that abundance be estimated for populations where no such estimates exist, and especially for those for which there is or may be a large incidental kill;
(5) that such studies consider the possibility that apparent declines in abundance may result from geographic shifts in distribution. Trends in abundance should be monitored on the basis of systematic surveys;
(6) that dedicated sightings surveys should be conducted in the North and Baltic Seas;
(7) that attention should be given to estimating g(0) for harbour porpoise surveys;
(8) that behavioural studies of free ranging harbour porpoises should be made to gain knowledge of habitat requirements in order to provide a framework for establishing management plans for the species and its habitat;
(9) that tissues of stranded and incidentally killed harbour porpoises should be collected and analysed in order to monitor their contaminant levels;
(10) that monitoring of pollutants be integrated with research on reproductive biology and other population parameters to increase the understanding of the possible effects of contaminant loads on the condition of the populations (this was considered especially important in the northeast Atlantic region);
(11) that a high priority be given to monitoring, as well as reducing, levels of incidental mortality in all fisheries;
(12) that when questionnaire and interview methodology is used to investigate or monitor incidental catches, studies of reliability and scaling of reported take estimates should also be included.

An additional recommendation is that all countries of the northeast Atlantic region should implement a recording scheme for incidental captures of harbour porpoises in their waters.

5.2.7 High Seas driftnet fisheries

5.2.7.1 *North Pacific*

Driftnet fisheries in the North Pacific Ocean include the following: (1) Japanese salmon drift gillnet fishery, (2) Japanese, Taiwanese and Korean drift squid gillnet fishery and (3) Japanese and Taiwanese large mesh drift gillnet fishery for tunas and billfishes. The major small cetaceans taken in these fisheries are the northern right whale dolphin, *Lissodelphis borealis*, Pacific white-sided dolphin, *Lagenorhynchus obliquidens* and Dall's porpoise *Phocoenoides dalli*. Other small cetaceans that are known or likely to be taken included common dolphin, *Delphinus delphis*, striped dolphin, *Stenella coeruleoalba*, bottlenose dolphin, *Tursiops truncatus*, Risso's dolphin, *Grampus griseus*, spotted dolphin, *Stenella attenuata*, pygmy killer whale, *Feresa attenuata*, pygmy sperm whale, *Kogia* spp. and ziphiids. The three major species are reviewed in turn below.

Lissodelphis borealis[14]

COMMON NAMES

Northern right whale dolphin; *semi-iruka* (Japanese); *severnyi kitovidnyi del'fin* (Russian).

DISTRIBUTION

The northern right whale dolphin is a cold-temperate water species endemic to the North Pacific Ocean. In the eastern North Pacific, it has been sighted from about 32° to 58°N (Fig. 4; Leatherwood and Walker, 1979; Kajimura and Loughlin, 1988). In the western North Pacific, the southern limit is as far south as 35°N from September to June (Kasuya, 1971) and about 40°N in the remainder of the year (Fig. 4); the northern limit is the southern Kurile Islands (Sleptsov, 1952; Klumov, 1959). The southern boundary in the central North Pacific is about 35°N (Fig. 4). Their temperature range is about 8° to 24°C, although the majority of the sightings have been in temperatures of 11°to 17°C (Fig. 4; Dohl *et al.*, 1983). Based on sightings

[14] Initial draft by L.L. Jones and E. Miller.

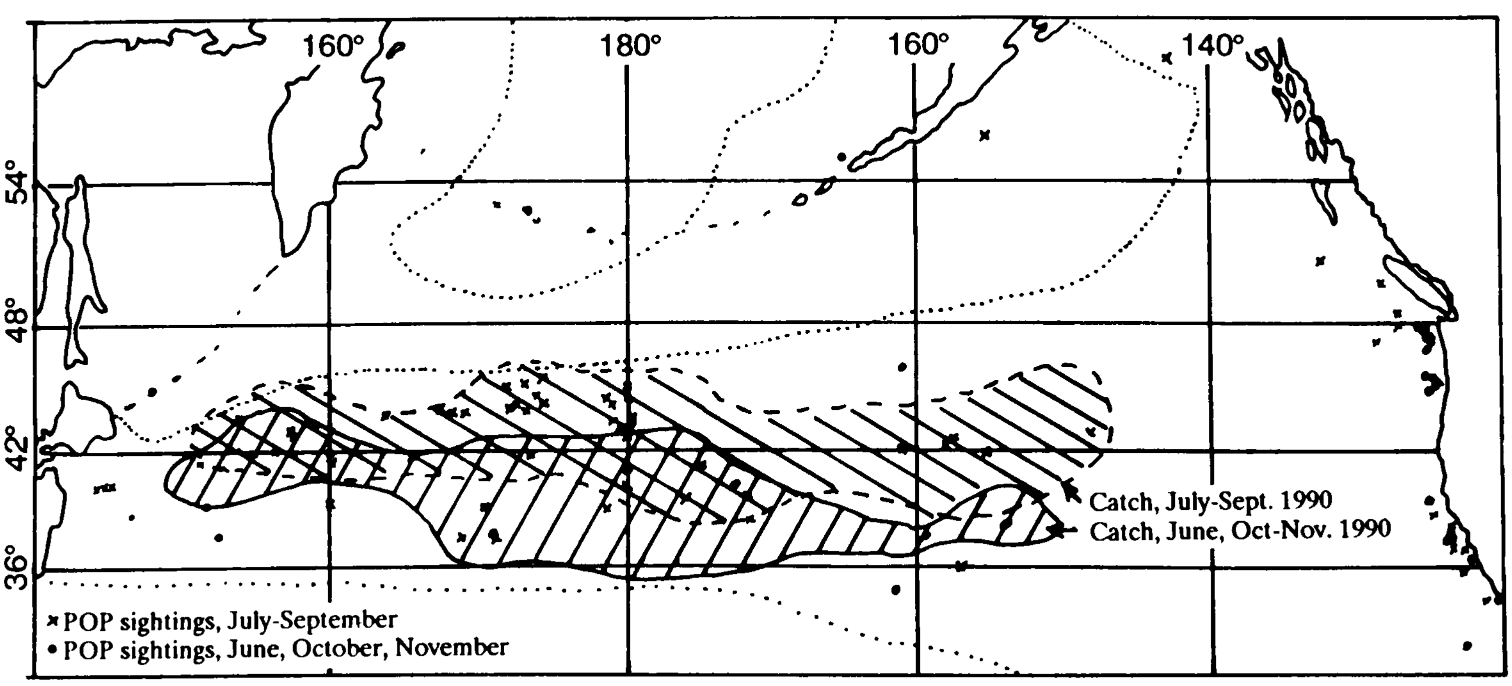

Fig. 4. Sightings of *Lissodelphis borealis* (1958–89) and high seas driftnet catch areas in 1990.

and bycatch data, off the Pacific coast of Japan and in the central North Pacific, seasonal movements appear to be related to the seasonal movements of the waters of the North Pacific Transition Zone.

Although this species occurs predominately in offshore waters, it does occur seasonally over the continental shelf in winter and spring off California (Leatherwood and Walker, 1979). Off Oregon and Washington it is also sighted more frequently nearer to shore in the colder water months (November to June; Fig. 4).

No colour morphs have been reported, although colour variants have (Nishiwaki, 1972; Leatherwood and Walker, 1979). Nishiwaki (1972) proposed two subspecies based on differences in colour pattern and dental formulae. However, Leatherwood and Walker (1979) examined these characteristics from animals from the eastern North Pacific and concluded there was not sufficient evidence for two subspecies.

PROBLEMS AND CATCH STATISTICS

Large numbers of northern right whale dolphins are currently taken incidentally in several high seas driftnet fisheries. Seven driftnet fisheries operate in the high seas in the North Pacific: Japanese squid, salmon mothership (now called the non-traditional landbased), salmon (traditional) landbased, and large-mesh for tuna and billfishes; Korean squid; and Taiwanese squid and large-mesh for tuna and billfishes. The northern right whale dolphin is probably taken in all except the salmon fisheries.

The largest known incidental take of northern right whale dolphins is in the Japanese high seas squid driftnet fishery which began in 1978. This fishery expanded rapidly, to a peak of 534 boats in 1981. In 1990, there were 457 vessels in the Japanese fleet which conducted 23,588 driftnet operations, deploying about 1,200,000 km of net (data from the Fisheries Agency of Japan).

Using a simple ratio estimator with the observed catch rate from June to September 1989, and reported fishing effort for the entire fishing season (33,646 operations, June-December 1989), nearly 11,000 northern right whale dolphins are estimated to have been incidentally taken by the Japanese high seas squid fishery in 1989. This estimate is based on a pilot observer programme in which 1,402 out of 33,646 driftnet operations (about 4%) were observed. The majority of the dolphins caught were dead but some (2%) were released alive. The survival rate of dolphins released is unknown.

In 1990, the scientific observer programmes were expanded in all the high seas driftnet fisheries in the North Pacific to increase observer coverage substantially and to cover all fishing seasons and grounds. These data are currently being analysed to provide more accurate estimates of the annual incidental take in these fisheries over the fishing areas and seasons. Summaries of the catch data from these fisheries will be available in June 1991.

Catch rates of northern right whale dolphins in other high seas driftnet fisheries may be lower than that of the Japanese squid fishery. Although the general fishing methods are similar, the driftnet fisheries use different mesh sizes, different amounts of net, and fish in different areas at different times of the year (Jones *et al.*, 1990). For example, the fishing grounds occupied by Korean squid driftnet vessels overlap with those occupied by Japanese squid driftnet vessels less than one-third of the season, mainly in June. The remainder of the season the Korean vessels fish further west than do Japanese vessels. Taiwanese vessels also tend to operate further west than the Japanese squid vessels. Therefore, applying take rates from one fishery to another may result in inaccurate estimates of the total incidental take for a species.

Two previous calculations for incidental take of northern right whale dolphins in high seas driftnet fisheries have been reported. Northridge (In press) provided a crude estimate of some 19,000 northern right whale dolphins taken in the three squid fisheries in 1989. This estimate was based on the gross catch rate observed in the Japanese squid driftnet fishery (Gjernes *et al.*, 1990) and an assumed total fishing effort of 3,000,000 km of netting set. This latter figure was based on the reported numbers of vessels operating in 1988 in each of the three fleets, with some allowance for differences in the average amounts of netting deployed by vessels from each of the three fleets. The actual fishing effort may have been lower than this in 1989, as the number of vessels and catch by the Republic of Korea which were recently reported by the Korean Government were lower than assumed by Northridge.

Beamish *et al.* (1989) stated that 50,718 northern right whale dolphins were caught each year in high seas squid driftnet fisheries. Their calculation was based on a total of 63 retrieval observations collected in 1986 and 1988, and the reported Japanese squid fishing effort in 1987. They also assumed the same kill rate for all fisheries and estimated the fishing effort for the Korean and Taiwanese fisheries as a proration of the Japanese fishing effort, based on the number of vessels in each fishery.

These two estimates of total kills demonstrate the problems inherent in extrapolating estimates of kill rates to entire fleets when adequate data on all parts of the fleet are not available.

In addition to these catches in driftnet fisheries, the northern right whale dolphin has been hunted in Japan historically (Gilmore, 1951; Wilke *et al.*, 1953; Mitchell, 1975a). Ohsumi (1972) reported that harpoon fishermen took northern right whale dolphins when billfish and tuna catch was low. From 1976 to 1982, a total of 252 northern right whale dolphins were reported caught by the harpoon fishery for Dall's porpoise (*Phocoenoides dalli*) off Sanriku in northern Honshu (Miyazaki, 1983). This species currently is also incidentally taken by Japanese coastal driftnets. The reported catch in 1988 was 268 (Anonymous, 1990d). Small numbers are also taken in gillnet fisheries in California (IWC, 1994).

POPULATIONS AND ESTIMATES

The northern right whale dolphin is reported to be an abundant species in temperate waters. Nishiwaki (1972) provided an unrealistic low abundance estimate of 10,000 northern right whale dolphins in the North Pacific Ocean. Subsequently, Leatherwood and Walker (1979) estimated the population in the Southern California Bight in winter, when density is known to be highest, to be about 17,800 (no variance given). Japan has conducted sightings surveys in offshore areas, including the area of the driftnet fishery. Results from these surveys will be presented in the near future. US sightings data are also currently being analysed to provide abundance estimates for the offshore area of the North Pacific.

ASSESSMENT AND STATUS

The number of stocks which the fisheries affect is not known, but probably includes more than one stock. Lacking population estimates and information on stocks, and with only a preliminary estimate of incidental take in one fishery, status of the northern right whale dolphin is unknown. However, large incidental catches for more than ten years raise concern for possible impacts by these fisheries, and the Scientific Committee (IWC, 1994) considered that the large catches of northern right whale dolphins were potentially not sustainable.

ADDITIONAL INFORMATION NEEDS

Incidental take in the high seas driftnet fisheries will continue to be monitored under international agreements at levels that will provide reliable estimates of incidental take in 1991 and early 1992 . Biological samples are being collected to determine age structure, reproductive parameters, food habits and stocks. Sighting data are being collected on commercial and research vessels to provide estimates of abundance. However, the survey effort will be low over much of the species range. The USA and Japan will both conduct sighting surveys in July and August 1991 to obtain estimates of abundance on the fishing grounds during the peak of the fishing season, and to relate cetacean distribution to Japanese fishing effort data and oceanographic features.

Lagenorhynchus obliquidens[15]

COMMON NAMES

Pacific white-sided dolphin, *kama iruka* (Japanese)

DISTRIBUTION

This species is found only in the North Pacific Ocean. In the western North Pacific it is found as far south as Taiwan, in the eastern North Pacific to southern Baja California, Mexico, and across the temperate waters of the North Pacific (Leatherwood *et al.*, 1984; Miyashita, 1989). Two stocks may occur within the coastal waters of both the western and eastern Pacific (Walker *et al.*, 1986; Miyazaki and Shikano, 1989).

PROBLEMS AND CATCH STATISTICS

Pacific white-sided dolphins are the second most frequently caught small cetacean in the high seas Japanese squid driftnet fishery in the central North Pacific. Northridge (In press) has provided a rough estimate of the number killed in 1989 at around 11,000 (see method used and caveat under *Lissodelphis borealis* section above). Additional Pacific white-sided dolphins may also be killed in the Japanese and Taiwanese large-mesh high seas driftnet fisheries that target tunas and billfishes (Watanabe, 1994). These dolphins are also known to be caught incidentally in the Japanese fisheries.

Small numbers of Pacific white-sided dolphins are killed each year in Japanese waters for human consumption. Larger numbers of these dolphins were taken in cull programmes during the 1970s and 1980s. Additionally, small numbers of Pacific white-sided dolphins are incidentally killed in various coastal fisheries on both sides of the North Pacific (e.g. Anonymous, 1987b; Barlow *et al.*, 1992).

POPULATION ESTIMATES

The total size of the populations throughout the range of this species is unknown.

ASSESSMENT AND STATUS

The number of stocks affected by high seas driftnet fisheries is unknown but probably more than one stock is taken. The Scientific Committee (IWC, 1994) considered that the large kills of Pacific white-sided dolphins were potentially not sustainable. Large incidental catches have occurred for more than ten years (since the start of the high seas squid driftnet fishery) and the total population size is unknown. Therefore, concern is noted over the status of the stocks taken in high-seas driftnet fisheries.

Dall's porpoise, Phocoenoides dalli *(True, 1885)*[16]

COMMON NAMES

Dall's porpoise, *ishi iruka* (Japanese).

DISTRIBUTION

The distribution of this species is described above in Item 5.1.1. The main stock of concern is that south of the Aleutian Islands.

PROBLEMS AND CATCH STATISTICS

This species has been taken in all four of the major driftnet fisheries of the North Pacific. In the past, incidental kills of 10,000 to 20,000 Dall's porpoises per year were considered possible in the Japanese high seas salmon driftnet mothership fishery (Mizue and Yoshida, 1965) which started in 1952. This fishery operated within the US 200 mile limit between 1978 and 1988. Eleven motherships and 368 catchers operated in this fishery during the 1960s, compared to only 4 motherships and 172 catchers in 1978. The estimated annual incidental catch of Dall's porpoises in the fishery between 1981 and 1987 within the US EEZ ranged from a low of 741 in 1987 to a high of 4,187 in 1982 (IWC, 1991c). In the western North Pacific, these porpoises are also taken in the Japanese land-based salmon gillnet fishery. Between 1981 and 1986 the estimated annual catch averaged 1,645 (Ito, 1986).

Incidental catches of Dall's porpoise have also been reported in the driftnet fishery for squid, operated by Japanese, Taiwanese and Korean vessels. An extensive observer scheme in the Japanese fishery in 1989 revealed catches of around 1.98 Dall's porpoises per 1,000km of netting set. Northridge (in press) suggested a possible total of around 3,000,000 km of netting set in these fisheries, which might suggest a total catch of about 6,000 animals. Jones and Miller (*Lissodelphis* section above) thought that total effort was less than this, and that this estimate might be therefore high because of variation in take rates between fisheries. Catch rates vary from year to year and fleet to fleet, so any estimate of total catch is necessarily very crude at this stage.

POPULATION ESTIMATE

There is no population estimate for the Dall's porpoise stock south of the Aleutian Islands, but (Turnock, 1987) gave an estimate of 741,000 porpoises for the western and central North Pacific region (see 5.1.1.).

ASSESSMENT AND STATUS

The pelagic squid drift net fishery may have taken around 6,000 porpoises in 1989 from a wide area across the North Pacific from more than one stock. The pelagic squid fishery was started by Japan in 1978. It does not exploit the same stocks as are taken in the hand harpoon fishery. Additional Dall's porpoises are killed in smaller numbers in the large-mesh drift net fishery off Japan for tunas and billfishes (L.L. Jones, pers. comm.). The total take from these populations is, therefore, somewhat less than 1% of the

[15] Initial draft by R.L. Brownell, Jr.

[16] Initial draft by R.L. Brownell, Jr. and T. Kasuya.

population estimate (741,000) for the western and central North Pacific. Impact on the 'South of Aleutian' stock is uncertain.

RECOMMENDATIONS

In line with the UN Resolution, it is recommended that all large scale pelagic high seas driftnet fishing in the North Pacific, as elsewhere, should be suspended by 30 June 1992, with the understanding that such a measure will not be imposed, or if implemented, can be lifted, should effective conservation and management measures be taken based upon statistically sound analysis to be jointly made by concerned parties of the international community with an interest in the fishery resources of the region, to prevent unacceptable impact of such fishing practices on the region, and to ensure the conservation of the living marine resources of the region.

The IWC Workshop (IWC, 1994) also recommended that should the North Pacific high seas driftnet fisheries continue, the observer programme should continue to collect statistically adequate data, and that the data collected on mammals taken in the squid driftnet and large mesh driftnet fisheries be analysed as soon as possible.

5.2.7.2 *South Pacific*

Two species of dolphins (common dolphin, *Delphinus delphis;* striped dolphin, *Stenella coeruleoalba*), were taken in considerable numbers by large-scale pelagic driftnet fisheries in the South Pacific region in the 1988/89 and 1989/90 seasons. At least three other cetacean species (southern bottlenose whale, *Hyperoodon planifrons;* short-finned pilot whale, *Globicephala macrorhynchus;* and Risso's dolphin, *Grampus griseus*) were also reported to have been taken incidental to fishing operations.

DISTRIBUTION

Striped and common dolphins are found in tropical and temperate waters worldwide; Risso's dolphin and the short-finned pilot whale are recorded from tropical and warm temperate waters; the southern bottlenose whale occurs throughout the Southern Ocean, and north to about 30°S (Klinowska, 1991).

PROBLEMS AND CATCH STATISTICS

A small number of Japanese vessels operated an experimental large-mesh driftnet fishery for several species of tuna in the Tasman Sea and the waters to the east and south-east of New Zealand from 1983–1988 (IWC, 1994). During the austral summer of 1988–89 there was a rapid increase in the number of vessels involved in the fishery. 64 Japanese vessels fished in the Tasman Sea, and between 60–130 Taiwanese driftnet vessels operated in the Sub-Tropical Convergence Zone (STCZ), south of the Cook Islands and French Polynesia. One driftnet research vessel from the Republic of Korea also operated in the region during part of the 1988/89 season.

No data are available for the numbers of small cetaceans incidentally taken during the course of the 1988/89 season, but estimates can be made from observations of the operations of the driftnet fleet during the 1989/90 season. An observer aboard a Japanese driftnet research vessel in the Tasman Sea in November/December 1989 observed 22 sets and reported an average catch rate of 0.64 common and striped dolphins per 10 km of net set (Sharples *et al.*, 1989). The proportion of common dolphins incidentally taken to striped dolphins was 4.5:1.

Surveys were also carried out on approximately 126 km of driftnet set by Japanese vessels in the Tasman Sea during January 1990 (Coffey and Grace, 1990). An incidental rate of capture of 0.54 striped and common dolphins was reported per 10 km of net set.

No data were provided by the Taiwanese driftnet fleet which operated in the Sub-Tropical Convergence Zone during the 1988/89, 1989/90 and 1990/91 seasons, and no observers were placed aboard the fleet. The Taiwanese Government announced a reduction in the fleet size from between 60 and 130 vessels in 1988/89, to 11 vessels in 1989/90 and 11 vessels in 1990/91.

Estimates of the likely catch rates can be derived from the report of the observer aboard the *Shin-Hoyo Maru* driftnet research vessel, which carried out trials in the STCZ in February/March 1990 (Shaples *et al.*, 1989). Cetacean catch rates of 0.17 per 10km of net were reported in the STCZ, and comprised mainly common dolphins, with one capture of a Risso's dolphin.

It is clear that thousands of dolphins may have been killed in these fisheries.

POPULATION ESTIMATES

No population estimates in the South Pacific region are available for any of the species subjected to incidental catch in driftnets.

ASSESSMENT AND STATUS

Because of the lack of reliable information on population abundance and biological parameters, the impact of large-scale pelagic driftnet fisheries on the small cetaceans of the South Pacific region cannot be reliably assessed.

Concern over the conservation of both tuna and non-target species gave rise to the Tarawa Declaration adopted by the South Pacific Forum in July 1989. The Declaration resolved to prevent and discourage the practice of large-scale pelagic driftnet fishing in the region. In addition, the UN Resolution (UNGA 44/225) on 'large-scale pelagic driftnet fishing and its impact on the living marine resources of the world's oceans and seas', paragraph 4b, called for 'immediate action should be taken to reduce progressively large-scale pelagic driftnet fishing activities in the South Pacific region with a view to the cessation of such activities by 1 July 1991, as an interim measure, until appropriate conservation and management arrangements for South Pacific albacore-tuna resources are entered into by the parties concerned'.

The Japanese Government suspended any further operations of driftnet vessels in the South Pacific in July 1990, pending the conclusion of negotiations to establish a management regime for albacore tuna in the region. This was one year before the onset of the moratorium agreed to under the UN resolution. The Republic of Korea suspended driftnet operations in the South Pacific from the end of the 1988/89 season. The Taiwanese Government has informed the Forum Fisheries Agency that there will be no further deployments of Taiwanese driftnet vessels in the region.

RECOMMENDATIONS

Nations of the South Pacific region should be encouraged to carry out surveys of cetacean abundance and distribution, especially for pelagic small cetaceans. The South Pacific Regional Environment Programme may be an appropriate vehicle to encourage and promote such research.

5.2.7.3 *Indian Ocean*

There are known to be about 140 Taiwanese driftnet vessels operating in the Indian Ocean targeting albacore, other tunas and sharks. The fishery operates in the Arabian Sea and in southerly latitudes between about 20°S and 40°S (Hsu and Liu, 1990). There is no information on catches of cetaceans, but this is the largest driftnet fishery currently operating outside of the North Pacific, and large numbers of cetaceans might be expected to be caught. This fact is of particular concern to the sub-committee in view of the status of the Indian Ocean region as a whale sanctuary, and in view of the almost complete lack of information on cetacean catches and the apparent inaction of the Indian Ocean Fisheries Commission in this regard.

RECOMMENDATIONS

The IWC Workshop (IWC, 1994) noted that fleets from Taiwan, China (with inadequate data for operations) operate in the Indian Ocean and recommended that, while such activities continue, data on all distant-water fleets must be collected by the flag nations and nations servicing these fleets, and independent observers placed on board vessels. The by-catches must be reported and evaluated and appropriate management actions taken before further fishing takes place.

5.2.7.4 *Atlantic and Mediterranean*

Taiwanese large-mesh fisheries for tunas and other species are known to operate in both the South and North Atlantic. In the South Atlantic, recent reports indicate a previously unknown driftnet fishery for albacore around Tristan da Cunha. As many as 160 Taiwanese vessels may operate in this fishery and reports indicate incidental catches of unknown species of small whales and dolphins (Ryan and Cooper, 1991). Observations from a South African deckhand have been used to produce a speculative estimate of some 7,500–10,000 dolphins, and 1,000–1,500 small whales killed in this fishery (IWC, 1994). In the North Atlantic a smaller fleet of about 20 Taiwanese vessels is thought to be operating and entanglements of cetaceans have also been reported, but in unknown numbers (Northridge, In Press).

In the Mediterranean Sea there are no 200 mile EEZs, and as a consequence much of the area is classified as high seas. Driftnets for tuna and swordfish are used by several nations, but until July 1990 the great majority of vessels, some 700 or more, were Italian. The Italian fishery was suspended in 1990, but recent unconfirmed information suggests a part of this fishery may be resumed. Striped dolphins are the most commonly taken species (see Item 5.2.4).

There is an expanding fishery for albacore operating in the Northeast Atlantic both inside and outside European EEZs. This fishery was initiated by the French in 1986, and 37 French vessels participated in 1989. Two Irish vessels joined this fleet in 1990 (Wray, 1990) and four English vessels have indicated an intention to join the fishery in 1991 (Anonymous, 1991). Cetacean species known to be taken include striped and common dolphins, but other species are also likely to be taken. The total dolphin catch by the French fleet was estimated as 131 in 1989 and 420–460 in 1990.

DISTRIBUTION OF SPECIES

Species taken in the Taiwanese fisheries are unknown. Common and striped dolphins have a worldwide distribution in tropical and temperate waters.

ASSESSMENT AND STATUS

The IWC's Workshop (IWC, 1994) proposed that catches of striped dolphins in the swordfish driftnet fishery in the Mediterranean were not sustainable (see also Section 5.2.4). Nothing is known of the stock size or status of any other species or population likely to be impacted by these fisheries.

RECOMMENDATIONS

(1) The IWC Workshop (IWC, 1994) noted that fleets from Taiwan, China, and other nations continue to operate without documentation in the Atlantic and recommended (as for the Indian Ocean) that, while such activities continue, data on all distant water fleets must be collected by the flag nation, and nations servicing these fleets, and independent observers placed on board vessels. The incidental catches must be reported and evaluated and appropriate management actions taken before further fishing is authorised.

(2) The United Nations resolution 44/225 recommended to member states 'that further expansion of large scale pelagic driftnet fishing on the high seas of the North Pacific and all other areas outside the Pacific Ocean should cease immediately'.

In view of the unanimously passed resolution, the Scientific Committee strongly **recommends** that member nations take immediate steps to curtail the expansion of driftnet fisheries in the Mediterranean and Northeast Atlantic into high seas areas, and in any event **recommends** that such fisheries should be terminated by June 1992 in accordance with paragraph 4a of the UN resolution 44/225.

(3) Paragraph 4a of the UN resolution 44/225 called upon member nations to impose moratoria on all large-scale pelagic high-seas driftnet fishing by 30 June 1992, with the understanding that such a measure will not be imposed in an area, or if implemented, can be lifted, should effective conservation and management measures be taken based upon statistically sound analysis to be jointly made by concerned parties of the international community with an interest in the fishery resources of the region, to prevent unacceptable impact of such fishing practices on that region, and to ensure the conservation of the living marine resources of that region.

In view of the absence of any relevant data on the status of cetacean stocks impacted by high seas driftnet fisheries in this area, the sub-committee **recommends** that research priority should be given by the EC and its member states to assessing the status of all cetacean stocks impacted by the European high seas driftnet fisheries. Such an action is required by the UN Resolution for any continued fishing.

5.3 Deliberate incidental catches in Eastern Tropical Pacific[17]

Since the late 1950s, large numbers of dolphins, perhaps as many as seven million have been killed incidental to purse seine fishing operations for yellowfin (and skipjack) tuna in the eastern tropical Pacific. Over 80% of the incidental kill involved just two stocks: the northern offshore form of spotted dolphin, *Stenella attentuata*, (62%) and the eastern form of spinner dolphin, *Stenella longirostris*, (22%). Also involved are common dolphins (*Delphinus delphis*) and striped dolphins (*Stenella coeruleoalba*). Incidental catch levels have been significantly reduced from the levels of the 1960s but have continued to average over 85,000 for the last 5 years. The total kill in 1990 was 53,000 dolphins.

[17] Initial draft by DeMaster, Wade and Sisson.

Some stocks were likely significantly reduced in the early years of the fishery. Information from recent analysis of trends suggests that no major changes in abundance have taken place in recent years. Insufficient information exists to compare reliably current abundance estimates of these dolphin stocks with their population levels prior to the commencement of purse-seine fishing operations in the ETP.

5.3.1 *Stenella attenuata*

COMMON NAMES

Spotted dolphin; spotted porpoise; *delfínmanchado* (Spanish).

DISTRIBUTION

Three stocks of spotted dolphins are recognised: northern offshore, southern offshore, and coastal. (Perrin *et al.*, 1985). Recent information on seasonal movement patterns (Reilly, 1990) and patterns of morphological variation (Perrin *et al.*, 1985) suggests that spotted dolphins move between the western and southern portions of their range, and the stock delineations are being re-examined.

PROBLEMS AND CATCH STATISTICS

Estimates of incidental mortality are reported in Smith (1983) for years 1959–1978, the IATTC Annual Report (Anonymous, 1989, for years 1979–1988), Hall and Boyer (1990) for 1989, and Hall and Boyer (1991) for 1990. These data are summarised in Table 18. Quotas for the US fleet have been set for the northern offshore, southern offshore, and coastal stocks (20,500, 5,697, and 250 respectively). Mortality estimates for the coastal stock are considered unreliable because of the difficulty in separating the offshore and coastal forms and because of the low level of effort in near-shore waters. Estimates of mortality between 1959–1972 and 1979–1985 are imprecise because of inadequate observer coverage. Since 1986, observer coverage of US and international fleets has yielded much more reliable estimates of mortality.

POPULATION ESTIMATES

Wade and Gerrodette (1992) analysed data from five years of research vessel surveys and produced estimates of relative abundance. The sub-committee believes that these are the best available estimates of absolute abundance of the stocks. The northern offshore spotted dolphin population size ranged between 658,300 and 2,205,500 (average 1,514,800) with CVs between 29 and 36 %. The southern stock size was estimated to be between 85,800 and 475,800 (average 267,400) with CVs between 48 and 86 %.

In addition to these estimates, Anganuzzi *et al.* (1992) reported estimated trends in relative abundance for the northern and southern stocks based on sightings data from observers aboard tuna vessels.

ASSESSMENT AND STATUS

At this time, the only reliable information on trends in abundance is based on sightings data collected aboard tuna vessels, because too few annual data points have been obtained from the research vessel surveys and the available history data have not yet been suitably analysed. Estimated trends (Anganuzzi *et al.*, 1992) suggest that there was a significant decline in the northern stock in the late 1970s, followed be a period of relative stability (and perhaps some increase) in the 1980s. For the southern stock, there is indication of a decline during the early 1980s. Recent high estimates suggest the possibility of exchange with the northern stock, so reported trends for the southern stock should be treated with caution. The tuna vessel estimates of Anganuzzi and Buckland (1989) were used by Edwards and Glick (1991) to test for linear trend over 10-year windows. Significant declines were only found for the northern stock in years 1975–1984 and 1976–1985. A power analysis with type 1 and type 2 error levels set at 0.1 indicated that significant trends would have had to be on the order of 6–7% per year over the 10 year period to be detected. It is currently thought that these populations under conditions of no incidental mortality should be increasing at approximately 2–6% per year (Reilly and Barlow, 1986). For the northern offshore stock, the current level of incidental mortality (Table 18) is at a level similar to the expected rate of increase, therefore, it is not surprising that no significant trends in abundance have been detected in recent years. Table 18 indicates that the take has been of the order of 2.1% to 4.5% of the northern stock and 0.6% to 1.9% of the southern stock annually since 1986.

Table 18

Estimates of population size, mortality and percent mortality from 1986 - 1990 of the three major dolphin species killed in the Eastern Tropical Pacific (ETP) purse seine fishery.

	Average abundance[1] 1986-90	1986		1987		1988		1989		1990	
		kill	% kill	kill	%kill	kill	%kill	kill	%kill	kill	%kill
Spotted											
N. offshore	1,514.8	68.0	4.5	51.7	3.4	36.1	2.4	52.1	3.4	32.3	2.1
S. offshore	267.4	5.1	1.9	3.3	1.2	2.2	0.8	3.9	1.5	1.6	0.6
Spinner											
Eastern	588.5	19.5	3.3	10.4	1.8	18.8	3.2	15.2	2.6	5.4	0.9
Whitebelly	993.7	11.0	1.1	6.0	0.6	3.5	0.4	8.3	0.8	7.0	0.7
Common											
Northern	467.4	13.3	2.8	8.2	1.8	4.8	1.0	1.1	0.2	0.7	0.1
Central	594.3	10.9	1.8	9.7	1.6	7.1	1.2	12.7	2.1	4.1	0.7
Common	2,117.5	0.1	0.0	6.8	0.3	4.2	0.2	0.6	0.0	0.3	0.0
Total		127.9		96.1		76.7		93.9		51.4	

[1] From Gerrodette and Wade (SC/43/SM13).

5.3.2 *Stenella longirostris*

COMMON NAMES

Spinner dolphin, spinner porpoise; *tornillo* (Spanish).

DISTRIBUTION

There are four recognised stocks of spinner dolphins in the ETP (northern whitebelly, southern whitebelly, eastern and Central American [formerly Costa Rican]. The last two have been recognised as subspecies (Perrin, 1990). Recent analyses by Perrin *et al.* (1991) suggest that the northern and southern whitebelly stocks should be combined into a single management unit. Subsequent references to whitebelly spinner dolphins here will follow this recommendation.

PROBLEMS AND CATCH STATISTICS

Incidental mortality estimates for the eastern stock have varied between a maximum of 133,000 in 1960 and a low of 745 in 1983 (Table 19). For the whitebelly stock, absolute mortality and % mortality has been much lower than for the eastern stock.

POPULATION ESTIMATES

Wade and Gerrodette (1992) estimated the eastern spinner abundance based on five years of research vessel surveys (1986–1990) to be between 391,200 and 754,200 (average 588,500) with CVs between 37 and 42 %. Abundance estimates for the whitebelly stock ranged from 363,300 to 1,398,400 (average 993,700) with CVs between 38 and 64%. Anganuzzi and Buckland (1989) reported abundance estimates of 584,000 (CV=18%) and 384,000 (CV=23%) for the eastern spinner in 1986 and 1987, respectively.

No significant trends in eastern spinner numbers during 1975/90 was detected by Anganuzzi *et al.* (1992). Eastern spinners may have had a similar pattern of decline to the offshore spotted dolphin, although estimated relative abundance in the late 1980s is roughly equal to that of the mid-1970s, so reduction between 1975 and 1983 may have been less than for northern offshore spotted dolphin.

The estimated trend for the whitebelly spinners is similar to that for northern offshore spotted, indicating a stable situation in recent years.

ASSESSMENT AND STATUS

Back calculation estimates of historic abundance of eastern spinner dolphins, based on recent estimates of population size, but with all other input parameters from Smith (1983), were performed by Wade (1991). He found that over the range of parameter estimates explored, the selection of the initial population size (defined as the current abundance (N_c) estimate divided by the historical abundance (N_h) estimate). Starting the population at 391,200 versus 754,200 (lowest and highest N_c used in simulations: Wade and Gerrodette, 1992) resulted in a 12–27% increase in relative abundance. Of even more significance is the range over which relative population size changes. Whereas Smith (1983) estimated relative population size for the eastern spinner dolphin population to be from 0.17 to 0.25, Wade (1991) using an N_c of 391,200 estimated relative population sizes from 0.21 to 0.33, and

Table 19

Dolphin mortality in the Eastern Tropical Pacific (ETP) purse seine fishery from 1959 through 1989. Data from Hall and Boyer, 1991, 1992; Smith, 1983, 1979; IATTC Annual Report, 1988.

	Spotted		Spinner			Common				
	Northern	Southern	Eastern	Northern	Southern	Northern	Central	Southern	Other	Total
1959	72,000		27,000						19,288	117,288
1960	375,000		133,000	0					74,481	582,481
1961	402,000		150,000	0					101,751	653,751
1962	167,000		62,000	0					40,259	269,259
1963	183,000		69,000	0					38,427	290,427
1964	306,000		115,000	0					51,691	472,691
1965	337,000		126,000	0					50,069	513,069
1966	326,000		115,000	0					19,655	460,685
1967	206,000		77,000	0					24,295	707,295
1968	178,000		67,000	0					21,620	266,620
1969	305,000		122,000	15,000					102,222	544,022
1970	355,000		118,000	14,000					40,659	527,659
1971	176,000		59,000	7,000					19,928	261,928
1972	288,000		96,000	12,000					29,678	423,678
1973	131,000		32,000	33,000					68,973	264,973
1974	95,000		26,000	47,000					6,682	174,682
1975	105,000		45,000	34,000					10,457	194,457
1976	47,000		9,000	20,000					52,222	128,222
1977	22,000		5,000	5,000					19,353	51,353
1978	19,000		2,000	4,000					5,513	30,513
1979	8,870	2,348	1,460	674	638	4,161	2,342	94	880	21,426
1980	13,058	6,828	1,108	1,425	6,707	1,060	963	188	633	31,970
1981	16,324	6,376	2,261	1,815	4,597	2,629	372	348	367	35,089
1982	15,427	4,504	2,606	1,770	1,946	989	487	28	1,347	29,104
1983	3,414	3,608	745	1,640	2,697	845	191	0	353	13,493
1984	15,940	4,042	6,033	1,496	5,636	0	7,403	6	156	40,712
1985	31,309	2,786	8,853	2,648	4,331	0	6,839	304	1,777	58,847
1986	67,989	5,125	19,526	6,804	4,238	13,289	10,884	134	5,185	133,174
1987	51,685	3,285	10,358	3,594	2,432	8,216	9,659	6,759	3,200	99,187
1988	36,137	2,192	18,793	1,844	1,701	4,829	7,128	4,219	2,074	78,927
1989	52,093	3,863	15,245	6,444	1,858	1,066	12,711	576	3,123	96,979
Total	4,439,000	46,541	1,547,000	227,000	37,743	37,788	63,032	12,928		7,177,000

using an N_c of 754,200 estimated relative population sizes from 0.33 to 0.60.

For ETP dolphins the results of such 'back-calculation' models are confounded by lack of information on movement patterns and exchange rates between neighbouring population centres. In addition, the sample sizes on which mortality estimates are based are very small for the period 1959–1972. Repeating the above calculations using mortality estimates 20% lower and 20% higher resulted in estimated relative population sizes from 0.18 to 0.41 using an N_c of 391,200, and estimated relative population sizes from 0.29 to 0.73 using an N_c of 754,200 (Wade, 1991).

5.3.3 Delphinus delphis

COMMON NAMES

Common dolphin; white belly porpoise; *delfín común* (Spanish).

DISTRIBUTION

There are three recognised stocks of common dolphins taken by the tuna fleet in the ETP (northern tropical, central tropical, and southern tropical). Reilly (1990) recently reported that common dolphins do not seem to have seasonal shifts in distribution centres, as do spotted and spinner dolphins. Rather, year round density centres in up-welling modified waters were identified near the Revillagigedos Islands, along the coast of Baja California and Ecuador and near the Costa Rican Dome. The extent to which this pattern of distribution confounds traditional stock identification methods is currently being examined.

PROBLEMS AND CATCH STATISTICS

Mortality levels for the three stocks are highly variable from year to year, but considerably less in absolute number than for northern offshore spotted dolphins or eastern spinner dolphins. Quotas for US fishermen exist for all three stocks (1,890, 8,112, and 4,045). In recent years, the central stock has suffered the greatest mortality. Estimates of % mortality are given in Table 18 but are thought to be unreliable because of the uncertainty in estimating population size.

POPULATION ESTIMATES

Estimates of population size for common dolphins in the ETP are relatively imprecise. CVs from research vessel data are between 44% and 84%, while those from tuna vessel data are 40% for the northern stock, 30% for the central stock, and 30% for the southern stock. Abundance estimates of common dolphin stocks made by Wade and Gerrodette (1992) based on research vessel data are between 23,500 and 1,272,400 (average 467,400) for the northern stock, 261,000 and 1,487,600 (average 594,300) for the central stock, and 152,000 and 3,664,000 (average 2,117,500) for the southern stock for the years 1986 through 1990.

ASSESSMENT AND STATUS

Edwards and Glick (1991) reported significant declines in the northern stock between 1975 and 1984 and for the central stocks between years 1975 and 1984, 1976 and 1985, and 1978 and 1987. Anganuzzi *et al.*, (1992) reported a significant decline in the northern stock during the 1980s. Their estimate of relative abundance for 1989 was significantly lower than those for 1979–1981. The central stock showed evidence of a decline between 1978 and 1983, with stability since. Data were sparse for the southern stock, but abundance in 1989 was significantly lower than in 1976/78.

5.3.4 Stenella coeruleoalba

COMMON NAMES

Striped dolphin; streaker porpoise; *delfín listado* (Spanish)

DISTRIBUTION

There are three recognised stocks of striped dolphins (northern, central and southern) in the ETP. The range in the ETP has been divided into management units based on apparent latitudinal gaps in distribution (Smith, 1983). Further investigation into the distribution and osteological material has led Perrin *et al.* (1985) to recommend that the stock definitions be changed. They recommended combining the central and southern stocks into a single southern stock. The striped dolphin would then consist of two stocks (northern and southern).

PROBLEMS AND CATCH STATISTICS

Quotas for US fishermen for the northern, central and southern tropical stocks are 429, 1,822 and 4,095 respectively. Estimates of incidental mortality are not as accurate as for the other three species, because the incidental mortality is relatively rare. Mortality estimates by Hall and Boyer (1991) combine striped and other dolphins; observed mortality of striped in 1990 comprised approximately 6% of the observed mortality for all species.

POPULATION ESTIMATES

Wade and Gerrodette (1992) used research vessel data to estimate the abundance for northern and southern (including central) stocks of striped dolphins. The northern stock ranged between 40,700 and 323,400 (average 172,400; CVs between 37 and 62%), while the southern stock was between 612,000 and 1,927,900 (average 1,313,500; CVs between 27 and 30%).

ASSESSMENT AND STATUS

Striped dolphin stocks are only slightly involved with the purse-seine fishery (Smith, 1979). Assessments have been made primarily for those animals found in the areas previously designated to the central tropical stock which have been taken by the fishery since 1973.

5.3.5 Recommendations Concerning Kills of Dolphins in ETP Purse-Seine Fisheries

Since 1979, the Scientific Committee has made a series of recommendations concerning kills of dolphins in ETP purse-seine fisheries. Many of these recommendations have been, or are being, acted upon by member states with coordination of international efforts through the IATTC.

Recommendations have consisted of the following types of requests: that (1) governments of nations with purse seine fisheries involving dolphin mortality systematically collect and routinely report on data on effort and takes in these fisheries, preferably through participation in appropriate international schemes; (2) observer programmes be initiated or expanded to provide a basis for estimating kills; (3) a research programme be conducted to improve estimates of abundance and trends; (4) biological sampling continue or be increased and analysis of sampled materials be continued or accelerated as part of the assessment process and (5) research be conducted to improve gear and evaluate alternative fishing techniques.

In 1988, the Scientific Committee recommended that a review be carried out to identify and account for possible sources of bias in abundance estimates. The sub-committee agreed to five additional **recommendations.**

(1) Observer coverage of the international fleet should continue at high levels to provide reliable estimates of mortality.
(2) Research vessel surveys should be conducted at regular intervals to provide better estimates of absolute abundance. Tuna vessel data should be used to assess estimates of trends in abundance of all main stocks. Further extension and refinement of the research vessel estimates for estimating absolute abundance should be carried out.
(3) The degree of exchange between different stocks of the same species should continue to be investigated.
(4) For striped dolphins, mortality levels should be managed so that they do not exceed some fraction of the expected net production, since estimated trends in abundance are not available from tuna vessel data. For stocks of spotted, spinner and common dolphin, trends in relative abundance should be included in the management strategy.
(5) Continued and increased cooperation with other international organisations (e.g. IATTC) involved in programmes of research, monitoring and reduction of incidental kill of cetaceans in the ETP is recommended.

5.4 Live-capture fisheries[18]

5.4.1 Orcinus orca *in Puget Sound and off Iceland*

COMMON NAMES

Killer whale (English), *háhyrningur* (Icelandic), *spekkhogger* (Norwegian), *spekkhuggare* (Sweden).

DISTRIBUTION

The killer whale is a cosmopolitan species. Its distribution in polar seas is limited by ice cover. The density of whales appears to be higher in colder waters (Martin, 1990). Although densities vary, killer whales are clearly abundant and widespread, and there are no current fears for the species' survival (Martin, 1990).

In the northeast Pacific, two sympatric forms of killer whale, resident and transient, have been distinguished on the basis of appearance, behaviour, social structure, foraging habits and acoustics (Bigg, 1982; Ford and Fisher, 1982; Bigg *et al.*, 1990; Morton, 1990). Analysis of mtDNA suggested as great a genetic distance between the residents and transients in Puget Sound as between allopatric populations in the Atlantic (Hoelzel, 1991).

The social organisation is best known for the residents and is complex (Bigg, 1982; Bigg *et al.*, 1990). Long term studies of known individuals indicate that these pods of matrilines have long term stable membership. No dispersal event from one pod to another has been recorded during almost two decades of study, although slow, gradual splitting of pods along maternal lineages seems to occur.

PROBLEMS AND CATCH STATISTICS – PUGET SOUND

A total of 68 killer whales was removed by a live-capture fishery in British Columbia and Washington State waters between 1962 and 1977. Olesiuk *et al.* (1990) estimated that 63 were of the resident form and that 76% of those were from the southern community (see below).

[18] Initial draft by A. Bjørge and G. Donovan.

POPULATION ESTIMATES – PUGET SOUND

Bigg *et al.*, (1990) reported that in 1987 there were over 261 residents killer whales in the region. The total population consists of two resident communities, northern and southern, comprising 16 and 3 pods, respectively, and a few tens of transient pods.

ASSESSMENT AND STATUS – PUGET SOUND

Olesiuk *et al.*, (1990) examined trends in population size in the resident communities. Both showed significant increases over the period 1973–87; around 2.6% per annum in the southern community and around 1.3% per annum in the northern community. Simulation studies indicated that both communities represented populations below their 'carrying capacity' and that they could sustain harvesting at rates of between 1.9 and 3.2%, depending on the age and sex of the animals removed.

PROBLEMS AND CATCH STATISTICS – ICELAND AND NORTHEAST ATLANTIC

In 1975, the Icelandic government instituted a system of regulation providing permits to be issued for the live-capture of killer whales. Between 1975 and 1988, permits for taking 84 animals were issued. In this period, 59 whales were actually captured; 8 were released, 3 died in holding facilities prior to export and 48 were exported to dolphinaria (Sigurjónsson and Leatherwood, 1988).

Of the exported whales, 13 were less than 3m long, and the largest animals captured and exported were a 4.9m male and a 4.5m female. Based on information on length at sexual maturity of killer whales in Norwegian waters (Christensen, 1984) and in North American dolphinaria (Duffield and Miller, 1988), Sigurjónsson and Leatherwood (1988) concluded that all exported animals were sexually immature.

Killer whales in the northeast Atlantic have been subjected to direct exploitation for many years. A total of 2,435 were killed by Norwegian whalers in the period 1938 –1981. This commercial hunt was halted when the IWC recommended a zero quota for the 1982 season (IWC, 1982a; b; c). The largest catches were made off Møre (634 whales) and Lofoten (662 whales). A total of 153 animals were killed in Icelandic waters and 442 in the Norwegian Sea, mainly between Iceland and Norway (Øien, 1988). The mean length of whales taken was 17.9ft for females and 20.2ft for males (Øien, 1988), indicating that sexually mature animals were removed from the matrilineal groups.

Substantial additional mortality has occurred as a result of cull operations off Iceland (Mitchell, 1975a) and hunting off Greenland (Heide-Jørgensen, 1988).

POPULATION ESTIMATES – ICELAND AND NORTHEAST ATLANTIC

Killer whales are common in Icelandic and Norwegian coastal waters, but little information is available on offshore abundance or migrations between the two areas. Christensen and Øritsland (1982) estimated about 1,400 killer whales for the entire Norwegian coastal waters. This estimate was based on a questionnaire survey of fishermen in 1982. Similar surveys were repeated in the period 1982–1986, and when summarising the surveys, Christensen (1988) concluded that at least 1,500 killer whales might be present in the coastal waters off Norway during January and February.

The international sighting surveys in the northeast Atlantic provided new information on the summer distribution and crude abundance of killer whales. About 3,100 (CV 0.63) whales were estimated for the Norwegian

Sea, Barents Sea and Norwegian coastal waters based on seven sightings (Øien, 1990), and about 6,600 (CV 0.32) whales for Icelandic and Faroese waters combined (Gunnlaugsson and Sigurjónsson, 1990).

ASSESSMENT AND STATUS – ICELAND AND NE ATLANTIC

A total of 143 killer whales had been photo-identified in Icelandic coastal waters up to 1986 (Sigurjónsson *et al.*, 1988). The authors noted that killer whales are widely distributed both around Iceland and far offshore, but the relationship of the study populations with these areas is unknown. To date, no matches exist with killer whales photo-identified off Norway. A total of 51 whales was removed by live-capture fisheries from 1976–1988 (Sigurjónsson and Leatherwood, 1988); another four were taken in 1989 and none in 1990.

The average annual removal rate (exported and dead whales per year) of about 3.6 in the period (1975–90), is within the range considered by Sigurjónsson and Leatherwood (1988) to be within the reproductive capacity of the overall Icelandic stock(s). The impact of removals on long-term matrilineal groups is unknown. The population structure and movements of killer whales in the northeast Atlantic are not well documented, but the live-capture fishery off Iceland may have cropped the same population units as were previously hunted by Norwegian whalers.

The regulatory system with possibilities to issue permits is still operative, but animals can no longer be captured for speculation; collectors must have a valid contract in hand. The Puget Sound killer whale fishery is closed and there is no known intention for it to be re-opened.

RECOMMENDATIONS

At the Workshop on Identity, Structure and Vital Rates of Killer Whale Population in 1981 (IWC, 1982c), it was recommended that precise data on the locality and date of capture for the live-capture fisheries in Iceland and elsewhere be provided. These data were provided for Iceland by Sigurjónsson and Leatherwood (1988).

In 1983, the Scientific Committee noted that killer whale population in a given geographical area consist of localised stocks and recommended that any planned live-captures by the USA, Iceland and Japan or elsewhere be preceded by an assessment of size and composition of the population to be affected (IWC, 1984a).

5.4.2 Tursiops truncatus *in the Gulf of Mexico and off the Atlantic coast of Florida*[19]

Bottlenose dolphins, *Tursiops truncatus*, particularly those taken from shallow, coastal environments, appear adaptable to captivity and have been the most common cetacean species maintained for public display and scientific research. The most common areas from which bottlenose dolphins have been collected have been the near-shore waters of the Gulf of Mexico and Atlantic coast of Florida in the USA. This section discusses issues related to the live-capture of bottlenose dolphins in the coastal waters of the Gulf of Mexico in the United States (Florida, Alabama, Mississippi, Louisiana, and Texas) and, to a lesser extent, off the Atlantic coast of Florida.

DISTRIBUTION

Bottlenose dolphins are distributed throughout the coastal waters of the Gulf of Mexico in embayments, inshore waters and offshore waters. For a series of aerial surveys for bottlenose dolphins in the Gulf, inshore waters were defined as extending from the coast to the 18.3m isobath; offshore waters were considered to extend seaward from that depth contour, although the survey ended 9.3km seaward of the 182.9m isobath (Scott, 1989). On the basis of the above definitions, Scott *et al.* (1989) reported that the dominant proportion of bottlenose dolphins were seen in the offshore waters, an area that comprised 68.5% of the area surveyed. Bottlenose dolphins inhabit deeper offshore waters of the Gulf of Mexico as well, although density and abundance there are as yet unknown. Bottlenose dolphins also occur along the Atlantic coast of Florida, although in lower numbers than in the Gulf (Leatherwood, 1979; Hansen and Scott, 1989).

Most live-captures take place in the embayments and inshore waters of the Gulf of Mexico (Scott, 1990) and to lesser extent along the Atlantic coast in a lagoon system called the Indian River-Banana River complex where a community of dolphins is resident (Odell and Asper, 1990).

The stock structure of bottlenose dolphins in the Gulf of Mexico and Florida waters is unknown. In the Atlantic, at least two forms, generally referred to as coastal and offshore, exist (see Hersh *et al.*, 1990, for review). In the Gulf of Mexico, less information is available about the existence of these two forms. However, it is possible that relative discrete communities occupy some embayments (Wells *et al.*, 1987) and that the level of immigration and emigration by individual dolphins is very low. It is also possible that superimposed on the embayment system of discrete communities, coastally migratory groups of dolphins occupy specific sites in a seasonally predictable manner (e.g. Shane, 1980; Gruber, 1981), without significant exchange of individuals with dolphin groups in the embayments. In addition, in the Gulf of Mexico, bottlenose dolphins are seen quite far offshore where the water depth is still shallow. There may or may not be movement of bottlenose dolphins on– and offshore.

PROBLEMS AND CATCH STATISTICS

The live-capture fishery for bottlenose dolphins along the Atlantic coast of the USA began at least as long ago as 1914 and is thought to be the longest running sustained fishery of its type in the world (Leatherwood and Reeves, 1982). Leatherwood and Reeves (1982) estimated that between 1938 and 1980, over 1,500 bottlenose dolphins were removed by live-capture, mainly from the US Gulf of Mexico. Accurate records have been kept since 1973, after passage of the Marine Mammal Protection Act. From 1973–1989, 16–56 bottlenose dolphins were removed annually through live-capture or accidental mortality during attempts at live-capture. In total, 477 dolphins were removed from 1973–1987 (Scott, 1990, for data from 1973–1987). In addition, 34 dolphins were taken in 1988 (an updated figure from that given in table 1 in Scott, 1990), 16 in 1989, and none in 1990. Of these, 195 were removed from Mississippi Sound and environs. Nine removals were made from the east coast of Florida since 1982 and none occurred from 1984–1987. In May 1990 a temporary, voluntary moratorium on removal by live-capture was implemented in the Gulf until further information on the cause and effects of the mortality has been determined.

[19] Initial draft by A. Hohn.

Since 1977, the number of animals removed by live-capture has been regulated by a quota system (Scott, 1990). The quota was revised in 1982, and remained constant until 1990. Quotas are under review in the light of recent survey results (Anonymous, 1990a).

Live-capture has been a controversial issue in the USA. Much of the controversy is due to the lack of information available, or in some cases to the lack of adequate analysis of available information. The controversy has arisen partly because the effects of removals may be greater than they would appear on the basis of numbers alone. The cumulative effects of human-induced (e.g. fishing incidental mortality, habitat changes, competition with fishermen for prey species) and natural factors (periodic high mortality events) on the dolphin populations are difficult to assess. For example, some embayments that previously contained bottlenose dolphins no longer do, possibly the result of human-induced changes in the environment. In those coastal areas where the residency of bottlenose dolphins has been investigated, at least some of the dolphins have been found to be resident (Caldwell, 1955; Caldwell and Golley, 1965; Shane, 1980; 1990; Gruber, 1981; Wells *et al.*, 1987; Odell and Asper, 1990; Scott *et al.*, 1990). If resident groups are repeatedly targeted and exchange rates of individuals by means of immigration are low, then the effects of removals on such resident groups could be severe.

ASSESSMENT AND STATUS

The total abundance of bottlenose dolphins in inshore and offshore waters in the US portion of the Gulf has been estimated as 35,000–45,000 (Scott, 1989). More localised surveys also have been conducted (summarised by Scott, 1990), but the data on stock structure are presently too limited to allow the stratification of abundance estimates so that they correspond precisely to stocks or relatively discrete communities. When stratified, estimates of abundance and density, as well as quotas for removal by live-capture, have been applied to management areas defined on the basis of where bottlenose dolphins have been live-captured historically (Scott, 1990).

Although the number of bottlenose dolphins removed by live-capture has been small relative to estimated total abundance (Scott, 1989), most live-captures have been from a small number of locations. Given our lack of knowledge about stock structure, the extent of other kinds of removal, such as fishery incidental mortality, and the effect of repeated removals from relatively discrete communities of dolphins, it is difficult to assess the effects of the removals on bottlenose dolphins in the areas where live-captures have been concentrated.

RECOMMENDATIONS

The Scientific Committee stated in 1983 that it considered the guideline for takes pending stock assessment of 2% per year to be prudent and that this guideline could be safely followed pending results of other assessments (IWC, 1984a). It recommended that the USA be encouraged to continue research on stock identity and that population census and interim management procedures be initiated for ongoing or planned live-captures of bottlenose dolphins elsewhere.

The sub-committee noted that the work called for was continuing in the USA.

5.4.3 Delphinapterus leucas in Hudson Bay and in the USSR[20]

COMMON NAMES

White whale, beluga, *belukha* (Alaska and USSR)

DISTRIBUTION

The species has a circumpolar distribution in the Northern Hemisphere, mainly north of 55°N (see section 5.1.2.1).

PROBLEMS AND CATCH STATISTICS

White whales have been captured alive and transported to marine parks and exhibitions since the 1860s (Reeves and Leatherwood, 1984). The first such collections were made in the St. Lawrence River, eastern Canada. In the late 1950s and 1960s, a few whales (10 or less documented by Reeves and Leatherwood, 1984) were captured in Bristol Bay, Alaska, for facilities on the east and west coasts of North America. From 1967 to the mid 1980s, all known collections were made in western Hudson Bay at the mouths of the Seal and Churchill rivers, Manitoba, Canada. The total known captured in this area from 1967 through 1988 is 73 (Reeves and Leatherwood, 1984; R.W. Moshenko, *in litt.* to Reeves, 13 February 1989). Approximately 70% of the whales taken in this fishery have been females.

Ognetov and Minibayeva (1986, as summarised by Ivashin, 1987) described the first attempt to capture and transport live white whales from the Kara Sea. At least one large and several younger white whales were taken. Subsequent papers summarised by Ivashin (1988) refer to work with captive white whales in the USSR. Tobayama (1991) referred to the capture of 12 white whales in Sakhalinskiy Bay, Sea of Okhotsk, for the TINRO Aquarium, Vladivostok, USSR, between 1988 and 1990. Three of these were delivered to Kamogawa Sea World, Japan, in October 1990.

POPULATION ESTIMATES

The population of white whales summering along the west coast of Hudson Bay, including the Seal and Churchill river estuaries, was estimated in 1987 as more than 23,000 whales (Richard *et al.*, 1990).

Available recent information on the white whale population in the Kara Sea does not include a population estimate. A commercial fishery for white whales was conducted in the Kara Sea as recently as the mid 1980s. The population of white whales in the Sakhalin-Amur area was estimated at 7,000–10,000 from aerial surveys in 1987 (Popov, 1990).

ASSESSMENT AND STATUS

The white whale live-capture fishery in western Hudson Bay represents no threat to the wild population, considering its presently small scale relative to the size of the population. Too little is known about the Kara Sea population's current status and the scale of the live-capture operation there to assess the impact of the fishery. Removals made to date from the large stock of white whales in the Sakhalin Amur area of the Sea of Okhotsk would have had little impact on the stock. In all cases where white whale live-capture fisheries have developed, there has been no information on their impact on white whale social groups and behaviour.

[20] Initial draft by R.R. Reeves.

RECOMMENDATIONS

Routine reporting of captures and the regulation by permit in Canada should continue. Basic information on the number of whales taken and the size of the stock in the Kara Sea should be made available, for example, in the USSR's annual progress report to the IWC.

5.4.4 General recommendations on live-capture fisheries

Live-capture fisheries are also known from a number of other areas. Those most active at present include Japan (multispecies), Cuba (*Tursiops*, mainly for export) and the Black Sea (*Tursiops*, *Delphinus* and *Phocoena* for display mainly in Bulgaria, Romania and USSR, and for research in USSR). Little or nothing is known of the status of the stocks from which these and other, live-captures are made. All governments with live-capture fisheries in their waters are urged to initiate the necessary studies to implement effective management regimes.

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Appendix 2

LIST OF SMALL CETACEAN SPECIES

There follows a list, in taxonomic order, of the living small cetacean species recognised by the IWC Scientific Committee (scientific names and English common names).

Suborder Odontoceti (toothed whales)	
Superfamily Platanistoidea	
Family Platanistidae	
Platanista gangetica	Ganges river dolphin
Platanista minor	Indus river dolphin
Family Pontoporiidae	
Subfamily Lipotinae	
Lipotes vexillifer	baiji
Subfamily Pontoporiinae	
Pontoporia blainvillei	franciscana
Family Iniidae	
Inia geoffrensis	boto
Superfamily Delphinoidea	
Family Monodontidae	
Subfamily Delphinapterinae	
Delphinapterus leucas	white whale
Subfamily Monodontinae	
Monodon monoceros	narwhal
Family Phocoenidae	
Subfamily Phocoeninae	
Phocoena phocoena	harbour porpoise
Phocoena spinipinnis	Burmeister's porpoise
Phocoena sinus	vaquita
Neophocaena phocaenoides	finless porpoise
Subfamily Phocoenidinae	
Australophocaena dioptrica	spectacled porpoise
Phocoenoides dalli	dall's porpoise
Family Delphinidae	
Subfamily Stenoninae	
Steno bredanensis	rough-toothed dolphin
Sousa chinensis	Indo-Pacific hump-backed dolphin
Sousa teuszii	Atlantic hump-backed dolphin
Sotalia fluviatilis	tucuxi
Subfamily Delphininae	
Lagenorhynchus albirostris	white-beaked dolphin
Lagenorhynchus acutus	Atlantic white-sided dolphin
Lagenorhynchus obscurus	dusky dolphin
Lagenorhynchus obliquidens	Pacific white-sided dolphin
Lagenorhynchus cruciger	hourglass dolphin
Lagenorhynchus australis	Peale's dolphin
Grampus griseus	Risso's dolphin
Tursiops truncatus	bottlenose dolphin
Stenella frontalis	Atlantic spotted dolphin
Stenella attenuata	pantropical spotted dolphin
Stenella longirostris	spinner dolphin
Stenella clymene	clymene dolphin
Stenella coeruleoalba	striped dolphin
Delphinus delphis	short-beaked common dolphin
Delphinus capensis	long-beaked common dolphin
Lagenodelphis hosei	Fraser's dolphin
Subfamily Lissodelphinae	
Lissodelphis borealis	northern right whale dolphin
Lissodelphis peronii	southern right whale dolphin
Subfamily Cephalorhynchinae	
Cephalorhynchus commersonii	Commerson's dolphin
Cephalorhynchus eutropia	black dolphin
Cephalorhynchus heavisidii	Heaviside's dolphin
Cephalorhynchus hectori	Hector's dolphin
Subfamily Globicephalinae	
Peponocephala electra	melon-headed whale
Feresa attenuata	pygmy killer whale
Pseudorca crassidens	false killer whale
Orcinus orca	killer whale
Globicephala melas	long-finned pilot whale
Globicephala macrorhynchus	short-finned pilot whale
Subfamily Orcaellinae	
Orcaella brevirostris	Irrawaddy dolphin
Superfamily Ziphioidea	
Family Ziphiidae	
Tasmacetus shepherdi	Shepherd's beaked whale
Berardius bairdii	Baird's beaked whale
Berardius arnuxii	Arnoux's beaked whale
Mesoplodon pacificus	Longman's beaked whale
Mesoplodon bidens	Sowerby's beaked whale
Mesoplodon densirostris	Blainville's beaked whale
Mesoplodon europaeus	Gervais' beaked whale
Mesoplodon layardii	strap-toothed whale
Mesoplodon hectori	Hector's beaked whale
Mesoplodon grayi	Gray's beaked whale
Mesoplodon stejnegeri	Stejneger's beaked whale
Mesoplodon bowdoini	Andrews' beaked whale
Mesoplodon mirus	True's beaked whale
Mesoplodon ginkgodens	ginkgo-toothed beaked whale
Mesoplodon carlhubbsi	Hubbs' beaked whale
Mesoplodon peruvianus	pygmy beaked whale
Ziphius cavirostris	Cuvier's beaked whale
Hyperoodon ampullatus	northern bottlenose whale
Hyperoodon planifrons	southern bottlenose whale
Superfamily Physeteroidea	
Family Kogiidae	
Kogia breviceps	pygmy sperm whale
Kogia simus	dwarf sperm whale

Appendix 3

COMMERCE IN NARWHAL MUKTUK, IVORY AND OTHER PRODUCTS

R.R. Reeves

Narwhal muktuk (called mattak or maktak in some areas), meat and sinew have long been sold by hunters for resale within Greenland (Bruemmer, 1971; Born, 1987). Some prices are given in Table 1. Bruemmer (1971) stated that about 80% of the muktuk obtained by hunters in Thule district was sold to the Greenland Trading Company (KGH, now KNI). Some of the muktuk obtained by hunters in Pond Inlet and Arctic Bay on northern Baffin Island is sold and exported to population centres elsewhere in the Northwest Territories (unpubl. data).

Born (1987) noted an apparent increase in the amount of muktuk bought in Thule district during the 1980s and suggested that this development represented a shift away from trade in relatively unprofitable sealskins. The price of muktuk is kept strong by the high demand for it in towns south of Thule district. Local residents in Upernavik district have expressed concern about the activities of trawl fishermen from the Disko Bay region who hunt narwhals along the ice edge in spring. This hunt is primarily for muktuk that is sold in urban areas (O. Hertz, pers. comm., 11 August 1990).

Human populations are growing rapidly in Greenland and the eastern Canadian Arctic. Although the number of people involved directly in hunting or in the local consumption of hunting products may not be increasing as rapidly, the internal trade of hunting products makes it possible for urban dwellers to continue their consumption of hunting products such as muktuk. Dog traction remains an important aspect of hunting in northwest Greenland, and there has been a resurgence of interest in maintaining dog teams in parts of the eastern Canadian Arctic. It should be expected, therefore, that the demand for narwhal skin and meat as human food and dog food will increase.

Since 1979, the narwhal has been on Appendix II of CITES, and this has obliged signatory states to document exports of tusks and other narwhal products. At least some of the apparent increase in the numbers of items, mainly tusks, exported under CITES permits from both Greenland and Canada (Tables 2 and 3) is due to improved documentation procedures rather than increased volume of trade. In 1984 the European Economic Community (EEC) banned the commercial importation of narwhal products by member countries, effectively eliminating an important market for tusks from Canada. Before 1984, most tusks from Canada were exported to the UK. Since 1984, more than 75% of the tusks legally exported from Canada have gone directly to Japan (Table 3). E. Bradley-Martin (*in litt.*, 23 February 1991) considers his photograph of a narwhal tusk on display next to a rhinoceros horn in the window of a traditional medicine shop in Kyoto, Japan (Bradley-Martin, 1983), to be unusual. In the course of his investigations into the use of rhinoceros horns, he has found no evidence to suggest the continuing widespread use of narwhal ivory in Japanese folk medicine (c.f. Hawley, 1960). Nor has he found any evidence of narwhal ivory being carved in Japan in modern times, 'as the tusks are more valuable plain for decoration in their original state.' Since the EEC ban does not apply to Greenland, most of the narwhal ivory exported from Greenland goes to Denmark, information on re-export destinations of narwhal ivory from Denmark has been requested but not yet received. Unlike Canada, Greenland exports a considerable amount of carved narwhal ivory (Table 2).

The increasing trend in the price of narwhal ivory in Canada was reversed in 1984; however, the price has recovered substantially since then (Table 4). When the EEC ban took effect in 1984, the narwhal ivory market in northern Baffin Island was controlled by a single private dealer and the Hudson's Bay Company. As the value of the ivory declined abruptly, both parties agreed to begin buying from hunters by the foot of length, rather than on the traditional per-pound of weight basis. This change rationalised the system, since the previous policy of buying by the pound and selling by the foot was illogical (K. Harper, pers. comm., 20 March 1991).

The statement by Newman and Cavanagh (1986) that the price paid to Canadian hunters for narwhal ivory increased from \$2 to \$120 per pound during the 1960s is incorrect (Table 4). At the end of the 1960s, the price was \$10 per pound (Bisset, 1968; Mary-Rousseliere, 1971). Newman and Cavanagh also greatly exaggerated the prices for 1982, stating that they peaked at \$300 to \$400 per pound. The price paid to hunters on Baffin Island never rose consistently above \$100 per pound before 1984 (K. Harper, pers. comm., 20 March 1991). Information on prices paid (unadjusted for inflation) for narwhal ivory in Greenland are given in Table 5.

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Table 1

Prices paid to Greenlandic hunters by the Greenland Trading Company (KGH, KNI) for narwhal products other than ivory. All prices in Danish crowns, uncorrected for inflation.

	Product			
Year	Muktuk (per kg)	Meat (per kg)	Sinew (per kg)	Reference/Source
early 1960s	1.00			Bruemmer, 1971
1967		2.50		Hansen, 1970
1968	7.50			Hansen, 1970; Bruemmer, 1971
1969	5.50*			Bruemmer, 1971
1970	6.00*			Bruemmer, 1971
1971	7.50		100.00	Bruemmer, 1971
1975	13.00	13.00		Durham, 1978
1976	13.00	13.00		Durham, 1978
1985	35.00	25.00		Born and Olesen, 1986; Born, 1987
1990	49.50			Heide-Joergensen, in litt. to Reeves, 1990

*Derived from total amount purchased divided by total Dkr paid.

Table 3

Greenland CITES permits issued for narwhal products, 1984-1990. Source: Gronlands Hjemmestyre, Sekretariatet, Nuuk.

Year	No. permits	No. raw tusks	Min. weight [1]	No. carvings [2]	Min. weight [3]	Whales[4]
1984	1	0	0	3	?	1
1985	47	58	242	17	?	59
1986	98	111	277	79	?	111
1987	119 [5]	100	210	174	8	101
1988	134	170	616	170	31	177
1989	152 [6]	169	679	153	16	172
1990 [8]	108 [7]	220	809	78	2	221

[1] Weights (in kg) available for only about 70-80% of the tusks. Figure listed is total weight of all tusks for which the weight is indicated.

[2] Includes carvings described as 'tupilaks' as well as jewellry (bracelets, necklaces, rings), crochet hooks/needles, lampstands, flagstands, and unspecified carvings and souvenirs.

[3] Weights (in kg) are available only sporadically for these items, and it is often unclear whether the weight includes other ingredients such as metal or wood. Figure listed is total weight of all carvings for which the weight is indicated.

[4] Assumes each raw tusk represents one whale. Minimum weight of carvings is divided by the average weight of raw tusks that year, to give an estimate of the minimum number of tusks needed to produce the carvings.

[5] One permit was for 2kg of muktuk exported to Denmark.

[6] One permit for shipment of 516kg of 'meat' (muktuk?) from Greenland to Greenlandic Society in Aalborg, Denmark. Under a special provision of CITES, up to 10kg per person can be imported to Denmark per year.

[7] Two permits for a total of 98kg of muktuk exported to Denmark.

[8] Preliminary figures.

Table 4

Prices paid to hunters for unbroken narwhal tusks in the E. Canadian Arctic (Reeves, in prep.). In Canadian dollars, per pound of weight.

Year	Actual	Inflation-adjusted[1]	Sources
1905-6	2.50-3.00	-	Low (1906)
1961	0.75	2.37	J.McDonald (pers. comm. to Reeves)
1965	1.25	3.68	Bruemmer (1966)
1966	2.00	5.68	Bissett (1968)
1967	10.00	27.40	Bissett (1968)
1970	10.00	24.39	Mary-Rousseliere (1971)
1971	11.00	26.07	A.W. Mansfield (pers. comm.)
1972	20.00	45.25	Riewe (1977)
1974	15.00	28.41	Treude (1977)
1975	25.00	42.74	Reeves, Unpubl. data
1976	30.00	47.69	Hay and Sergeant (1976)
1978	37.00-50.00	50.07-67.66	Kemper (1980)
1979	45.00	55.76	Finley and Miller (1982)
1981	60.00-70.00	60.00-70.00	Anonymous (1985)
1982	70.00-90.00	63.18-81.23	Anonymous (1985)
1983	55.00-75.00	46.93-63.99	Anonymous (1985)
1984	23.60[2]	19.30	Reeves, Unpubl. data
1990	135.00[3]	85.31	Reeves, Unpubl. data

[1] Using 1981 dollar as standard; inflation-adjusted values are expressed in 1981 dollars. Based on Consumer Price Index for Canada, all items.

[2] Prices were per tusk: $150 for 4-5ft, $200 for 5-6ft, $250 for 6-7ft, $300 for over 7ft. Price per pound calculated by assuming an average tusk weight of 5.3kg (11.66lb) and that such a tusk would be 7ft long (i.e., worth approx. $275).

[3] Prices were per foot of length (those used were for Arctic Bay, Northern Stores [formerly Hudson's Bay Company]): $100 for 5-6ft, $150 for 6-7ft, $200 for 7-8ft, $250 for over 8ft. Price per pound calculated as in footnote 2.

Table 5

Prices paid for narwhal ivory by Greenland Trading Company (formerly KGH, now KNI) (Reeves, in prep.). In Danish crowns, per kg of weight except as indicated.

Year	Actual	Sources
1968	45	Hansen (1970)
1971	45 (broken)	Bruemmer (1971)
1975-6	300	Durham (1978)
1984	715	Born (1987)
1985	500	Born (1987)
1990	660 (unbroken) 215 (broken)	M.P. Heide-Joergensen (*in litt.*, 1990)

Table 2

Export destinations of raw narwhal tusks from Greenland and Canada according to CITES permit data, 1975-1990. Canadian data are from CITES Reports issued by Canadian Wildlife Service; Greenland data are from files of Gronlands Hjemmestyre, Sekretariatet, Nuuk, Greenland withdrew from the EEC effective 1 Feb. 1985. This implied withdrawal from the EEC/Denmark custom area and meant that CITES export permits would thenceforth be issued by Greenland Home Rule authorities, incl. for exports to Denmark and other EEC countries.

Year	From:/To:	AU	GB	CH	BE	FR	JP	DK	DE	IT	US	SA	IE	MC	NO	FO	CA	SE	NC	GL	NL	AT	SG	CU	NZ	FI	MX	Tusk totals
1975	Canada	-	38	-	7[1]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	38
1976	Canada	1[1]	26	-	42[1]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	26
1977	Canada	-	25	-	-	1	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28
1978	Canada	-	48	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	52
1979	Canada	-	96	-	-	2	2	-	-	6	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	107
1980	Canada	-	60	-	-	3	3	-	-	3	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	70
1981	Canada	-	36	1	-	-	1	-	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	41
1982	Canada	3	33	-[2]	-	4	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	42
1983	Canada	-	63	2	-	3	4	-	-	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-[3]	1	-	-	90
1984	Canada	-	33[4]	1	-	3	16	-	2	1	-	-	-	-	-	-	-	-	1	-[5]	-	-	-	-	-	-	-	57
1985	Canada	-	-	-	-	-	15	-	-	-	-	-	-	-	-	-	-	-	-	-[6]	-	-	-	-	-	-	-	15
	Greenland	-	-	-	-	1	-	42	-	-	-	-	-	-	-	1	3	2	-	-	-	-	-	-	-	-	-	49
1986	Canada	-	-	-	-	1	20	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	23
	Greenland	-	-	2	-	1	11	93	-[7]	-	-	-	-	-	1	2	1	-	-	-	-	-	-	-	-	-	-	111
1987	Canada	-	-	10	-	-	9[8]	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	21
	Greenland	-	4	-	-	-	1	90	2	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	99
1988	Canada	-	-	2	-	-	27	-	4	3	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	38
	Greenland	-	-	-	-	2	2	158	-	-	-	-	-	-	4	-	3	1	-	-	-	-	-	-	-	-	-	170
1989	Canada	-	1	17	-	-	104	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	123
	Greenland	-	-	3	1	-	3	153	4	-	-	-	-	-	1	2	-	2	-	-	-	-	-	-	-	-	-	169
1990	Canada	-	-	23	-	-	76	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	107
	Greenland[9]	-	-	-	-	-	2	190	1	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	1	-	196
																											Total:	1,6712

[1] Carved, carvings; [2] One preserved brain from a narwhal; [3] Bag of small tusk pieces; [4] Also one 'carved tusk'; [5] 13.3kg of 'meat' (muktuk?); [6] 20kg of 'meat' (muktuk?); [7] One skull; [8] Also one skull; [9] Preliminary.

Note: AU - Australia, GB - United Kingdom, CH - Switzerland, BE - Belgium, FR - France, JP - Japan, DK - Denmark, DE - West Germany, IT - Italy, US - United States, SA - Saudi Arabia, IE - Ireland, MC - Monaco, NO - Norway, FO - Faroe Islands, CA - Canada, SE - Sweden, NC - New Caledonia, GL - Greenland, NL - Netherlands, AT - Austria, SG - Singapore, CU - Cuba, NZ - New Zealand, FI - Finland, MX - Mexico.

North Atlantic
(including the Baltic and Mediterranean)

SC/O90/G6

Interactions Between Cetaceans and Gillnet and Trap Fisheries in the Northwest Atlantic

Andrew J. Read
Woods Hole Oceanographic Institution, Woods Hole, MA 02543, USA

ABSTRACT

Gillnet and trap fisheries of the Northwest Atlantic and their potential for cetacean entanglement are reviewed. Ten major categories of passive fisheries are identified, five of which are known to take substantial numbers of cetaceans during the course of their operations: Atlantic Canada and Gulf of Maine groundfish gillnets; Atlantic Canada cod traps; Bay of Fundy and Gulf of Maine herring weirs; Atlantic Canada and Greenland salmon gillnets; and US east coast swordfish driftnets. The cetacean species most threatened by incidental mortality in commercial fisheries in this region are the harbour porpoise, *Phocoena phocoena*, which is taken in large numbers and the endangered northern right whale, *Eubalaena glacialis*.

KEYWORDS: INCIDENTAL CAPTURE; NORTH ATLANTIC; FISHERIES; PINNIPEDS; HARBOUR PORPOISES; WHITE-SIDED DOLPHINS; WHITE-BEAKED DOLPHINS; LONG-FINNED PILOT WHALES; WHITE WHALES; HUMPBACK WHALES; MINKE WHALES; FIN WHALES; RIGHT WHALES

INTRODUCTION

Cetaceans frequently encounter fishing gear in the Northwest Atlantic, due to the intensive fishing activity and large numbers of whales, dolphins and porpoises in this area. The concentration of researchers in the region has assisted in the documentation of interactions between cetaceans and fisheries (e.g. O'Hara *et al.*, 1986; Kraus *et al.*, 1990). Despite past research into these interactions, however, our efforts to understand the impacts of fisheries on cetaceans are still in their infancy. In none of the fisheries described in this paper do we have an accurate estimate of the numbers of cetaceans killed or a clear understanding of the impact of this incidental mortality on affected populations. The numbers of cetaceans taken by some of these fisheries are startling; they should spur us to work harder in attempts to understand and mitigate these conflicts.

My objective in this paper is to review all major passive gillnet and trap fisheries in the northwestern Atlantic and document their known interactions with cetaceans. The review is incomplete; we know little of either cetaceans or fisheries in some areas. I have restricted my review to gillnets and traps that are truly passive in nature and have not included fisheries that employ gear in an active fashion, such as the 'run-around' gillnets used to take a variety of species in the southeastern United States. Neither have I included trap and pot fisheries for crustaceans, although whales and dolphins are known to become entangled in crab and lobster pot lines on occasion (e.g. Douglas, 1989). Cetaceans were probably taken by two gillnet fisheries that are currently inoperative: the sturgeon fishery of the mid-Atlantic states (Reynolds, 1985) and the king mackerel fishery off the southeast coast of Florida.

To restrict the review to a manageable size, I have pooled similar fisheries together in major categories. Thus, all groundfish gillnet fisheries in Atlantic Canada and the northeastern USA are considered together. Ten major categories of fisheries are identified. These categories are divided into two groups: those that are known to take substantial numbers of cetaceans in their operations and those in which incidental catches have been reported only infrequently. In some cases, inclusion in the second category may reflect poor documentation of cetacean fisheries interactions rather than their infrequent occurrence.

Fisheries in the first category are considered in more detail than those not known to take large numbers of cetaceans. For these fisheries, I have attempted to obtain the following information, although it was seldom possible to obtain complete data: (1) location of ports; (2) target species; (3) area of operation; (4) description of vessels and crew; (5) description of gear; (6) description of operation; (7) economics and history; (8) landings; (9) fishing effort; (10) interactions with cetaceans; (11) interactions with pinnipeds; (12) information requirements.

There are several biases inherent in the amount of coverage given to different fisheries. As noted above, certain fisheries have been better documented than others, particularly in regard to their interactions with cetaceans. In addition, I bring my own biases to the review, formed by having worked with groundfish gillnet and weir fisheries for several years.

* Unless otherwise stated $ refers to US dollars.

FISHERIES KNOWN TO TAKE LARGE NUMBERS OF CETACEANS

Atlantic Canada and Gulf of Maine groundfish gillnet fishery

Various forms of this fishery exist throughout eastern Canada and the Gulf of Maine. Intensive fishing effort occurs in southern Labrador, eastern Newfoundland, the Gulf of St. Lawrence, the eastern shore of Nova Scotia, the Bay of Fundy, and the Gulf of Maine. Groundfish gillnets are also used in southern New England (Ruais and Goodreau, 1987). In eastern Canada, gillnet fishermen tend to operate out of small ports that are scattered along the coastline. The US groundfish gillnet fishery is similarly dispersed.

The main target species are Atlantic cod (*Gadhus morhua*) and, in the southern range of the fishery, pollock (*Pollachius virens*) and white hake (*Urophycis tenuis*). A variety of demersal species are also taken and in many areas spiny dogfish (*Squalus acanthias*) often comprise a large proportion of the catch. Haddock (*Melanogrammus*

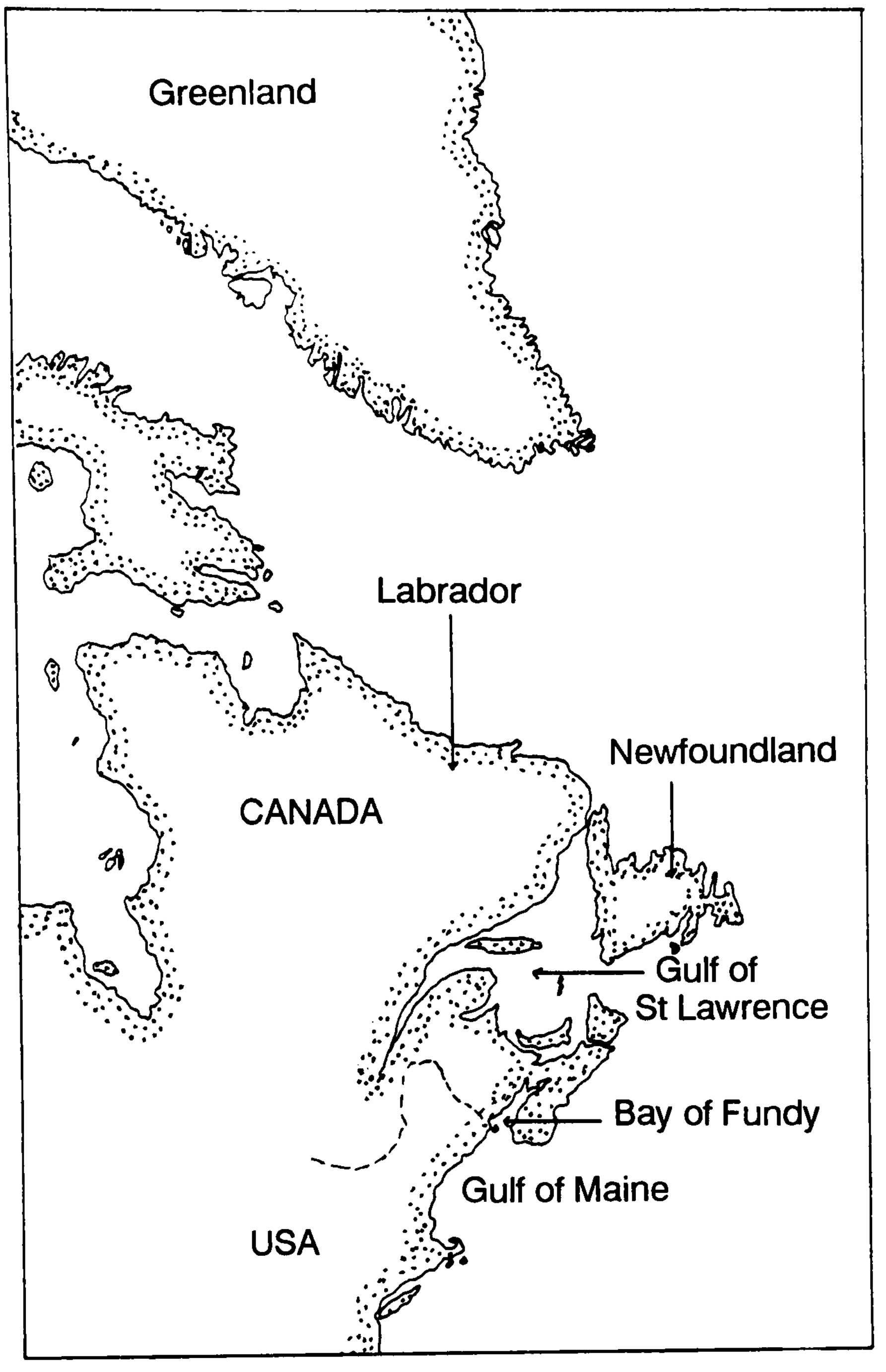

Fig. 1. Eastern Canada and Greenland, showing fishing regions described in the text.

aeglefinus) was once a major species taken by gillnets in the southern range of this fishery, but stocks of this species no longer support significant catches. In some areas fishermen configure their nets to take other species of groundfish, notably lumpfish (*Cyclopterus lumpus*) or flatfishes.

Groundfish gillnets are set throughout the inshore waters of eastern Canada and Gulf of Maine. Areas of operation are constrained by both water depth and local regulations. In the Bay of Fundy and Gulf of Maine, nets are usually set in water depths of less than 600ft (Read and Gaskin, 1988; NMFS, 1990b). Complex regulations restrict the use of gillnets in many nearshore areas to minimise conflicts with vessel traffic and other fisheries; these regulations are not reviewed here.

Groundfish gillnet fishermen typically employ small, versatile inshore vessels that are also used in a variety of other fisheries. In the Gulf of Maine between 1974 and 1981, the mean length of groundfish gillnet vessels varied between 31 and 44ft and mean vessel weight varied between 20 and 29 gross registered tons (GRT) (Ruais and Goodreau, 1987). Gillnet vessels are typically operated by their owners and an additional crew member or two. Fish are usually gutted at sea and brought back to port either fresh or on ice.

An excellent description of the gear used by groundfish gillnet fishermen in the Gulf of Maine is given by Drew (1990). Although there is some variation in gear configuration in this fishery, many fishermen use a standard monofilament gillnet. In the United States, minimum stretched mesh size is restricted to 5½ inches; maximum mesh size is 9 inches (Drew, 1990). Canadian fishermen in the Bay of Fundy use nets with a similar mesh size (Read and Gaskin, 1988). Panel depth varies between 8 and 12ft (Drew, 1990), but panel length is much more variable. In the Bay of Fundy, most fishermen use five strings of net, each 1,800ft long (Read and Gaskin, 1988). Fishermen in the Gulf of Maine may only set four strings of net, but each string is usually between 1,500 and 3,600ft long (Drew, 1990). Total net length is the most variable component of gear type; fishermen in the Gulf of Maine set nets between 1,500 and 7,500ft in length.

The nets are strung between a lower lead line and an upper float line. Nets set for flounder and other flatfishes have tie-down lines that keep the float line only 2–3ft above the lead line, allowing the webbing to lie slack (Drew, 1990). Gillnet locations are marked by buoys and radar reflectors in some areas, such as the Bay of Fundy. In other areas, gillnets are not marked in a consistent manner (Ruais and Goodreau, 1987). Most vessels set nets over the stern as they travel; the nets are usually hauled to the surface with hydraulic gear.

Groundfish gillnets are anchored on the bottom in depths of 360–600ft. In the Bay of Fundy, the nets are set in the morning and retrieved, whenever possible, the following day (Read and Gaskin, 1988). Occasionally the nets are left in the water for longer periods, although fish quality deteriorates if the nets are not retrieved each day. In areas where fishermen set a large amount of gear or fish far from shore, fishermen are unable to retrieve all of their gear each day and haul nets on alternative days. Flounder nets are often left for longer periods because these species can survive long periods of entanglement (Drew, 1990). In general, fishermen operating close to shore make day trips and those setting nets further offshore stay at sea for two or more consecutive days.

Most of these fisheries are seasonal in nature, reflecting the migratory nature of target species and their seasonal availability in inshore waters. In Newfoundland, the fishing season is short and gillnets are used only between early June and mid-August (Piatt and Nettleship, 1987). In the Bay of Fundy, fishermen set groundfish gillnets between June and October (Read and Gaskin, 1988). Further to the south, in the Gulf of Maine, gillnets are used throughout the year, with peak operations between April and November (Payne *et al.*, 1990). Peak seasons may vary from location to location, reflecting local conditions and the existence of alternative fisheries. In the Bay of Fundy, for example, the gillnet season ends in September or October so that fishermen can prepare their gear for the lobster season, which begins in November.

There is little information available on the history or economics of this fishery. Ruais and Goodreau (1987) noted that gillnets have been used in the Gulf of Maine since the late 19th century. The introduction of monofilament provided a durable and inexpensive net material and undoubtedly had an immense impact on the groundfish industry. According to fishermen in the Bay of Fundy, monofilament nets were first used in the mid-1970s (B. Carey, pers. comm.) at about the same time that they were introduced in the Gulf of Maine (Ruais and Goodreau, 1987). In some areas, the level of gillnet activity appears to have increased over the last twenty years (NMFS, 1990b), although accurate effort data are difficult to obtain (see below). In other areas, it is impossible to ascertain trends in gillnet effort.

The price fishermen receive for groundfish fluctuates both annually and geographically, reflecting a bewildering variety of market forces. For example, the landed value of cod rose from $0.22 to $0.38 per lb between 1986 and 1987 in the Bay of Fundy, causing a temporary expansion of the gillnet fleet (L. Murison, pers. comm.). Most of the groundfish captured in US gillnets is either consumed fresh or frozen; all processing occurs in New England (NMFS, 1990b). In Canada, most groundfish is frozen and exported to the USA, although a portion is exported fresh or salted. About 80% of groundfish from the Scotia-Fundy region is exported to the USA (Hache, 1990).

Total landings are seldom compiled by gear type, so it is often difficult to determine how much of the total groundfish landings each year are made by gillnets. Ruais and Goodreau (1987) estimated that in 1984 gillnet fishermen landed approximately 14,000 tonnes of groundfish in New England. In 1983, Canadian fishermen landed over 13,400 tonnes of groundfish in the provinces of New Brunswick and Nova Scotia (DFO, 1985).

It is clear that the groundfish gillnet fishery is an important industry in both eastern Canada and New England. In the Canadian provinces of New Brunswick and Nova Scotia, the landed values of groundfish captured in gillnets during 1983 was $3 million and $6 million ($CAN), respectively (DFO, 1985). The landed value of cod in New England was $48 million in 1989 and gillnets accounted for approximately 40% of landings of this species (NMFS, 1990b).

Effort is perhaps the most difficult statistic to obtain for this and other fisheries, because fishermen are seldom required to report the relevant data. In many areas it is even difficult to determine how many licence holders are actively fishing in any particular year. There are a large number of fishermen licenced to use groundfish gillnets in eastern Canadian waters, although it is impossible to determine how many individuals actually participate in the fishery. In 1989, approximately 6,800 groundfish fixed gear licences were issued to fishermen along the southern coast of Labrador, and northeast and southern coasts of Newfoundland (G. Brocklehurst, DFO, pers. comm.). In the Gulf of St. Lawrence, there were approximately 3,900 groundfish fixed gear licences issued in 1989 (S. Guinchard, DFO, pers. comm.), and in the Bay of Fundy and southwestern Nova Scotia 659 fishermen held groundfish gillnet licences (J. Conway, DFO, pers. comm.). The only information on the proportion of licenced Canadian fishermen that actually fish was obtained in the western Bay of Fundy, where approximately 25% of licence holders used gillnets in 1984 (Read and Gaskin, 1988). During August 1986, 14 Bay of Fundy gillnet fishermen set their gear on 46% of monitored days (Read and Gaskin, 1988).

Slightly better information exists on the level of fishing effort in US waters. In the Gulf of Maine there were 317 vessels registered to use groundfish gillnets under the NMFS Marine Mammal Exemption Program in 1989 (see below) (Payne *et al.*, 1990), although the number of active vessels is unknown. Gillnet vessels made over 12,000 trips in 1988, which increased to over 14,000 in 1989 (NMFS, 1990b).

Groundfish gillnets frequently entangle cetaceans during the course of their operations, resulting in damage to fishing gear and injury or death to the entangled animals. I will discuss groundfish gillnet interactions with cetaceans in three separate regions in which these fisheries operate: Newfoundland-Labrador, Gulf of St. Lawrence and Bay of Fundy-Gulf of Maine.

(A) Newfoundland and Labrador

A variety of cetacean species are known to become entangled in groundfish gillnets in this region (Perkins and Beamish, 1979; Lien, 1987; 1994; Piatt and Nettleship, 1987; Lien *et al.*, 1990) including: harbour porpoises (*Phocoena phocoena*); white-sided dolphins (*Lagenorhynchus acutus*); white-beaked dolphins (*Lagenorhynchus albirostris*); long-finned pilot whales (*Globicephala melas*); white whales (*Delphinapterus leucas*); humpback whales (*Megaptera novaeangliae*); minke whales (*Balaenoptera acutorostrata*) and fin whales (*Balaenoptera physalus*).

Most small cetaceans are killed during entanglement, because they are unable to reach the surface to breathe. Large whales are often able to break through gillnets and escape, although they may carry fragments of net with them. Lien *et al.* (1990) received reports of 34 humpback entanglements in groundfish gillnets in Newfoundland and Labrador during 1989. The majority of these whales were either released alive with the aid of an entrapment assistance crew from Memorial University (20) or escaped towing gear (11). A single whale extricated itself from a net and two died as a result of entanglement. Six minke whales were reported entangled in gillnets during 1989; five of these smaller whales died and the other individual escaped towing gear. Many small cetaceans that are killed in groundfish gillnets in this region are retained for human consumption. This is particularly true for harbour porpoises, which are frequently consumed by fishermen and their families in Newfoundland and Labrador (Lien, 1987). Larger cetaceans that die in gillnets are usually discarded.

There are no reliable estimates of the total number of cetaceans entangled by groundfish gillnets in this region. Lien (1987) noted that the majority of humpback and minke whale entanglements were reported, perhaps 90% and 75%, respectively. If these figures are accurate, approximately 40 humpbacks and 8 minke whales became entangled in 1989. It is more difficult to estimate the number of smaller cetaceans taken in gillnets, because fishermen seldom report these events. It is clear, however, that the incidental take of at least one species, the harbour porpoise, is substantial. The only information on the level of harbour porpoise entanglements was obtained by Lien (1987). In 1980, 100 fishermen from eastern Newfoundland were interviewed and asked how many small cetaceans they had encountered in their gillnets. The fishermen reported taking approximately 214 harbour porpoises during the course of the fishing season. Four fishermen, working in the St. Mary's Bay area, reported catches of 25, 29, 41 and 112 porpoises. The concentration of high porpoise catches in this location makes it impossible to extrapolate to other areas, even if adequate effort data were available. Recent reductions in fishing effort have occurred in Newfoundland and Labrador as a result of fisheries conservation measures implemented to protect overexploited groundfish stocks. The number of cetaceans entangled in these nets has presumably been reduced proportionally to the reduction in fishing effort.

The mortality of large whales in groundfish gillnets and other fishing gear has been greatly reduced by the efforts of the entrapment assistance programme at Memorial University of Newfoundland (Lien *et al.*, 1990; Lien, 1994). Since 1978 this programme has trained fishermen to remove large whales from their fishing gear, reducing the risk of mortality to the animals and minimizing damage to the nets. Fishermen are able to call a 24 hour toll-free phone to obtain advice and, if necessary, assistance. Prior to the initiation of this programme, mortality of humpbacks entrapped in fishing gear was about 50% whereas the mean level of humpback mortality from entrapment between 1987 and 1990 was only 11% (Lien, 1994). This programme should serve as a model for other attempts to reduce the mortality of large cetaceans in fishing gear.

Historically, groundfish gillnets posed potential threats to two cetacean populations in this area. Incidental entanglement posed a serious threat to northwestern Atlantic humpback whales with the high mortality rates observed prior to the initiation of the entrapment release programme. The catches of harbour porpoises, however, may have been large enough to have had a deleterious effect on the population of porpoises in this area. Harbour porpoises in Newfoundland and Labrador are believed to form a distinct stock (Gaskin, 1984), but at present there are no estimates of abundance for this population. Assessment of the impact of porpoise mortality in groundfish gillnets will require information on abundance and more data on the historical level of incidental catches. Harbour porpoises were listed as threatened in eastern Canada, due in large part to the perceived threat caused by incidental mortality in gillnet fisheries. Recent fisheries conservation measures make it unlikely that these fisheries will pose a threat to cetacean populations in the near future.

(B) Gulf of St. Lawrence

Until recently, the only research into incidental mortality of cetaceans in fisheries of this area was the work of Laurin (1976), who noted that an undetermined number of harbour porpoises were taken in groundfish gillnets each year. Fontaine *et al.* (1994) have recently initiated a programme to examine the extent of this problem. Their work indicates a substantial incidental catch of harbour porpoises and smaller takes of white whales, white-beaked dolphin, and unidentified rorquals (*Balaenoptera* spp.). Minke whales are abundant in the Gulf of St. Lawrence and probably become entangled in gillnets on occasions (R. Sears, pers. comm.). There is no information on the proportion of cetaceans that are killed during the entanglement process in this area. As noted above, however, it is unlikely that any of the smaller cetaceans survive encounters with groundfish gillnets. Harbour porpoises captured in gillnets are often retained for food by fishermen in the Gulf of St. Lawrence.

There are no direct estimates of the numbers of cetaceans taken by groundfish gillnets in the Gulf of St. Lawrence. Fontaine *et al.* (1994) sent questionnaires to 968 coastal fishermen and asked them about the numbers of harbour porpoises they encountered in their nets. One-third of the fishermen responded and indicated that between them they had caught approximately 445 porpoises in groundfish gillnets during 1988 (Fontaine *et al.*, 1994; P. Fontaine, pers. comm.). If the respondents were representative of the entire sample, and it is not possible to determine whether or not this is the case, over 1,900 porpoises were captured in groundfish gillnets during 1988. Although such extrapolations are risky, it is clear that the take of harbour porpoises in this area is substantial. Most porpoises were taken in July, but some were caught in all months from April to November.

Groundfish gillnets pose a potentially serious threat to the harbour porpoise population in this area. As is the case in Newfoundland, the animals in the Gulf of St. Lawrence are believed to form a single stock (Gaskin, 1984), but estimates of abundance are lacking. Further research is required to address the impact of incidental catches on harbour porpoises in this area. The only other potential threat to cetacean populations may be the occasional capture of white whales from the endangered St. Lawrence population (IWC, 1992, table 9). The available information is insufficient to address the impact of incidental catches on this population.

(C) Bay of Fundy and Gulf of Maine

A large body of information exists on the nature and magnitude of incidental catches in this area, due in large part to the concentration of marine mammal researchers in the region. The species known to be taken in groundfish gillnets in this area (Katona *et al.*, 1978; Reeves *et al.*, 1978; Gilbert and Wynne, 1983; Read and Gaskin, 1988; Douglas, 1989) include: harbour porpoises; white-sided dolphins; pilot whales; minke whales; humpback whales; and northern right whales (*Eubalaena glacialis*).

Most small cetaceans die after becoming entangled in groundfish gillnets in the Bay of Fundy and Gulf of Maine. Researchers have suggested that small cetaceans, such as harbour porpoises, become entangled either as the nets are being set or as the nets are fishing on the bottom (Gilbert and Wynne, 1983). Experimental sets conducted by Read and Gaskin (1988) were too limited to demonstrate which of these alternatives is correct. As noted above, many large whales survive their encounter with gillnet gear. There have been six records of right whales becoming entangled in groundfish gillnet gear in the Bay of Fundy and Gulf of Maine between 1975 and 1990 (Kraus, 1990; NMFS, 1990a; L. Murison, pers. comm). In all six instances, the right whales were either released or escaped on their own, although several whales have been observed carrying net fragments (S. Kraus, pers. comm.). Humpback whales also frequently survive encounters with groundfish gillnets. Eleven of fourteen humpback whales known to have become entangled in Gulf of Maine gillnets since 1975 either escaped or were released alive (C. Coogan, NMFS, pers. comm.). A few harbour porpoises are still consumed by fishing families in the Bay of Fundy, but this practice has been largely discontinued. A moderate number of small cetaceans and a few large whales that die in groundfish gillnets are made available to researchers.

There have been several attempts to estimate the magnitude of incidental mortality of harbour porpoises in the groundfish gillnet fishery in the Bay of Fundy and Gulf of Maine. Incidental catches of other species occur relatively infrequently and have received correspondingly less attention. Based on anecdotal evidence, Prescott and Fiorelli (1980) suggested that gillnet vessels might take two porpoises per vessel per year. In 1979, there were approximately 150 gillnet vessels active in the Gulf of Maine (Ruais and Goodreau, 1987), leading Prescott and Fiorelli to suggest that as many as 300 porpoises might be taken each year. The first study to systematically estimate harbour porpoise incidental mortality in this area was conducted by Gilbert and Wynne (1983). These researchers interviewed 17 gillnet fishermen from the state of Maine, who reported an incidental catch of 118 small cetaceans, predominantly harbour porpoises, during 1982. Gilbert and Wynne (1983) considered the results of interviews to provide only minimal estimates of the numbers actually taken by fishermen. Gilbert and Wynne (1987) later used logbook data to suggest a maximum figure of 600 porpoises taken annually in the entire Gulf of

Maine. This maximum figure was derived by applying the reported average annual catch per vessel (5.1 porpoises) to the total fleet (estimated as 90 – 120 active vessels). Gilbert and Wynne (1987) considered this maximum figure unrealistic, because they felt vessels with a high level of incidental catch were over-represented in the logbook sample. As noted by Polacheck (1989), sampling problems associated with the diffuse and varied nature of this fishery complicate attempts to estimate total incidental mortality in groundfish gillnets.

Read and Gaskin (1988; 1990b) investigated the incidental take of harbour porpoises in the western Bay of Fundy, an area not covered by the work of other researchers. Year-end interviews were made with the majority of vessel operators in this relatively small fishery (20 to 30 active vessels each year). The results of these interviews were used to generate estimates of annual mortality, which varied from 80 to 129 porpoises between 1986 and 1989 (Read and Gaskin, 1990b). Kraus *et al.* (1990) combined these data from the Bay of Fundy with estimates of incidental catches in the Gulf of Maine and suggested that the number of porpoises taken in the entire region may be as high as 1,000 per year.

Amendments to the US Marine Mammal Protection Act made in 1988 require the US National Marine Fisheries Service (NMFS) to classify fisheries based on their likelihood of killing marine mammals and to assess the impacts of such incidental takes. NMFS has classified the Gulf of Maine groundfish gillnet fishery as likely to take marine mammals frequently during the course of its operations (Category I) and has placed observers on gillnet vessels to collect information on the number of cetaceans taken. From August 1989 to July 1990, 158 fishing days were observed, during which 15 harbour porpoises were killed (Payne *et al.*, 1990). Most observed sets had no porpoises killed; the maximum number of porpoises killed in a single set was three (T. Smith, NMFS, pers. comm.). Porpoises were entangled between October and April; no porpoises were taken during other months. The observed seasonality of this catch agrees well with the hypothesized north-south migration of harbour porpoises in the region (Payne *et al.*, 1990). During the summer months, harbour porpoises leave the Gulf of Maine and are found further to the north in the Bay of Fundy. The number of trips observed comprised between 1 and 3% of total fishing effort but were not, however, proportional to the geographical distribution of fishing effort, making extrapolation to an estimate of total kill difficult (Payne *et al.*, 1990). Increased observer effort in 1990, 1991 and 1992 allowed better estimates to be generated of the magnitude of these incidental catches in the Gulf of Maine. During these years, bycatches of harbour porpoises varied between 900 (95% CI 700 to 1,200) and 2,400 (95% CI 1,600 to 3,500) (Smith, *et al.*, 1993). These bycatch estimates only include observations from the US waters of the Gulf of Maine north of Cape Cod.

The above data indicate that groundfish gillnets have the potential to exert significant effects on two cetacean populations in the Bay of Fundy and Gulf of Maine. Gillnets pose a threat to northern right whales in such areas where both whales and nets can be found in close proximity. Although there have been no deaths directly attributed to gillnets, the precarious status of the right whale population magnifies the threat associated with such fishing gear (NMFS, 1990a). Over half of the known individuals in this small population have scars resulting from entanglement in fishing gear (Kraus, 1990). Gillnets also pose a significant threat to the harbour porpoise population in this region. Although it is difficult to generate an actual estimate of the current harbour porpoise incidental mortality caused by groundfish gillnets, it seems clear the take is large relative to population size. Estimates of abundance for this stock range from 37,500 (95% CI 26,700 to 86,400) to 67,500 (95% CI 32,900 to 104,600) (Smith, *et al.*, 1993). Demographic models suggest that this population is unlikely to sustain mortality levels of 4% (Woodley and Read, 1991). Changes in summer distribution patterns and life history parameters (such as age at sexual maturity) have been documented that are consistent with a reduction in harbour porpoise density (Read and Gaskin, 1990a).

Groundfish gillnets also take unknown numbers of pinnipeds in several parts of eastern Canada and New England. In eastern Newfoundland, large numbers of harp seals (*Phoca groenlandica*), and lesser numbers of harbour (*Phoca vitulina*) and hooded seals (*Cystophora cristata*) are taken by demersal gillnets (Piatt and Nettleship, 1987). Similar nets also take harbour and grey seals (*Halichoerus grypus*) in New England waters (Gilbert and Wynne, 1985) and in the Gulf of St. Lawrence (P. Fontaine, pers. comm.). For unknown reasons, groundfish gillnets do not capture pinnipeds in the western Bay of Fundy (Read and Gaskin, 1988).

Large numbers of cetaceans, mostly harbour porpoises, are killed in this fishery each year. It is impossible to fully assess the threat to affected populations, even in the best studied areas, because of a lack of critical information. It should be evident, however, that the potential threats are serious enough to warrant comprehensive assessments of the impact of these incidental catches throughout the range of this fishery. These assessments will require accurate information on the numbers of cetaceans killed by gillnets in each area. Such data are best collected by on-board observations, such as in the NMFS programme, because data obtained from interviews with fishermen may not be reliable (e.g. Lien *et al.*, 1994). The assessments will also require much better information on fishing effort than is presently available. Particular attention should be paid to resolving problems of determining fishing effort in the Gulf of Maine, so that accurate estimates of total incidental mortality may be generated.

Atlantic Canada cod traps

The cod trap fishery is scattered along the coasts of Newfoundland and Labrador and, to a lesser extent, along the north shore of the Gulf of St. Lawrence. Most cod traps are found on the southern and eastern shores of Newfoundland and the Labrador coast. There are also an unknown number of cod traps set along the West Greenland coast (F. Larsen, pers. comm.). The diffuse nature of the fishery does not allow for concentration of fishermen in any particular port.

The primary target species is Atlantic cod, although a variety of demersal species may be taken in smaller numbers. The traps are fixed structures that are deployed in near-shore areas. Their areas of operation are dictated largely by water depth and local topography. The traps are tended by small inshore vessels of varying size and design. Each boat will tend from three to five traps each season (DFO, 1984).

Cod traps are essentially rectangular boxes of netting, open at the top and with an opening or 'door' on the inshore side (DFO, 1984). The trap is kept afloat with buoys and anchored on the corners to maintain position and shape. Fish are guided into the structure by a long 'leader' that extends from shallow water to the mouth of the trap. Traps are of varying dimensions, depending on local topography, but a typical structure will measure 75ft in each direction. The length of the leader is also extremely variable. Once fish are inside the cod trap, fishermen can close the door, preventing their escape. The floor of the trap is hauled to the surface and across the boat, concentrating the fish in one corner of the trap. Fish are then removed with a dip net. Cod traps are often emptied twice daily during the fishing season. This is a highly seasonal fishery, dependent on the inshore cod run during the summer months. Cod traps are usually set out early in the summer and are often taken up by the end of August, when cod become scarce in nearshore areas (Perkins and Beamish, 1979).

As noted above, most Canadian groundfish are processed locally and then shipped to the USA. Cod is usually exported in frozen blocks. Inshore cod landings in Newfoundland have decreased dramatically over the past decade, although the causes of this decline are uncertain. In 1988, 46,778 tonnes of cod were taken by traps in eastern Newfoundland and Labrador (L.M. Collins, DFO, pers. comm.).

There were 3,121 cod traps operating in Newfoundland and Labrador during 1979, that fished over 320,000 trap days (Lien, 1980). Lien (1987) estimated that the number of cod traps had grown to approximately 7,500 by 1980. The cod trap fishery in Newfoundland was closed in 1993 due to the precarious state of the groundfish resources in northeastern Canada. At the time this paper was revised (May 1994) there were no plans to reopen this fishery.

Harbour porpoises, white whales, pilot whales, humpback whales, right whales and minke whales are known to become trapped or entangled in Newfoundland cod traps (Perkins and Beamish, 1979; Lien, 1980; 1994; Piatt and Nettleship, 1987). Entanglement is typically with the leader, rather than with the trap itself (Lien and Merdsoy, 1979), apparently as the whales and porpoises move parallel to shore pursuing prey. As with gillnets, there is considerable opportunity for live release, particularly with larger cetaceans. In 1989, only two of 22 humpbacks died after entrapment in Newfoundland cod traps (Lien *et al.*, 1990). Smaller whales, such as minkes, do not fare as well. All five minke whale entrapments in Newfoundland cod traps during 1989 resulted in the death of the animal (Lien *et al.*, 1990). Smaller cetaceans killed in cod traps may be used for local consumption; larger whales are cut free and discarded when possible.

The only information on entanglement rates in cod traps comes from the entrapment assistance programme at Memorial University of Newfoundland (Lien *et al.*, 1990; Lien, 1994). A summary of past entrapments reported to Memorial researchers is included in O'Hara *et al.* (1986). Between 1979 and 1990, Lien (1994) reported that about 47% of all humpback and minke whale entrapments in Newfoundland and Labrador occurred in cod traps. In 1989, the assistance programme was notified of 22 humpback and six minke whale entrapments. Using the estimates of under-reporting presented for groundfish gillnets, Lien *et al.* (1990) estimated that about 25 humpbacks and 8 minke whales became entangled in Newfoundland cod traps during 1989. A much larger number of collisions is reported to Memorial University by fishermen; presumably these collisions do not result in the entanglement of the whale, although they may damage the gear. The entrapment assistance programme has greatly reduced the mortality of large whales in Newfoundland cod traps. With this programme in place, cod traps do not appear to pose a serious threat to the humpback whale population. The numbers of minke whales and other small cetaceans killed each year in cod traps are probably too small to exert significant effects on any population.

Pinnipeds are adept at navigating around fish traps in shallow water, so it is unlikely that cod traps kill many seals in Newfoundland. Piatt and Nettleship (1987) report a single harbour seal captured in a cod trap, but do not provide details of the entrapment. It is likely, however, that many seals are shot around cod traps by fishermen.

The Newfoundland cod trap fishery is unlikely to exert significant mortality on any cetacean population, due largely to the efforts of the entrapment assistance programme and the recent decline of the fishery. The humpback population has increased during the last decade (Lien *et al.*, 1990), despite occasional mortality in cod traps. Katona and Beard (1990) estimated the Newfoundland-Labrador feeding aggregation of humpback whales at 2,310 (±580) for the 1978–83 period. Cod traps may have contributed some additional mortality to endangered or threatened populations, such as harbour porpoises and right whales, but are not responsible for the precarious status of these populations.

Bay of Fundy and Gulf of Maine herring weirs

Herring weirs are scattered along the shores of eastern Canada and New England. There are no particular ports in which herring weir fishermen congregate. Most herring weirs are located along the southwestern shore of the Bay of Fundy, with weirs also scattered along the western Nova Scotia and northern Maine coasts.

The main target species for this fishery is Atlantic herring (*Clupea harengus*). Various other pelagic species, particularly mackerel (*Scomber scombrus*), are also taken in quantity. Herring weirs are restricted to shallow near-shore waters and there are many local restrictions on the placement of these fixed structures that relate to navigation and spacing between weirs. In most areas it is only possible to construct a weir on a licensed site.

Weirs are usually tended by several vessels. In the Bay of Fundy, fishermen check weirs each day using small dories. More vessels are required to remove fish from a weir, including a seine skiff, pumper (often a multi-purpose lobster boat) and a carrier that transports the catch to a processing plant. A good description of herring weirs is given in McKenzie and Tibbo (1960). Weirs are usually kidney-shaped structures consisting of fine nylon mesh strung from stakes that are driven into the bottom of the sea floor. The shape of the weir is variable, to some extent, but always designed to minimise escape once fish have entered the structure. The mouth of the weir faces shoreward and a leader of varying length extends from the mouth towards the shore. The stakes are placed 10–15ft apart and are from 15–40ft in length, depending on the water depth. Fish are removed from herring weirs with a fine mesh (0.25 to 0.5 inch) purse seine.

Fishermen usually check their weir each morning around dawn, estimating the quantity of fish inside the structure with either an echosounder or a fine copper line with which they can feel the vibration of passing fish. If there is a sufficient quantity of herring in the weir, the mouth will be closed to prevent the fish from escaping. Fish are usually removed from the weir at low tide to facilitate handling of the purse seine. The seine is stretched around the inside perimeter of the weir until the fish are encircled. The seine is then pursed and the fish pumped from the weir into the carrier. In the Bay of Fundy, weirs are constructed on a seasonal basis to take advantage of the migration of juvenile herring into inshore waters. The netting or 'twine' is taken down in the autumn in response to dwindling catches and the prospect of winter storms. In the spring or early summer, damaged or lost stakes are replaced and the twine is again restrung. The vast majority of herring weir catches in the Bay of Fundy are recorded from May to November (McKenzie and Tibbo, 1960).

Amongst a number of market factors, the price received by fishermen for herring reflects the size of the fish, the quantity of other species mixed with herring and the amount of herring being captured by other weirs. Smaller herring are canned and marketed as 'sardines.' In recent years, larger Canadian herring have been sold to Eastern European and Soviet factory freezer vessels under joint-venture agreements (Wilbur, 1990). Processing facilities are usually located close to weirs, because the fish are only lightly salted while being transported and spoil quickly. The herring weir fishery has a long history, dating back to at least 1820 in New Brunswick (McKenzie and Tibbo, 1960). In some areas along the Maine coast and in the Bay of Fundy, weirs are now being replaced by salmon aquaculture operations (C. Pendleton, pers. comm.). The landed value of the herring weir fishery in southwestern New Brunswick was estimated as approximately $2.2 million ($CAN) annually between 1974 and 1979 (Smith, *et al.*, 1983).

Herring weirs are capricious devices and a weir that fishes well in one year may catch nothing the next year. Recent landings in the Bay of Fundy have ranged from 30,000 tonnes in 1987 to 45,000 tonnes in 1989 (Wilbur, 1990). These figures do not include the relatively small weir fishery in American waters. There are no quotas for weirs, but markets may become saturated in years of good catches.

Effort in the herring weir fishery is usually measured by the number of weirs active each year. This does not, of course, account for variation in the number of months that each weir is active. In 1990, there were 180 active weirs in the western Bay of Fundy (Wilbur, 1990). The Maine Department of Marine Resources licenced 56 active weirs during 1990 (J. Fatterman, pers. comm.). In addition to those in the western Bay of Fundy and Maine, there are a few active weirs in western Nova Scotia and in southern New England.

The species of cetaceans known to become trapped in herring weirs include: harbour porpoises, humpback whales, minke whales and right whales (Smith, *et al.*, 1983; Kraus, 1990; A. Read, unpubl. data). Whales and porpoises apparently enter weirs when chasing prey and are then unable to find their way out of the structures. In the Bay of Fundy, fishermen reported that most harbour porpoises enter herring weirs at night (Smith, *et al.*, 1983). The vast majority of large whales that become trapped in herring weirs are released alive by fishermen, occasionally assisted by researchers. At least one weir in the Bay of Fundy has a net panel ('whale door') that can be opened to facilitate the release of a whale. Between 1980 and 1990, six humpback whales were trapped in Bay of Fundy herring weirs and all were released alive (A. Read, unpubl. data). Fifteen of seventeen minke whales were released alive during the same period; two whales died during seining operations. A right whale mother and calf were also released alive from a Bay of Fundy weir in 1976 (Kraus, 1990). Harbour porpoises trapped in herring weirs have a more uncertain fate. In questionnaire returns, fishermen indicated that 39% of harbour porpoises died after becoming trapped in weirs (Smith, *et al.*, 1983). Porpoises are either shot by fishermen or become entangled in the purse seine during the removal of the fish. Many fishermen attempt to remove harbour porpoises from weirs, however, and the practice of shooting porpoises is not widespread. As noted earlier, a few porpoises may still be used for human consumption in the Bay of Fundy.

The entrapment of a large whale in a herring weir is typically an unusual event, occurring only once or twice a year. 1990 was a highly unusual year in which ten minke whales and five humpbacks entered weirs in the Bay of Fundy. Weir entrapment is also unusual in New England; only four humpback and one minke whale entrapments have been recorded since 1975 – all escaped or were released alive (C. Coogan, NMFS, pers. comm.).

Smith *et al.* (1983) used questionanire returns to estimate that approximately 70 porpoises become trapped in Bay of Fundy herring weirs each year and that, on average, 27 die as a result of entrapment. In 1990, at least 43 porpoises were known to have become trapped in Bay of Fundy weirs, with an unknown number being killed (A. Read, unpubl. data). Since 1990, increasing numbers of porpoise entrapments are reported each year as part of a co-operative programme between Bay of Fundy weir fishermen and Canadian biologists. In 1993, over 100 porpoises were released alive as part of this programme (A. Read, unpub. data).

Fishermen operating herring weirs are acting in their own interest by removing whales from these structures alive, because large whales can easily damage both the netting and stakes. As noted above, many fishermen co-operate with researchers to free harbour porpoises from weirs and many porpoises have been tagged in this manner (Smith, *et al.*, 1983).

Herring weirs in New England and Atlantic Canada have little potential impact on cetacean populations. The only potential adverse effects are additional mortality on a stressed harbour porpoise stock and a very minor potential for mortality of endangered right whales. Herring weirs are listed as a Category III fishery under the 1988 amendment to the MMPA, because they have only a remote likelihood of taking marine mammals (Douglas, 1989).

Both harbour seals and grey seals feed around and inside herring weirs, but are able to navigate in and out of the structures with ease. Although the pinnipeds do not become trapped or entangled, large numbers of harbour seals and a few grey seals are shot each summer by herring weir fishermen in the Bay of Fundy.

Although herring weirs do not pose a direct threat to cetaceans in the Bay of Fundy or Gulf of Maine, the impact of harbour porpoise mortality in weirs must be considered in conjunction with the relatively large incidental mortality in groundfish gillnets. Action should be taken, therefore, to encourage fishermen to release harbour porpoises alive and minimise the number that are either shot or die during seining.

Atlantic Canada and Greenland salmon gillnets

This fishery operates along the western coasts of Greenland, and the Canadian shores of Newfoundland, Labrador and the northern Gulf of St. Lawrence. There are no ports of concentrated salmon gillnet activity. The target species is Atlantic salmon (*Salmo salar*). A variety of both pelagic and demersal species are also taken (see Christensen and Lear, 1977).

The northern limit of salmon gillnet operations in western Greenland is Godhavn at approximately 70°N. Most salmon nets are set in inshore waters along the Greenland coast (F. Larsen, pers. comm.). Salmon gillnets are set throughout inshore waters in northeastern Atlantic Canada.

The domestic Greenland fishery is dominated by small boats (less than 30ft in length) that work fairly close to shore (S. Northridge, pers. comm.). There was formerly a large driftnet fishery operated by vessels from the Faroes, Denmark and Norway in Greenland, but this practice ceased in 1976 and the fishery is now open only to Greenlandic vessels. In 1987 there were approximately 350 boats active in this fishery (S. Northridge, pers. comm.).

The number of active vessels declined in 1992 to 213 (J. Jensen, pers. comm.) and these Greenlandic fisheries were suspended in 1993 as a result of an agreement between fishermen and the North Atlantic Salmon Fund.

These fishermen used both monofilament and multifilament nylon nets, with mesh sizes of 130–140mm (Lear and Christensen, 1975; Christensen and Lear, 1977). Most nets were between 25 and 35m in length and extended from the surface to a depth of about 5m. The nets were suspended between a bottom lead line and an upper line equipped with floats. In the mid-1970s, the foreign fishery used up to 100 nets attached in 'links' which measured up to 1.8 n.miles in length (Christensen and Lear, 1977). Each foreign vessel set an average of 440 nets, extending for 7.8 n.miles (Lear and Christensen, 1975). In recent years domestic vessels seldom used more than 40 nets (S. Northridge, pers. comm.). In Canada, most commercial salmon gillnets are constructed of 5 inch (127mm) stretched mesh monofilament (B. Short, DFO, pers. comm.).

In the domestic Greenland fishery, both fixed and drift gillnets were used to take salmon (C. Kinze, pers. comm.). The foreign fleet used to set their nets just before sunset and started to haul just before sunrise, usually finishing before noon (Christensen and Lear, 1977). Salmon driftnets have been banned in Canadian waters and all commercial salmon gillnets must be fixed. Most nets are set with one end attached to the shoreline, although a few are anchored offshore (B. Short, DFO, pers. comm.). The nets fish in the upper portion of the water column.

The fishery is seasonal in both Greenland and Canada. In Greenland, the salmon fishery peaked in August and September (C. Kinze, pers. comm.). In Newfoundland, the season runs from early June to August or September, ending when the quota is filled or the weather deteriorates (B. Short, DFO, pers. comm.).

I have obtained little information on landed prices received by fishermen or market destinations. Nominal catches in the domestic Greenland fishery were 274 tonnes in 1990, 472 tonnes in 1991 and 237 tonnes in 1993 (J. Jensen, pers. comm.). Presumably most salmon is sold either fresh, iced, or frozen. The recent fishery in Greenland was considerably smaller than the fishery in the early 1970s when both domestic and foreign vessels were active. The domestic Greenland gillnet fishery took 963 tonnes of salmon in 1987 (NAFO, 1990). The Canadian driftnet fishery took 481 tonnes in Labrador, 794 tonnes in eastern and southern Newfoundland, and 306 tonnes in the Gulf of St. Lawrence (NAFO, 1990). Quotas exist in both Canadian and Greenland waters.

There are no effort data available for the Greenland fishery (F. Larsen, pers. comm.). There were 2,196 'gear units' used in southern and eastern Newfoundland and Labrador during 1989, each gear unit consisting of a net 300ft long. This gear was used by 549 individuals (B. Short, DFO, pers. comm.).

In Greenland, salmon gillnets took large numbers of harbour porpoises and an occasional pilot whale (Christensen and Lear, 1977; C. Kinze, pers. comm.). Salmon gillnets in Canada take a greater variety of cetaceans, including harbour porpoises and pilot, humpback and minke whales (Perkins and Beamish, 1979; Lien, 1980; Piatt and Nettleship, 1987; Lien *et al.*, 1990). In addition, an experimental driftnet fishery for salmon conducted by Canadian government researchers has taken the following species: harbour porpoises, white-sided dolphins, common dolphins (*Delphinus delphis*) and pilot whales (Stenson and Reddin, 1990).

There is little known about the entanglement process in salmon drift or fixed nets. Harbour porpoises are seldom reported to be released alive, although such an occurrence would be unlikely in Greenland where they are commonly consumed by local residents and occasionally used for bait (C. Kinze, pers. comm.). Five humpback whales entangled in salmon nets in Newfoundland during 1989 were either released alive or escaped unharmed (Lien *et al.*, 1990). Single humpback and minke whales both died after becoming entangled in salmon nets in Newfoundland during 1979 (Lien, 1980). Between 1979 and 1990, about 10% of humpback and 15% of minke whale entrapments occurred in salmon gillnets (Lien, 1994). There are few data on the number of cetaceans currently taken by salmon nets in eastern Canada. Both the foreign and domestic fisheries were known to have taken large numbers of harbour porpoises in the early 1970s. The foreign fishery is estimated to have taken approximately 1,500 porpoises in 1972 (Lear and Christensen, 1975) and the catch of the domestic fleet may have been almost as large (Christensen and Lear, 1977; Kapel, 1977). The number of harbour porpoises taken in Canadian waters is unknown, although catch rates reported by Newfoundland fishermen were lower for salmon gillnets than either groundfish gillnets or cod traps (Lien, 1987; Piatt and Nettleship, 1987). Laurin (1976) also noted that harbour porpoise entanglement rates were lower for salmon gillnets than groundfish gillnets in the Gulf of St. Lawrence.

With the limited data at hand, it is difficult to assess the potential impact of salmon gillnets on cetacean populations. It does appear, however, that this fishery affects only one species, the harbour porpoise, in its range of operations. Historical catches of harbour porpoises have been large and there is no evidence to demonstrate that they do not remain so. There has been no assessment of harbour porpoises in this area. Catches of harbour porpoises in Newfoundland, Labrador and the Gulf of St. Lawrence are unlikely to be as high as the historical records from Greenland. As noted above, however, these populations of harbour porpoises suffer considerable mortality from other fisheries; salmon gillnets contribute an unknown but additional mortality.

Salmon nets take harp seals, hooded seals, ringed seals (*Phoca hispida*) and bearded seals (*Erignathus barbatus*) in Greenland (Christensen and Lear, 1977) and harbour seals in Canada (Piatt and Nettleship, 1987). The magnitude of incidental catches of harbour porpoises should be assessed, if the salmon gillnet fishery is ever revived or expanded. At its current level of effort, this fishery is unlikely to exert a significant impact on any cetacean population.

US East coast swordfish driftnet fishery

This fishery operates from several ports in southern New England, although fishing operations are pelagic. The primary target species in this fishery is the swordfish (*Xiphius gladius*), but albacore (*Thunnus alalunga*), yellowfin tuna (*Thunnus albacares*), a variety of sharks and other large pelagic fish are also taken (NMFS, 1990b).

The fishery operates along the continental shelf break, north of Cape Hatteras from Block Canyon east to the boundary line separating the US and Canada. A few vessels may also operate in the waters of the Gulf of Mexico (Fox, 1990; NMFS, 1990b; Tillman, 1991). There is no information available on vessel size. This is a domestic US fishery, operating within the US EEZ. There are approximately 75 vessels registered in the fishery (Fox, 1990; Tillman, 1991), although only about 20 have been active (T. Smith, NMFS, pers. comm.).

The driftnets are made of 18 to 24 inch multifilament mesh and are up to 1.5 miles in length and 60ft deep (Gilbert and Wynne, 1987; NMFS, 1990b; T. Smith, pers. comm.). Fishing trips may last as long as two weeks, depending upon fishing success and weather conditions. Sets are made at dusk and the nets hauled at dawn. The nets are attached to the vessel at one end while the other end floats freely, with the net typically 2–6m below the surface. The vessel and net drift with currents and wind (NMFS, 1990b).

The catch is landed fresh at ports in southern New England, but there is little information available on landings for this fishery. Driftnets have been used to capture swordfish in New England since 1980 (Gilbert and Wynne, 1987). Effort data are recorded in logbooks maintained by each vessel and submitted to the International Commission for the Conservation of Atlantic Tunas (ICCAT). At the time of writing, these data were not available.

At least seven cetacean species have been taken, with common dolphins occurring most frequently in the bycatch (T. Smith, pers. comm.). Other species present in the bycatch are, in order of decreasing frequency: bottlenose dolphins (*Tursiops truncatus*), Risso's dolphins (*Grampus griseus*), beaked whales (*Mesoplodon* sp.), pilot whales, spotted dolphins (*Stenella* sp.), striped dolphins (*Stenella coeruleoalba*) and spinner dolphins (*Stenella* sp.). There is little or no opportunity for live release after entanglement in these driftnets. Cetaceans found entangled in the nets are either discarded or retrieved by researchers. No pinnipeds are taken by this fishery.

Swordfish driftnets are classified as a Category I fishery under the 1988 amendment to the MMPA (Tillman, 1991). Observations have been made by NMFS observers aboard these vessels since August 1989. To date, however, these observations have been voluntary and sampling has not been proportional to fishing effort. Despite these drawbacks, the observations do provide some idea of the relative magnitude of incidental mortality in this fishery. Between August and December 1989, 44 cetaceans were killed during 54 sets (T. Smith, pers. comm.). The number of animals killed per set varied from 0 to 12; at least one cetacean was killed in almost half of observed sets, but few sets kill more than two (T. Smith, pers. comm.). Between January 1990 and December 1992, 208 sets were observed and a mean bycatch per set of 1.35 was recorded (T. Smith, pers. comm.).

The non-proportional sampling and lack of effort data make it impossible to generate an estimate of total kill at the present time. Approximately 5–10% of the fishing trips are thought to have been sampled, but the exact sampling intensity has not yet been determined (T. Smith, pers. comm.). It is clear, however, that the incidental catch level in this fishery is substantial and deserves further assessment. The observed levels of incidental take in this fishery are high enough to pose a potential threat to several cetacean populations. The impact of these bycatches needs to be evaluated, although the pelagic nature of these animals will complicate assessment of their status.

The relatively small size of this fishery, combined with the availability of reliable effort data and an existing observer scheme should allow the accurate estimation of total incidental mortality. Current research and management efforts should be directed towards this goal. Once an estimate has been generated, the status of affected stocks will have to be evaluated on a species by species basis. Proposed legislation that would ban the use of large-scale driftnets within the US EEZ would not apply to this fishery due to length of nets used (T. Smith, pers. comm.).

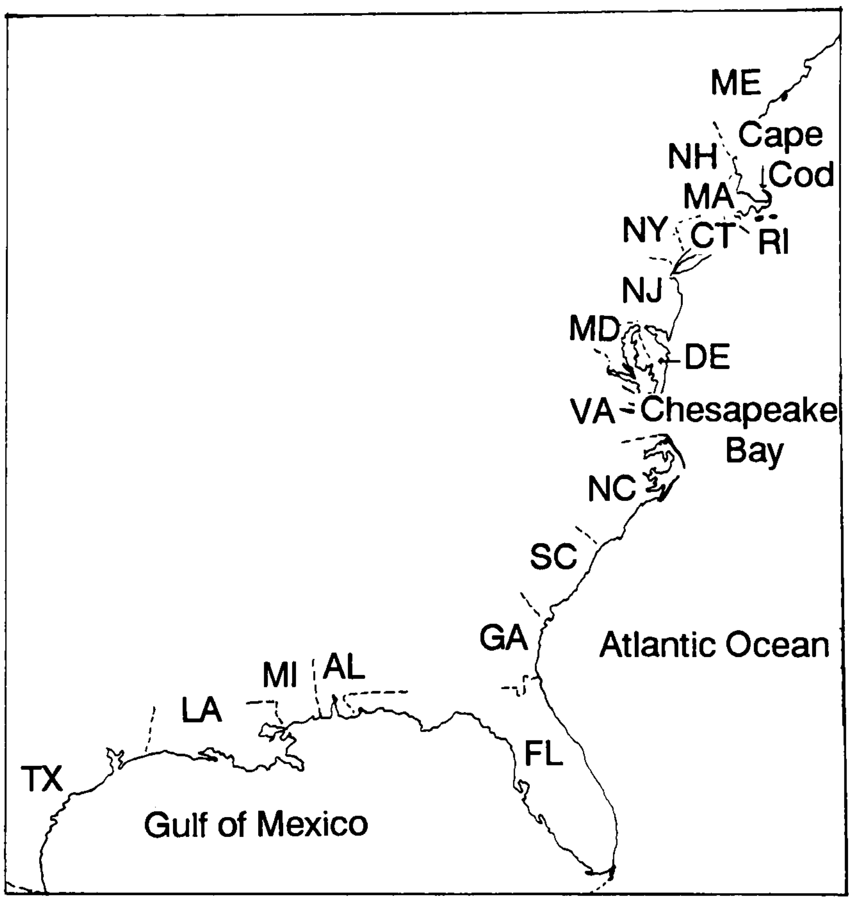

Fig. 2. Eastern United States, showing state boundaries and fishing regions described in the text.

FISHERIES NOT KNOWN TO TAKE LARGE NUMBERS OF CETACEANS

US East coast shad gillnets

A gillnet fishery exists for American shad (*Alosa sapidissima*) in near-shore waters from Connecticut to Georgia. The fishery is seasonal, taking advantage of the spawning migration of shad into river estuaries. Thus, in most areas, gillnets are set in ocean waters early in the season and are then moved into fresh water. In South Carolina, the shad fishery runs from February to May (C. Beardon, S.C. Marine Resources Inst., pers. comm.).

This fishery operates within the jurisdiction of coastal states, most of which require shad gillnets to have mesh sizes of 5 to 6 inches (NMFS, 1990b). Both drift and set nets are used, although most nets set in salt water are anchored or staked to the beach. The nets are constructed of monofilament nylon and are fished at or near the surface. Net length is highly variable, with maximum allowable lengths ranging from 300ft in New Jersey (J. McLean, N.J. Division of Fish, Game, & Shellfisheries, pers. comm.) to 3,000ft in Delaware (R. Seagraves, Delaware Division of Fish & Wildlife, pers. comm.).

It is particularly difficult to obtain effort data for this and other small coastal fisheries, because fishermen are not required to report this information. In addition, it is often impossible to determine how many fishermen are active in each state, because individuals are required to obtain a general salt water commercial licence rather than a permit for each fishery. In its assessment of marine mammal interactions, NMFS estimated that approximately 4,500 individuals were active in this fishery (NMFS, 1990b). From conversations with state management personnel, however, this number appears to be high and may include recreational fishermen using shad gillnets in estuarine and freshwater areas; commercial fishermen setting nets in salt water probably number in the hundreds.

Although this fishery has declined during the last century, shad are still an important resource in many coastal states. The North Carolina shad fishery, for example, recorded landings of over 558 tonnes between 1985–1988, with a value of over $740,000 (Parker, 1990).

Several species of cetaceans are known to become entangled in shad nets, but there has been no systematic study of incidental catches in this fishery. Reynolds (1985) documented frequent reports of bottlenose dolphin entanglements in nets set for shad or Atlantic sturgeon (*Acipenser oxyrhynchus*) in South Carolina. The sturgeon fishery was probably responsible for most of this mortality, but has since been closed in both South and North Carolina for other reasons (C. Beardon, pers. comm.). It is likely, however, that a few bottlenose dolphins are still taken each year by shad nets.

Polacheck and Wenzel (1994) reported the incidental entanglement of a harbour porpoise in shad nets in the York River, which empties into Chesapeake Bay. J. Musick (Virginia Institute of Marine Science, pers. comm.) confirmed that harbour porpoises are occasionally taken in shad nets in the York River estuary and suggested that a few porpoises are taken each year in this manner. Recent observations of large numbers of stranded harbour porpoises bearing net marks and coinciding with the opening of the shad season (A. Read, unpublished data) have raised concerns over the numbers of this species taken in shad nets. Humpback whales have been entangled in shad nets set in Virginia on at least two and possibly three occasions since 1975, resulting in the death of two animals (C. Coogan, pers. comm.). Entanglement of large whales in this fishery is an unusual occurrence.

The shad gillnet fishery was classified in Category III by NMFS, as unlikely to take marine mammals during the course of its operations (Douglas, 1989). Although incidental captures probably occur each year in the fishery, the probability of capture of a cetacean in any particular net appears to be low. Nevertheless, a systematic evaluation of the fishery, including estimation of total effort and observations of net retrievals, would be useful.

Florida East coast shark driftnets

This is a small and poorly documented fishery operating on the east coast of Florida. In 1990, there were 11 vessels operating between Cape Canaveral and Jacksonville, Florida (E. Snell, NMFS, pers. comm.) using gillnets between 2,000–4,500ft in length and 60ft deep. The nets are made from 8–12 inch mesh and are usually allowed to drift within 10 miles of shore (NMFS, 1990b). The primary target species are blacktip sharks (*Carcharhinus limbatus*), but large numbers of brown sharks (*Carcharhinus plumbeus*) are also taken.

This fishery is currently unregulated, although a Fisheries Management Plan is being formulated. Permits, quotas, limits to net size, and reporting systems may be implemented in the future (NMFS, 1990b; C. Shelfer, Florida Marine Fisheries Commission, pers. comm.). In 1988, the fishery recorded landings of about 307 tonnes of sharks, valued at $352,523 (E. Snell, pers. comm.).

Almost nothing is known of the incidental catches made by this fishery. In its initial assessment, NMFS listed bottlenose dolphins as the only species taken and classified the fishery in Category III (Douglas, 1989). A subsequent review noted that the fishing methods were similar to those employed by US swordfish driftnetters and shark nets were, therefore, likely to take marine mammals. The fishery was thus reclassified as Category II (Fox, 1990). Turtles are also known to be taken at least occasionally by shark driftnets (C. Shelfer, pers. comm.).

As noted in the NMFS review, the large mesh size and drift operation utilized by this fishery makes it likely to take cetaceans during the course of its operations. A significant portion of the endangered northern right whale population winters in northeastern Florida and at least one right whale entanglement has been reported from this area although the type of gillnet was not identified (Kraus, 1990; NMFS, 1990a). A systematic evaluation of the incidental catches of cetaceans and other non-target species should be undertaken for this fishery; particular attention should be given to the potential for interactions between right whales and driftnets.

US East coast fish traps and pound nets

Pound nets, fyke nets and fish traps are used in the US mid-Atlantic states to take a variety of coastal fishes. These fishing devices are used from Massachusetts to North Carolina and are restricted to shallow near-shore areas. The nets are most useful where fish actively move through relatively narrow passages (Rounsefell, 1975). Pound nets, traps and fyke nets are constructed in varying fashion, depending on target species, regulation, topography and local tradition. Fyke nets are essentially long net cylinders, often supported by hoops, attached to net wings set obliquely on either side of the mouth of the cylinder (Rounsefell, 1975). As fish encounter the wings they are deflected towards the mouth of the net. Pound and trap nets are similar to the weirs and cod traps described above. These nets use a long leader that usually extends towards shore; as fish encounter the leader they are forced to turn and are lead into the mouth of the trap or pound. The mesh size used in these traps, pound nets and fyke nets varies with target species, but is typically fairly fine. In New York State, for example, fish traps are constructed from 2.25 inch mesh (A. Weber, N.Y. Department of Environmental Conservation, pers. comm.).

Many species of fish are taken with this gear. In Rhode Island, striped bass (*Morone saxatilis*), tautog (*Tautoga onitis*), mackerel, menhaden (*Brevoortia tyrannus*), scup (*Stenotomus chrysops*) and bluefish (*Pomatomus saltatrix*) are taken in fish traps (R. Sisson, Rhode Island Division of Fish & Wildlife, pers. comm.). In North Carolina, croaker (*Micropogonias undulatus*), spot (*Leiostomus xanthurus*), weakfish (*Cynoscion regalis*), summer flounder (*Paralichthys dentatus*) and bluefish are taken in pound nets (Burns, 1990).

In many areas, pound nets, fyke nets and fish traps are in decline. In Rhode Island only six fish traps remain, operated by three companies. Earlier this century there were over 140 companies operating traps that took striped bass (R. Sisson, pers. comm.). Two or three pound nets still operate in Conneticut (E. Smith, Marine Fisheries Division, pers. comm.) and there are approximately 65 active fish traps in New York State (A. Weber, pers. comm.). Effort information was unavailable for other states. Pound nets are still used frequently in the waters of Chesapeake Bay, traditionally from spring to autumn (O'Hara *et al.*, 1986).

The only records of entanglement in these fisheries is of a minke whale killed in a Rhode Island fish trap in 1976 (C. Coogan, pers. comm.) and rare entrapments of bottlenose dolphins in pound nets (O'Hara *et al.*, 1986). These gears are classified as Category III fisheries (Douglas, 1989). The relatively small size of the structures, the fine mesh used in their construction and their location make it unlikely that they take many cetaceans.

US East coast and Gulf of Mexico mixed species coastal gillnets

This category contains a large number of diverse fisheries, most of which are limited in size and poorly documented. Because there is huge regional variation in the nature of these fisheries and because they fall within the jurisdiction of coastal states, I will describe the fisheries separately for each state. In most New England states (Maine, New Hampshire, Massachusetts, and Conneticut) coastal gillnets are set for groundfish; these fisheries are described above. Coastal gillnets have been banned in three states: South Carolina, Georgia and Texas, largely to conserve fish stocks. All of the remaining Atlantic and Gulf states have some form of coastal gillnet fishery.

In Rhode Island, a small gillnet fishery exists for flounder and tautog. Five or six fishermen set nets up to 300 or 600ft in length, depending on their location. The nets are constructed of 5.5 inch monofilament mesh and set on the bottom. Fishermen must tend their nets and haul them every 24hrs (R. Sisson, pers. comm.).

In New York, gillnets are set for striped bass and weakfish in the spring, summer and autumn. The mesh size of the nets varies from 3.5 to 7 inches depending on the target species. There are various restrictions on net length and operation that vary from location to location. In 1989, 181 commercial fishermen reported using some type of gillnet, although this number includes individuals that set fine mesh nets for lobster bait (A. Weber, pers. comm.).

Commercial fishermen in New Jersey set driftnets for bluefish and weakfish during the summer months. The minimum mesh size is 2.75 inches, but some individuals use mesh as large as 5 inches. The maximum net length is 1,200ft, although it is possible to put two nets together end to end. A total of 300 to 400 fishermen use gillnets, but this number includes bait fishermen (J. McLean, pers. comm.).

Weakfish are also taken in the spring, summer and autumn in Delaware, where 30 to 40 fishermen set both anchored and driftnets. Mesh size varies from 3.5 to 5.5 inches and nets are no more than 3,000ft in length (R. Seagraves, pers. comm.). Gillnets in Delaware also take croaker, striped bass and bluefish (O'Hara *et al.*, 1986).

Bluefish and weakfish are taken in anchored gillnets in Maryland during the summer by 20 to 30 fishermen. These nets are similar to those used in Delaware and New Jersey, with mesh sizes of up to 5 inches and maximum length of 3,000ft. There is also a fishery for white perch (*Morone americana*) in Chesapeake Bay that employs small mesh (minimum 2.5 inch) driftnets. Approximately 350 individuals participate in this fishery, setting nets that range from 250 to 2,400ft in length (H. Spear, Maryland Department of Natural Resources, pers. comm.). A small gillnet fishery also takes striped bass in Maryland, using 5–7 inch mesh nets that are limited to 1,200ft in length. This fishery is highly restricted, operating only during the month of January in 1991 (Valliant, 1991).

A variety of gillnets are used in the waters of Virginia, including a large number of weakfish nets set by recreational fishermen. Approximately 5,000 recreational gillnet licences were issued in 1988, but there is no information on actual effort. A total of 278 commercial licences were issued for staked gillnets during 1988. These commercial nets have mesh sizes ranging from 3–6 inches and may measure up to 1,200ft in length. There is also a very limited fishery for black drum (*Pogonia cromis*) that employs 11–13 inch mesh in shallow water (E. Smoller, Virginia Institute of Marine Science, pers. comm.). In general, gillnets are gradually replacing the pound net fishery in Virginia (J. Musick, pers. comm.).

Bottom set gillnets are referred to as 'sink nets' in North Carolina. These are heavily weighted monofilament nets with mesh sizes from 3–6 inches. The average vessel fishes approximately 3,000 to 4,500ft of net that is from 12 to 15ft deep. The fishery operates mainly from late autumn to early spring in water depths of up to 120ft. Most fishing activity occurs on the eastern shore of the Outer Banks. The nets are set on concentrations of fish and either hauled immediately or allowed to fish for several hours. The primary target species are weakfish, bluefish and Atlantic croaker (*Micropogonias undulatus*). The landed value of the fishery was $3.8 millions in 1987 (Ross, 1989). In 1989, over 100 vessels participated in this growing fishery (M. Street, N.C. Division of Marine Fisheries, pers. comm.). An excellent description of the North Carolina sink net fishery is given by Ross (1989).

Two major gillnet fisheries are used in the coastal waters of Florida: a near-shore fishery for pompano and a mixed species fishery in Florida Bay. Pompano nets are set perpendicular from shore for periods that vary from 30 minutes to several hours. The nets are usually made of 4.25–4.75 inch mesh and extend 600–1,200ft from the beach, where they are anchored onshore. The vessel is required to tend the net at all times (L. Fulford, pers. comm.). In Florida Bay, gillnets are used to catch fish either at the surface ('stab nets') or near the bottom ('sink nets'). These gillnets are up to 2,000ft in length and take a variety of species, depending on how they are employed. There are few data on effort in either of these fisheries (S. Kennedy, Florida Department of Natural Resources, pers. comm.; C. Shelfer, Florida Marine Fisheries Commission, pers. comm.).

Gillnets are also commonly employed in the northern Gulf of Mexico (Florida panhandle, Alabama, Missisippi and Louisiana). In Missisippi, for example, between 210 and 220 fishermen are licensed to use gillnets to take weakfish and a variety of other coastal species in the winter months. The minimum mesh size is 3 inches and nets can be up to 1,200ft in length (M. Buchanan, Missisippi Bureau of Marine Resources, pers. comm.).

So little is known about many of these fisheries that it is difficult to assess their potential for entanglement of cetaceans. A humpback whale was killed in a gillnet at Cape Henry, Virginia in February, 1975 (Perkins and Beamish, 1979). Harbour porpoises and bottlenose dolphins are also known to become entangled in these coastal gillnets. A stranded harbour porpoise was recovered from the Outer Banks of North Carolina in 1979 with net marks on its body (Prescott and Fiorelli, 1980). A large number of harbour porpoises were stranded during the 1976–1977 winter on the Outer Banks; it is not known whether these animals died from natural causes or were entangled in fishing gear before washing ashore (Gaskin, 1984). Polacheck and Wenzel (1994) documented the strandings of several harbour porpoises that had been entangled in unknown fisheries along the mid-Atlantic coast: one from New Jersey; two from Virginia; and three from North Carolina. Bottlenose dolphins are known to be taken occasionally by gillnets in Chesapeake Bay (O'Hara *et al.*, 1986), in western Florida pompano nets (Reynolds, 1985; Morgan and Patton, 1990; R.S. Wells, pers. comm.) and gillnets in Missisippi Sound (Reynolds, 1985).

These gillnet fisheries are all classified as Category III fisheries by NMFS (Douglas, 1989). The opportunity for entanglement seems fairly low, although undoubtedly more animals are actually taken than reported. The entanglement of harbour porpoises along the mid-Atlantic coast should be examined to determine the actual extent of incidental catches in this area. The North Carolina sink net fishery has some striking similarities to the Gulf of Maine groundfish gillnet fishery and has the potential to take significant numbers of harbour porpoises if the winter range of the porpoise population overlaps with the area utilized by the fishery.

Atlantic Canada and US East coast small pelagic gillnets

These fisheries occur throughout Atlantic Canada and along the US east coast, taking small pelagic fish with fine mesh gillnets. The major target species are herring, mackerel and menhaden. Catches are used for human consumption and as bait for lobster and crab fisheries.

At one time, gillnets accounted for the majority of herring landings in Atlantic Canada. These catches have since dwindled and most herring is now landed by purse seiners (McKenzie and Tibbo, 1960). Both driftnets and anchored nets are still used; there were 4,273 herring and mackerel gillnet licences issued in the Bay of Fundy and western Nova Scotia region in 1989; most of these individuals take fish for use as lobster bait (J. Conway, DFO, pers. comm.). Mesh size varies from location to location; herring gillnets in the Bay of Fundy traditionally use mesh sizes of 2.25 to 2.75 inches (McKenzie and Tibbo, 1960). Gillnets in the Bay of Fundy took 2,289 tonnes of herring in 1987 (Stephenson and Power, 1988).

Mackerel gillnets are used throughout Atlantic Canada and along the coast of northern New England. As is the case with herring, gillnets used to account for the majority of mackerel catches, but have been largely replaced by purse seines in many areas. Mackerel may be captured in either drift or anchored gillnets fished near the surface. In Cape Cod Bay there is a small winter fishery for mackerel that uses nets constructed of 2 inch mesh, from 100 to 200ft long and 15ft deep (Gilbert and Wynne, 1983).

Fishermen from Maine to New Jersey set driftnets to catch menhaden and other small pelagic fish, largely for lobster and crab bait. These fisheries vary from area to area depending on local conditions and state regulations. The menhaden fishery in Rhode Island is probably typical of many bait fisheries in New England. The maximum mesh size allowed in Rhode Island bait nets is 3.75 inches and nets must not exceed 100ft in length. There are many restricted areas in which fishing is prohibited. All bait nets must be constantly tended by fishermen (R. Sisson, pers. comm.).

Small numbers of harbour porpoises are known to be taken in herring nets in the Gulf of St. Lawrence (P-M. Fontaine, pers. comm.), Nova Scotia (S. Smith, Dalhousie University, pers. comm.) and probably also in Newfoundland. Pilot, humpback and fin whales are all known to become entangled in Newfoundland herring gillnets on occasion (Lien, 1980; Loch, 1983). There is little information on cetacean incidental catches in Canadian mackerel nets, other than a record of a pilot whale entangled in Newfoundland during 1982 (Goodman, 1984). Incidental captures of both harbour porpoises and white-sided dolphins have been reported from the small mackerel fishery in Cape Cod Bay by Gilbert and Wynne (1983), a Category I fishery (Douglas, 1989). Fishermen reported entanglement of nine harbour porpoises and fourteen white-sided dolphins in 77 days of fishing in which a total of 1,500 nets were set. The majority of these animals were released alive (Gilbert and Wynne, 1983).

The fine mesh used in most of these gillnets, combined with their short fishing times, ensures that the potential for incidental capture of cetaceans is fairly low. The only exception to this may be the mackerel gillnet fishery in Cape Cod Bay, in which nets are fished for 24 hours (Gilbert and Wynne, 1983).

DISCUSSION

Substantial numbers of cetaceans have been and are taken in gillnet and trap fisheries in the Northwest Atlantic. The fisheries accounting for the majority of this mortality are the groundfish gillnet fishery, the Greenland salmon driftnet fishery and the US swordfish driftnet fishery. Entanglement usually results in the mortality of dolphins and porpoises; many large whales are able to survive their encounters with nets, sometimes with the aid of humans. In terms of numbers, harbour porpoises are the cetacean species most affected by incidental catches in gillnets and traps, followed by bottlenose dolphins, humpback whales and minke whales. Incidental mortality in commercial fisheries poses a serious threat to the several populations of harbour porpoises in this region. Occasional incidents of entanglement may also threaten the already endangered northern right whale population, due to its highly depleted status. The takes of pelagic dolphins and beaked whales by swordfish driftnets have an unknown effect on these populations.

There is an enormous amount of work still to do if we are to better understand the nature, magnitude and effects of this incidental mortality. In almost all major fisheries, we need to estimate the numbers of cetaceans killed each year. Assessments of the impact of these catches will of course require estimates of abundance and potential rates of increase. This is an enormous undertaking, even for only the most threatened populations.

Constructive management action should not be delayed while the effects of incidental catches are assessed. In the New England groundfish gillnet fishery, for example, managers, biologists and fishermen should explore potential means of reducing the impact of incidental mortality, without waiting for the results of the assessment. Short term management tools such as closed areas should be considered in addition to longer term options, such as gear modification. Groundfish gillnets are important components of the inshore fishing industry in eastern Canada and New England and provide a valuable income to a large number of fishermen. Gillnets also cause the deaths of large numbers of marine mammals and seabirds (Piatt and Nettleship, 1987) each year. Management agencies will face a difficult task in assessing the detrimental effects of this fishery and finding means of mitigating the problem of incidental catch.

In my initial draft of this paper I made several recommendations for immediate action. These are listed in general order of priority below, with a brief statement on any subsequent action.

(1) Estimation of incidental catches of harbour porpoises made by groundfish gillnets in (i) Newfoundland and Labrador and (ii) the Gulf of St. Lawrence should be undertaken. Such estimates will require an on-board observation programme, if accurate data on catch rates are to be obtained. An observer programme should be formulated as soon as possible, even with very low sampling intensity, to provide rough estimates of the magnitude of mortality. This programme could be incorporated as part of DFO's existing on-board fishery monitoring programme. In addition, attempts should be made to improve the reporting of fishing effort. *No estimates of this mortality were made between 1990 and 1994. The situation in Newfoundland is now less critical because of regulated reductions or elimination of fishing effort. Large numbers of harbour porpoises continue to be taken in the Gulf of St. Lawrence, however.*

(2) Estimates should be made of the magnitude of past harbour porpoise incidental mortality in the Greenland salmon driftnet fishery. As noted for (1), this will require accurate information on both catch rates and total effort. *This fishery has now ceased, eliminating the requirement to estimate this mortality.*

(3) Efforts to estimate harbour porpoise incidental catch rates and fishing effort for the Gulf of Maine groundfish gillnet fishery should be continued and intensified. These efforts must ensure that sampling intensity is proportional to fishing effort and explore the effects of variation in gear type and mode of operation on mortality rates. In addition, the level of incidental mortality should be assessed in previously unstudied areas, such as southwestern Nova Scotia. *Considerable effort, on the part of fishermen, management agencies and conservation organisations, has been expended on this problem. At the time this paper was revised (May 1994), the New England Fishery Management Council has proposed the institution of time-area closures to reduce this mortality to sustainable levels.*

(4) On-board observations of the swordfish driftnet fishery should be continued in a fashion that is proportional to fishing effort. Consideration should be given to increasing sampling intensity given (i) the large number of cetaceans killed and (ii) the relatively small size of the fishery. It should be possible to sample a large proportion of all sets made by this fishery, increasing the reliability of statistical estimates of incidental mortality. Fishing effort data should be obtained from ICCAT, allowing the estimation of total kill. *These observations have been continued, but estimates of total mortality have not yet been made.*

(5) The magnitude of incidental mortality of cetaceans should be assessed for the Florida east coast shark driftnet fishery. A small observer programme would suffice to determine whether or not substantial incidental catches are recorded by this fishery. *I am unaware of any progress with this recommendation.*

(6) The magnitude of incidental mortality of cetaceans should be assessed for the North Carolina sink net fishery and some of the other small coastal gillnet fisheries in the mid-Atlantic states. As noted above, very small observer programmes would be sufficient to determine whether or not cetaceans are taken by these fisheries. *In 1993, observers were first used to monitor incidental mortality in fisheries south of Cape Cod. No data are yet available from this programme.*

(7) Projects such as Memorial University's entrapment assistance programme should be encouraged and supported. The threat of gear damage is an excellent incentive to persuade fishermen to co-operate in programmes that release entangled large whales. Unfortunately, there is no similar incentive for fishermen who encounter small cetaceans in their gear, because dolphins and porpoises cause little or no gear damage when entangled. *A programme has developed rapidly in the western Bay of Fundy, where fishermen and biologists co-operate to ensure the safe removal of harbour porpoises from herring weirs. Similar programmes run by the Center for Coastal Studies and other organisations on the US East coast have successfully disentangled many large whales from fishing gear in the coastal waters of New England.*

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Entrapments of Large Cetaceans in Passive Inshore Fishing Gear in Newfoundland and Labrador (1979–1990)

Jon Lien

Memorial University of Newfoundland, St. John's, Newfoundland A1C 5S7

ABSTRACT

In 1979 an assistance program was established for inshore fishermen in Newfoundland and Labrador who caught large whales and sharks in their fishing gear. The widely advertised program allowed fishermen to call toll-free for assistance and receive help from a trained crew in releasing the animal from the gear. From 1979–1990, 576 humpback whales, 124 minke whales, 13 fin whales, 68 long-finned pilot whales, 20 animals from other species of large whales and 51 large whales of unknown species have been reported entrapped in codtraps, groundfish gillnets, salmon gillnets and other passive inshore fishing gear. Mortality has varied according to the species entrapped and the duration of the entrapment. Distribution of the whales, variability of bait, fishing effort, numbers of animals in a population, and species characteristics each contribute to the relative frequency of incidental entrapments of large cetaceans.

KEYWORDS: INCIDENTAL CAPTURE; MORTALITY; FISHERIES; BEHAVIOUR; NORTH ATLANTIC; HUMPBACK WHALE; RIGHT WHALE; FIN WHALE; PILOT WHALE-LONG FINNED; BEAKED WHALE-SOWERBY'S; BOTTLENOSED WHALE; WHITE WHALE; NARWHAL.

INTRODUCTION

Incidental collisions and entrapments of cetaceans in inshore fishing gear in Newfoundland and Labrador have been occurring for decades or longer (Cuff, 1976; Scammell, 1980). However, written material is rare and anecdotal.

Typically, older fishermen stated that collisions by whales and sharks with fishing gear have always occurred. In the past, most whale collisions resulted in damage to the cotton and hemp fishing gear that was used but actual entrapments of animals in the gear were relatively infrequent. With the introduction of stronger synthetic ropes and webs, however, collisions have more frequently resulted in the whales becoming entangled and held by the fishing gear (Lien, 1980).

There is only one published summary of whale collisions with fishing gear in Newfoundland and Labrador prior to 1979. Perkins and Beamish (1979) reported a total of 19 humpback *Megaptera novaeangliae*, 13 minke *Balaenoptera acutorostrata* and one fin whale *Balaenoptera physalus* entrapments from 1969–1977. It is not possible to infer from their data, however, the actual numbers of entrapments or changes in the pattern or frequency of entrapments.

Some information on incidental collisions is available from a 1978 petition presented by a group of fishermen, that requested the resumption of whaling because of perceived increases in whale damage to fishing gear (Lien, 1980). The fishermen included figures on the amount of gear lost to whales but did not present information on down-time losses or on the numbers of whales caught. The petition contained 442 signatures, reporting 80 instances of whale damage at an average cost of $630, between 1976–1978 (Lien, 1980). It is not possible to extrapolate these data to the entire fishery. However, the fact that fishermen were sufficiently motivated by losses to organise a petition requesting reductions in the numbers of whales, and that 6% of the fishermen reported personal losses due to whales, indicates that whale collisions were a problem of some magnitude in the inshore fishery.

A third source of information is the weekly reports submitted by field officers in the Department of Fisheries and Oceans. Walsh and Lien (1978) reviewed these reports; they do not often contain references to whales. From 1975–1978 there were only 21 reports of whale collisions with fishing gear in the Newfoundland Region. Several comments in the field officers' reports, however, indicate that problems with whales in fishing gear may have been increasing (Lien, 1980).

A final source of information is the result of a questionnaire distributed to fishermen in 1979; it requested retrospective reports of incidental entrapments in fishing gear from 1974–1978 (Lien, 1980). A total of 2,200 questionnaire cards were distributed at fishermen's meetings; fishermen were asked to take them home, fill them out and return them through the mail. Response to the questionnaire was poor; only 136 replies were received (6% of total cards distributed). Most replies (72%) reported damages; 56% reported several instances of collisions. Fishermen who had experienced damage from whales were probably more likely to return the questionnaire card than were those who had not. If all fishermen in the sample who had received whale damage returned their report, and if these percentages were to be extrapolated to the entire inshore fishery of Newfoundland and Labrador, the annual average of whale collisions with fishing gear would be estimated as 320. Collisions which were reported involved all kinds of fishing gear: 27% groundfish gillnets; 35% surface gillnets and 39% codtraps (Lien, 1980).

Although it is clear from the evidence cited above that large cetaceans collided with and were entrapped by inshore fishing gear, it is not possible to infer the frequency of these events, their impact on the fishery, or the amount of whale mortality.

In 1979 a province-wide program was established to monitor the entrapment of large cetaceans in inshore fishing gear and provide assistance to fishermen in releasing animals from gear. Annual summaries of the program have been provided to the fishery management agencies that sponsored it, but these have not been published. This paper summarises the results of the program for the period 1979–1990.

METHODS

Methods used in the Entrapment Assistance Program between 1979–1990 have varied slightly each year. Details are given in the annual program reports (Lien, 1980; Lien and Aldrich, 1982; Lien *et al.*, 1982; 1983; 1984; 1986; 1987; 1988; 1989a; 1990a) and summaries and analyses of the effectiveness of the methodology used are presented in Lien (1988) and Lien *et al.* (1989c). Details of the educational and publicity programs and an analysis of their role in the Entrapment Assistance Program are given in Lien *et al.* (1985a) and Lien (1989).

Each year, fishermen throughout Newfoundland and Labrador were encouraged to report whale and large shark problems to management officers of Fisheries and Oceans or the Newfoundland/Labrador Department of Fisheries. A toll-free number for reporting incidents was made available and was widely advertised. In some cases, entrapments were reported to the Royal Canadian Mounted Police, the Newfoundland/Labrador Department of Environment or the Canadian Coast Guard. All of these agencies relayed calls to the Entrapment Assistance Program at Memorial University of Newfoundland.

The University maintained a year-round capacity to respond to entrapment calls from any location in the province. As appropriate, fishermen were given advice or provided with access to tools. A trained crew was sent to help any who requested assistance in removing animals from gear. In all cases, assistance was given within 24 hours of the fishermen's request; usually the fishermen's problem was addressed within hours of receiving the report.

Because the program is an emergency assistance program for fishermen, it does not offer extensive opportunities for research on the whales themselves. However, for all entrapments the date, species, type of gear involved and outcome of the entrapment were recorded.

RESULTS

The number of large cetaceans reported entrapped in inshore fishing gear between 1979–1990, and the condition of the whales upon release from the gear are presented in Table 1. Mortality as a result of entrapment is presented in Table 2.

Humpback whales are most commonly caught; an annual average of 48 was reported (range 26–75), with an annual mean of 7.8 deaths; 83.6% of the entrapped humpbacks were released from the gear alive. Few large humpbacks (>12m) were entrapped. The pattern of entrapments has varied little from year to year; most humpback entrapments occur around the Avalon Peninsula, and along the northeast coast of the island of Newfoundland (Fig. 1).

The minke whale was the next most commonly reported species caught in fishing gear (n=124; mean=10.4/year); mortality was much higher (70%) than for humpback

Table 1

Large cetaceans reported entrapped in inshore fishing gear in Newfoundland and Labrador (1979-1990) and their condition on release. Misc. species includes Sowerby's beaked whale *Mesoplodon bidens*, northern bottlenose whale *Hyperoodon ampullatus*, white whales *Delphinapterus leucas*, narwhal *Monodon monceros*, right whales *Eubalaena glacialis*. * Increase due to special program in Labrador (Lien *et al.,* 1983).

Species	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	Totals
Humpback													
Dead	13	17	8	5	5	6	8	3	3	12	4	10	94
Alive	34	44	23	30	30	20	44	31	41	54	66	65	482
Total	47	61	31	35	35	26	52	34	44	66	70	75	576
Minke													
Dead	9	9	8	4	4	6	7	4	8	7	10	11	87
Alive	1	3	3	5	7	2	2	3	4	2	2	3	37
Total	10	12	11	9	11	8	9	7	12	9	12	14	124
Fin													
Dead	4	1	1	0	0	0	0	0	1	0	0	0	7
Alive	3	2	0	0	0	0	0	0	0	0	0	1	6
Total	7	3	1	0	0	0	0	0	1	0	0	1	13
Pilot													
Dead	4	3	37	5	0	0	0	0	0	0	0	0	49
Alive	1	3	6	7	0	0	0	0	0	2	0	0	19
Total	5	6	43	12	0	0	0	0	0	2	0	0	68
Misc. spp.													
Dead	2	8	1	0	0	1	0	0	0	1	2	2	17
Alive	0	1	0	0	0	1	1	0	0	0	0	0	3
Total	2	9	1	0	0	2	1	0	0	1	2	2	20
Unknown spp.													
Dead	0	3	0	0	1	0	0	0	0	0	0	0	4
Alive	2	0	0	15	13	4	7	2	0	4	0	0	47
Total	2	3	0	15 *	14 *	4	7	2	0	4	0	0	51
Total (all species)													
Dead	32	41	55	14	10	13	15	7	12	20	16	23	258
Alive	41	53	32	57	50	27	54	36	45	62	68	69	594
Total	73	94	87	71	60	40	69	43	57	82	84	92	852

Table 2

Mortality of large cetaceans as a result of entrapment in inshore fishing gear in Newfoundland and Labrador (1979-1990) as a percentage of total number of entrapments.

Spp.	Mean %	Hump-back (*n*=576)	Minke (*n*=124)	Fin (*n*=13)	Pilot (*n*=68)	Misc. spp. (*n*=20)	Unknown (*n*=51)
1979	76	28	90	57	80	100	0
1980	44	28	75	33	50	89	100
1981	63	26	73	100	86	100	-
1982	20	14	44	-	42	-	0
1983	17	14	36	-	-	50	7
1984	18	23	75	-	-	0	0
1985	22	15	78	-	-	-	0
1986	16	9	57	-	-	-	0
1987	21	7	67	100	-	100	-
1988	24	18	78	-	0	100	0
1989	19	6	83	-	-	100	-
1990	25	13	79	0	-	100	-
Mean %	30	16	70	54	72	85	8

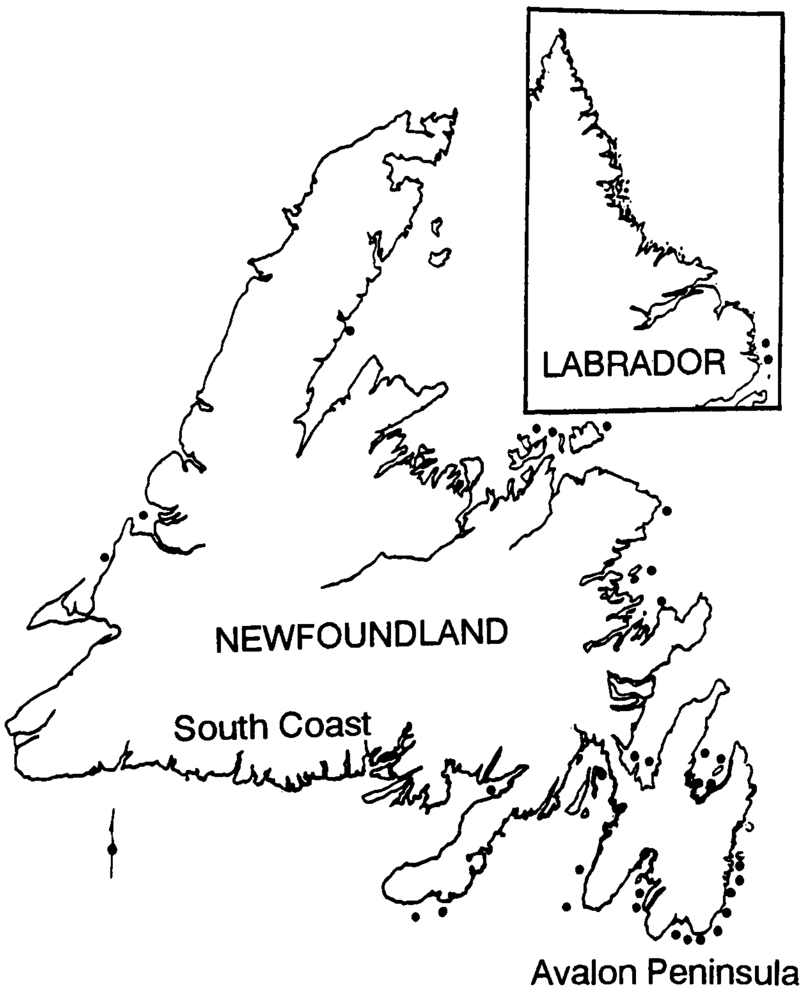

Fig. 1. (a) Humpback whale entrapments, 1979–80.

whales. The sizes of minke whales caught varied from small to full grown (3.7–9m). The primary areas of entrapments were similar to those for humpback whales (Fig. 2).

Although the number of humpback and minke whales entrapped in fishing gear in an area correlates with the number of fishermen there (Fig. 3), good estimates of effort by gear type in the inshore fishery are not available. Most fishing effort on the south coast of the island occurs in the winter; there is little summer effort. Fishing effort on the west coast of the island is generally lower and in summer, mostly directed to lobsters.

An annual average of just over one fin whale was reported entrapped in gear (n=13, mean=1.1), with 54% deaths. Most of the animals that died were small (<15m).

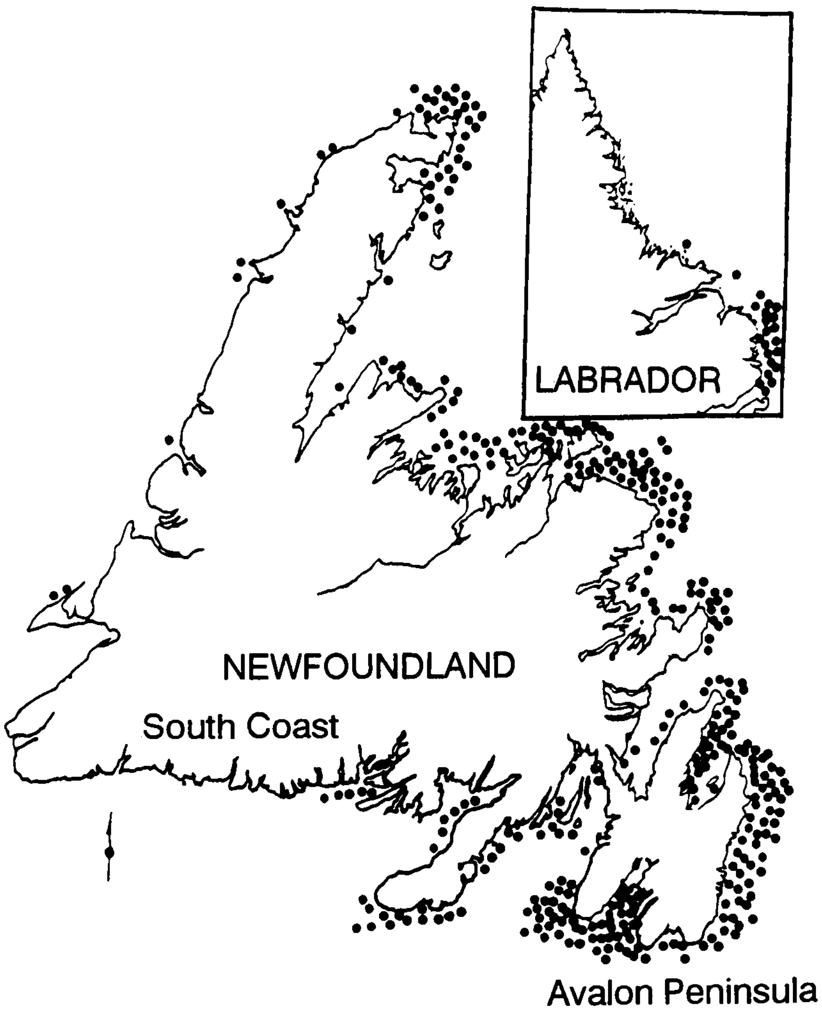

Fig. 1. (b) Humpback whale entrapments, 1981–87.

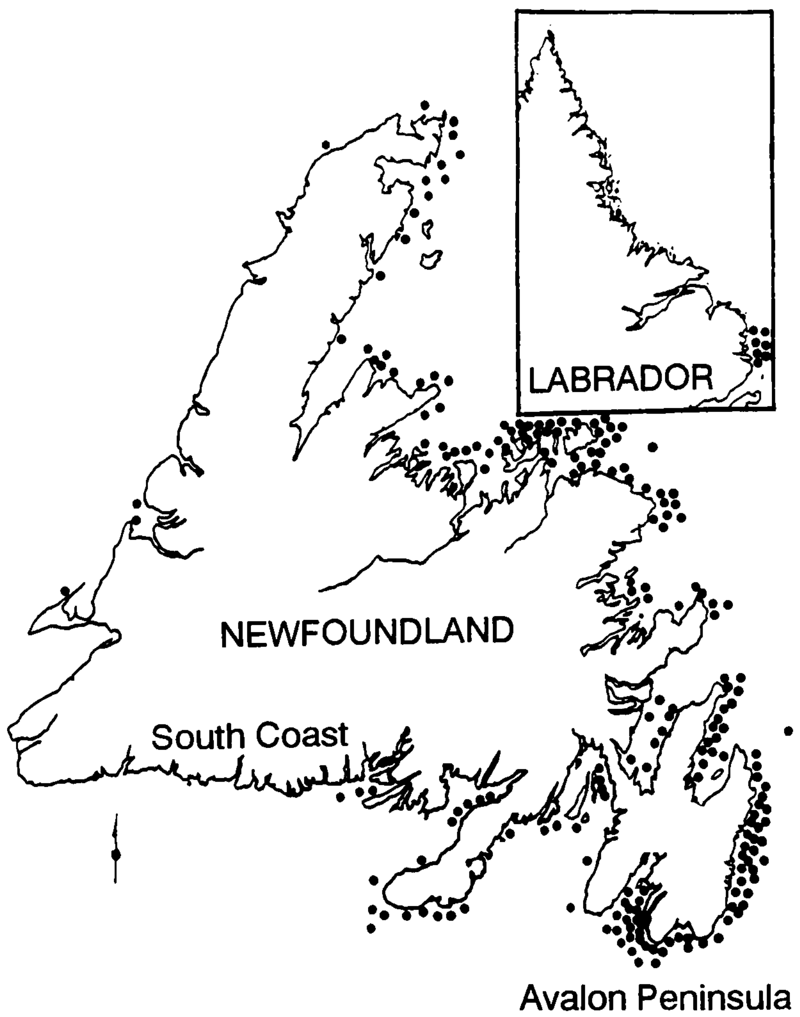

Fig. 1 (c) Humpback whale entrapments, 1988–90.

Fin whale entrapments were relatively frequent in 1979–1980, but have been reported only occasionally since then.

Most (97%) of the 68 long-finned pilot whale, *Globicephala melas*, entrapments occurred during the period 1979–1982. Mortality from entrapment was high (average=72%). There have been only two long-finned pilot whale entrapments since 1983.

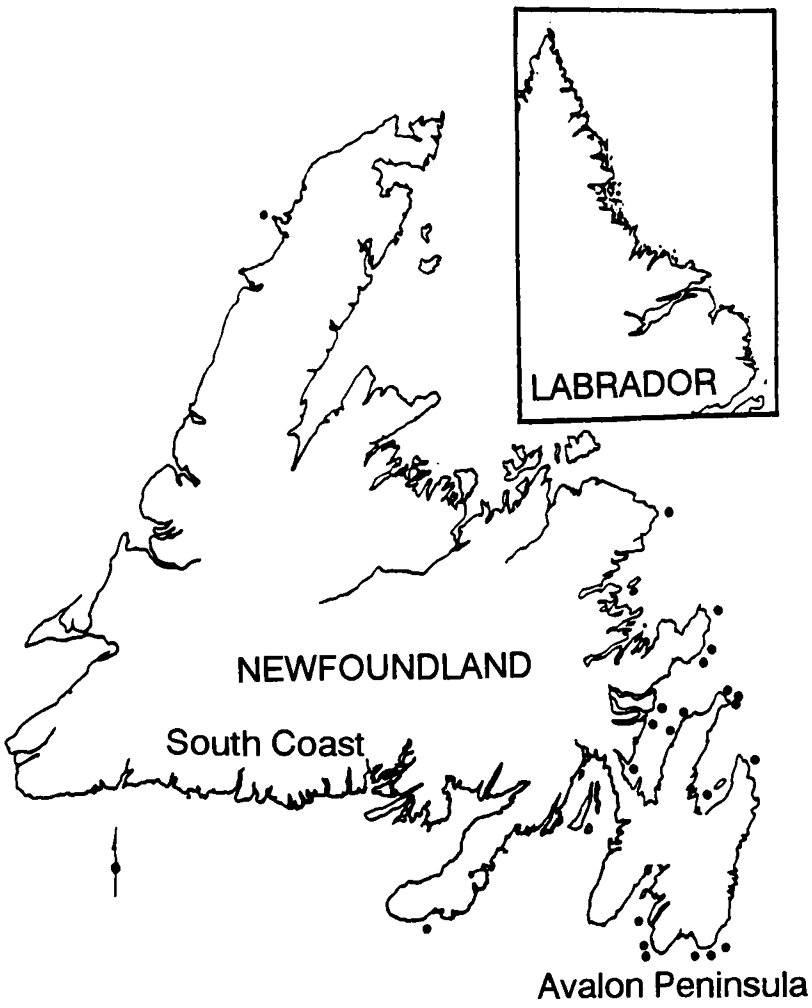

Fig. 2 (a) Minke whale entrapments, 1979–80.

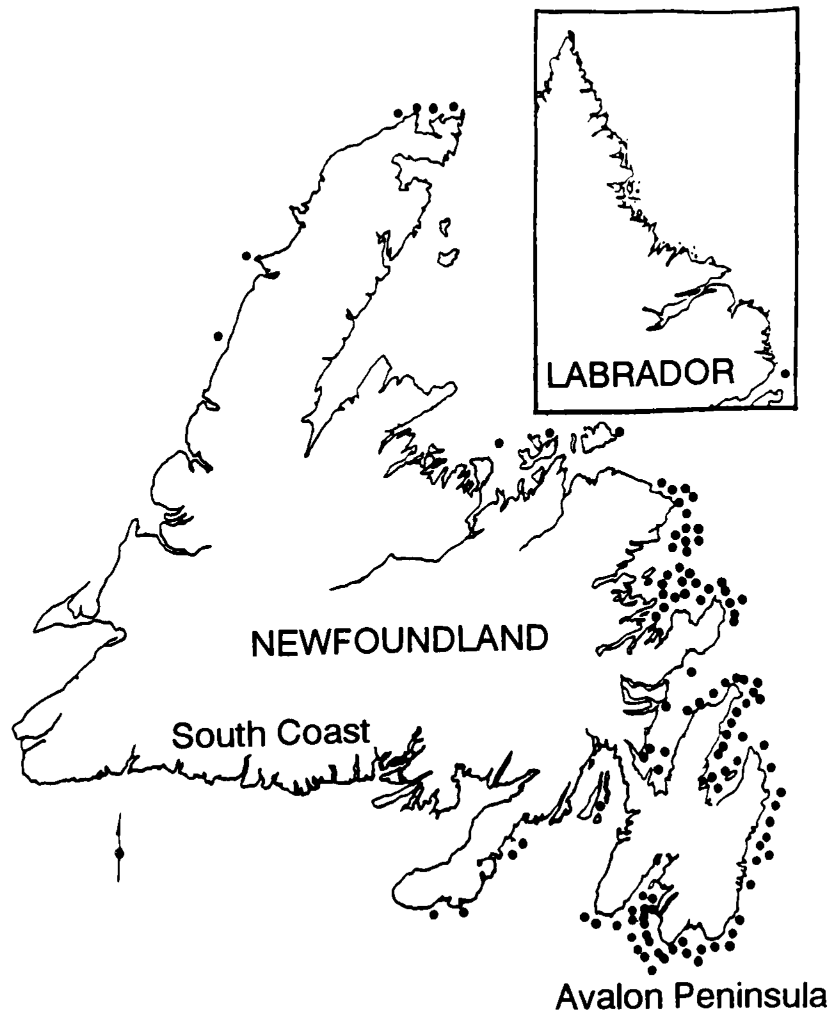

Fig. 2 (c) Minke whale entrapments, 1988–90.

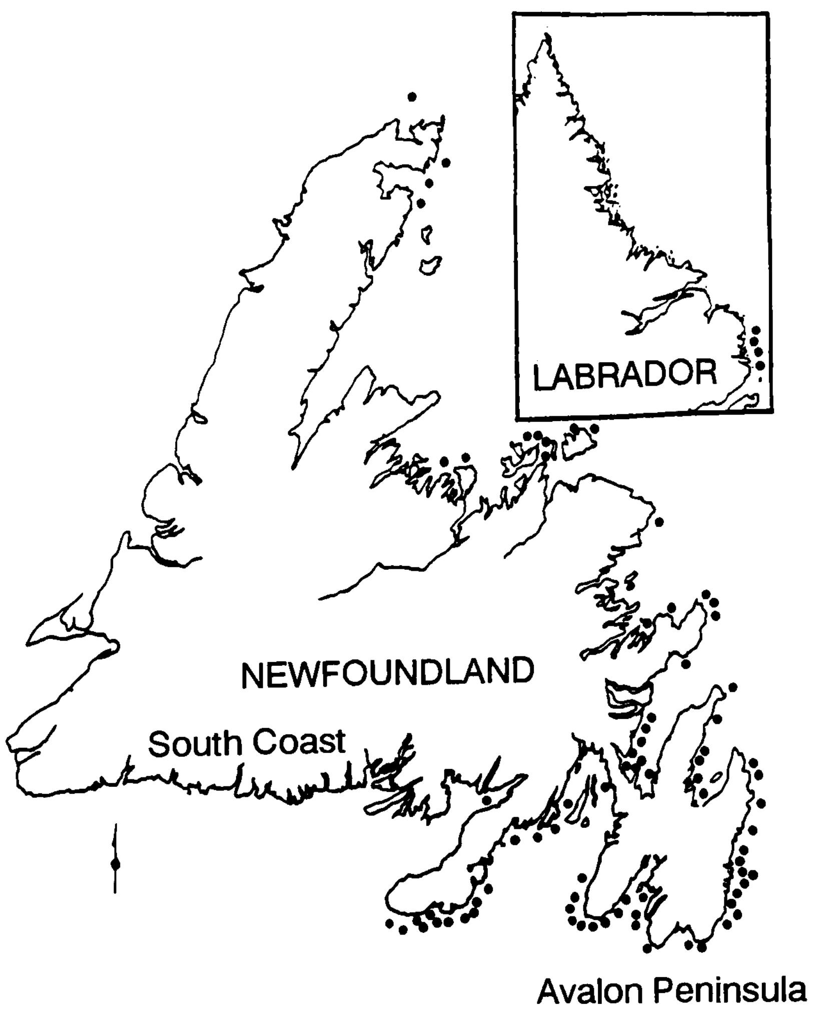

Fig. 2 (b) Minke whale entrapments, 1981–87.

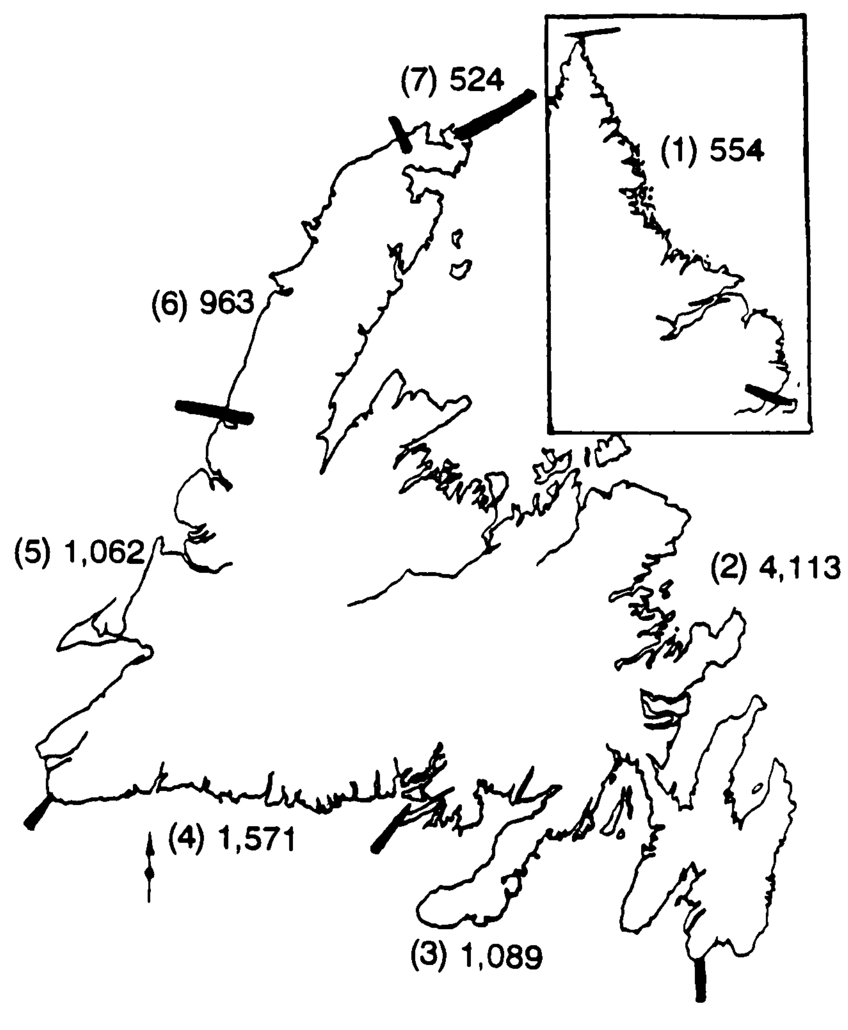

Fig. 3. Marine regions and number of fishing crews.

A variety of other species of cetaceans were also reported entrapped in inshore fishing gear (n=1.67/year). These included: 1 right whale, *Eubalaena glacialis*; 1 Sowerby's beaked whale, *Mesoplodon bidens*; 2 northern bottlenose whales, *Hyperoodon ampullatus*; 4 narwhals, *Monodon monoceros*; and 12 white whales, *Delphinapteras leucas*.

On occasion, large whales unidentified to species, were reported entrapped in fishing gear. These were typically groundfish gillnets, which were towed by the whale. In many of these cases, the whale's mobility made relocation impossible. Somewhat more than four reports each year (4.25/year) were in this category. Known mortality was low for this group of animals (8.5%) because the final outcome of the entrapment could not be determined.

The overall average mortality for all large cetaceans reported entrapped in fishing gear between 1979–1990 was 30% (Table 2). Humpback whales had the lowest average mortality from entrapment (16%); minke (70%) and long-finned pilot whales (72%) fared less well. Mortality was highest in the 'misc. species' category (85%). Many of these less common species appeared to be young, injured, or diseased prior to entrapment in fishing gear.

The percentage mortality resulting from reported entrapments has been steady since 1982, ranging from 16–25%/year for all large cetaceans. This is much lower than during the first years of the Entrapment Assistance Program (and presumably before); from 1979–1981 mortality averaged 61%.

Table 3

Percentages of entrapments of humpback and minke whales in types of passive fishing gear used in Newfoundland and Labrador (1979-1990). Total number of humpbacks = 576; total number of minkes = 124.

	Type of fishing gear					
	Codtrap	Groundfish Gillnets	Salmon Gillnets	Other Gillnets	Other Traps	Other
Humpback						
Mean	46.8	37.7	9.7	0.8	1.7	3.3
SD	12.2	12.5	6.2	1.4	2.6	2.7
Range	32-69	11-51	0-20	0-4	0-7	0-8
Minke						
Mean	46.9	29.6	14.7	1.0	0	2.8
SD	18.7	18.7	15.2	3.5	0	6.9
Range	18-87	4-73	0-43	0-12	0	0-22

Codtraps and groundfish gillnets accounted for 80–90% of incidental entrapments of all large cetaceans (Table 3); there were species differences. Minke whales were more likely than other species to be caught in salmon (*Salmo salar*) nets and slightly less likely to be caught in groundfish gillnets. Long-finned pilot whales were almost always caught in squid (*Illex illecebrosus*) traps. The percentage of entrapments in different types of fishing gear varied widely among years; for example, the annual percentage of humpback whales entrapped in codtraps ranged from 32%-69% and for minke whales from 18%-87%.

The frequency of entrapments coincides with the peaks of effort in the inshore fishery (Table 4) which begins in May and, for the most part, ends in October. Most entrapments occurred in June, July or August; incidental entrapments before May and after October were unusual. On occasion, whales towing fishing gear from the previous fishing season were found and released during winter months (November-March).

DISCUSSION

Under-reporting

The number of large cetaceans reported caught in inshore fishing gear each year represents a minimum estimate of the number actually caught, for a number of reasons. First, it has been estimated that actual number of collisions with fishing gear by large whales are 4–5 times the numbers of entrapments (Lien, 1980; Lien *et al.*, 1987). In many of these collisions, the whale strikes the gear and becomes entangled, at least for a period. What percentage of these collisions involve brief entrapments, from which the animal struggles free before detection, is not known. It is also not known how often injury or mortality occurs in such brief entrapments with self-release.

A second reason is that fishermen under-report the events. Willingness of fishermen to report entrapments varies with the species of animal caught, location of the entrapment, anticipation of a market for the animal, compensation and the general state of the fishery (Lien *et al.*, 1989a; Lewis, 1992). Participation in the program by fishermen is voluntary; fishermen report large entrapped whales and sharks because the assistance which they receive results in lower gear loss and down-time (Lien, 1988). There is no legal requirement to report entrapped whales in Canada. The numbers of animals reported here are the number of entrapments that required the involvement of staff from the Entrapment Assistance Program.

Several methods have been used to estimate the degree of under-reporting of entrapped whales to the Entrapment Assistance Program. Observers have been placed in several locations and the reported catches of large whales compared with the numbers observed. In 1979 and 1980, when the Entrapment Assistance Program was first begun, estimates of under-reporting obtained by this method were about 30% for humpback whales (Lien, 1980; Lien and Aldrich, 1982); in later years, the estimates were about 10–20% (Lien *et al.*, 1982) and recent estimates have been 10% (Lien, 1988).

A second approach was to interview fishermen, by phone and in person, at the end of each fishing season. This similarly indicated under-reporting estimates of entrapped

Table 4

Entrapments of humpback and minke whales in passive inshore fishing gear in Newfoundland and Labrador by month. Values in percentages of total entrapments (1979-1990). Total number of humpbacks = 576; total number of minkes = 124.

	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
Humpback										
Mean	0	0.2	5.7	28.0	52.8	11.5	1.2	0.9	0.1	0
SD	0	0.6	5.0	14.0	18.6	9.7	2.1	2.3	0	
Range	0	0-2	0-12	10-63	18-85	0-37	0-7	0-8	0-1	0
Minke										
Mean	0	0	3.1	30.8	52.8	9.2	1.3	1.0	1.3	0
SD	0	0	4.6	24.2	19.4	10.8	3.1	3.7	3.4	0
Range	0	0	0-10	0-71	18-86	0-33	0-9	0-13	0-10	0

humpback whales of 30% in 1979–1980 and about 10% in following years (Lien, 1988).

That almost all of the larger whales (humpback and finbacks) entrapped in fishing gear were reported during the last five years of the program seems evident as: (1) commonly, several calls from different individuals are received which report the same entrapment; (2) there were few instances of entrapments which were discovered through calls from secondary agencies, community visits, or end-of-season interviews that were not reported at the time by the fishermen themselves; and (3) rarely were fresh dead whales discovered with clear indications that fishing gear was implicated, that were not reported while entrapped.

Under-reporting of the smaller cetaceans (including minke, pilot whale and some misc. species) was higher as they tend to be less of a threat to fishing gear when entrapped, and fishermen often did not require assistance in removing them from gear (Lien, 1988). Under-reporting of entrapments of these species was estimated at about 25–30% (Lien *et al.*, 1988). Generally it is not possible to determine the numbers of small cetaceans, especially dolphins and porpoise, which are incidentally caught in fishing gear (SMRU, 1988).

Species numbers, distributions and entrapments

Numbers of entrapments which occur in inshore fishing gear are not closely correlated with the estimated sizes of whale populations in waters near Newfoundland and Labrador, although there are correlations between the frequency with which a species is sighted inshore and the number of entrapments.

There are no good estimates of numbers of fin whales in the area (Meredith and Campbell, 1988) but Lynch (1987) reports a decrease in the numbers seen in inshore waters since the early 1980s. This decrease in inshore sightings parallels the decrease in numbers of fin whales incidentally caught in fishing gear since 1981.

Inshore numbers of long-finned pilot whales fluctuate with abundance cycles of squid (Sergeant, 1962; Mercer, 1975). Squid were abundant inshore between 1979–1982 but have not been common since that time. Sightings of these whales inshore, mass strandings and entrapments in fishing gear follow this trend (Lien, 1988).

Although there are no useful estimates of abundance of the minke whale in Newfoundland and Labrador waters (Stewart and Leatherwood, 1985), it is an extremely common whale (Lien *et al.*, 1985b). The relatively low number of reported collisions, despite its apparent abundance in heavy inshore fishing areas, would seem to indicate that it is able to avoid collisions with fishing gear. However, inshore fishermen in Newfoundland believe that it does collide with gear quite frequently, but its pointed head and smooth body allow it to pass through the nets leaving just a hole, unlike humpback whales (see below).

Katona and Beard (1990) present an estimate of 2,310 (95% CI 1,730; 2,890) humpback whales for the feeding sub-population off Newfoundland and Labrador. In addition to their abundance, two factors contribute to the frequency with which humpbacks become entangled in fishing gear: one behavioural, the other morphological. Off Newfoundland and Labrador they are dependent on capelin (*Mallotus villosus*), the key bait species which attracts target commercial populations of fish and, therefore, fishing effort. Capelin abundance is correlated with the inshore abundance of humpbacks (Whitehead and Carscadden, 1985) which ensures that whales and fishing gear are found in the same locations. Given this, the morphology of the humpback whale (long pectoral fins and barnacles) is commonly the reason it is prone to being held by the nets (Lien, 1988)

Most of the species of large whales that have been only occasionally caught in fishing gear are rare in Newfoundland and Labrador waters. The right whale (Gaskin, 1987; Lien *et al.*, 1989b) and Sowerby's beaked whale (Dix *et al.*, 1986; Lien and Barry, 1989) only occasionally visit inshore waters. Other species uncommonly caught in fishing gear such as the narwhal (Merdsoy *et al.*, 1979; Strong, 1988), the white whale (Sergeant and Fisher, 1954; Sergeant *et al.*, 1970; Sergeant and Brodie, 1975) and the northern bottlenose whale (Mead, 1989) appear to be extralimital in Newfoundland's inshore waters.

How entrapments occur

The pattern of entrapments, or the relative frequency of entrapment of different species of cetaceans, provides little information on understanding factors which produce entrapments. It is not known how often whale activities in the vicinity of fishing gear result in incidental entrapment, or the type of activities which may enhance the probability of incidental entrapment. Feeding by the whales and human fishing activity both occur in the most productive inshore zones and therefore, coincidentally, result in contact (Lien, 1980).

Most entrapments of large cetaceans in inshore fishing gear in Newfoundland and Labrador appear to be the result of accidents where the whale does not detect the gear, at least in time to avoid it (Lien, 1980; Lien *et al.*, 1990b). Prime fishing areas, where nets are located, are often characterised by poor visibility (Lien, 1980). Sounds passively produced by nets and which might provide clues to the nets' presence are a function of drag characteristics; these can be modified as nets fill with fish, making the nets more difficult to detect acoustically (Lien *et al.*, 1990b). Generally, bait used by the whales is in the area of fishing gear, but is not the target species of the fishing gear. For example capelin will commonly school densely next to leaders of codtraps and avoid swimming through the meshes. Such schools may attract whales and stimulate feeding directly next to fishing gear. Further, the dense schools might obscure the fishing gear's presence behind the bait (Lien *et al.*, 1989a).

There are two exceptions where the presence of fishing gear appears involved directly in attracting whales and this attraction results in entrapments. Minke whales commonly establish ranges (Dorsey, 1983); these ranges may include codtrap berths. The whales appear to approach fishing boats engaged in hauling gear within their range. 'Pet' minke whales are a common phenomenon in Newfoundland, especially on the Southern Shore of the Avalon Peninsula and the Virgin Rocks. These whales will approach immediately when a trap is being hauled; fishermen feed the animals small, non-commercial codfish *Gadus morhua*. On occasion, it is these 'pet' whales that are later caught in the fishing gear.

Similarly, long-finned pilot whales are almost always caught in the net boxes of squid traps which hold the catch. The whales enter the box through doors and feed on the squid. As the box is small, and provides limited room to manoeuvre, the whale sometimes contacts the net sides of the trap and becomes caught.

Most humpback whales caught in fishing gear were small (<11m). It is possible that larger, more powerful individuals are better able to break free so fewer are found entrapped, but it also may suggest it is the younger animals which are more commonly caught due in part at least, to a lack of experience.

Whales often receive wounds during entrapment (Lien, 1988) and these can leave scars which provide a record of prior entrapments (Kraus, 1990). While fresh wounds are observed on entrapped humpback whales, scars from previous entrapments are rarely seen (Lien *et al.*, 1983; Lewis, 1992). One encounter with fishing gear that results in an entrapment may increase wariness or avoidance of nets.

On release from an entrapment, humpback whales typically leave the area rapidly (Lien, 1988). On the three occasions when humpback whales were radio tagged during entrapment, each animal moved rapidly away from entrapment locations when released and travelled long distances, up to several hundred n.miles in the first few days after release (Mate, pers. comm.). There are only three known instances where a humpback released from fishing gear became entrapped a second time (Lien and Aldrich, 1982; Lien *et al.*, 1988; 1990b); these all occurred within a few minutes of initial release and are probably the result of the whale's efforts to quickly leave the area.

Mortality

Humpback whales have the lowest percentage mortality from entrapments while minke and pilot whales have high mortality (Table 2).

Mortality appears to be a function of: (1) the size and behaviour of the whale when entrapped; (2) the duration of the entrapment; and (3) the assistance given in releasing the animal.

Following a collision, humpback whales frequently become calm and lie restrained by the fishing gear without struggling. Following gear contact, minke whales commonly begin rolling; the net becomes wrapped around the body in such a manner that they can no longer surface to breathe. Long-finned pilot whales also tend to become quite frantic following a collision. Generally, the more vigorous or frantic the struggle once a collision occurs the higher the mortality (Lien, 1988).

There seems to be generally lower mortality for larger whales during entrapments. Smaller whales would certainly have more difficulty in repeatedly pulling long fleets of gillnets or gear the size of a standard codtrap to the surface in order to breathe.

The probability that an entrapped whale will die increases with the amount of time that passes before it is released. The highest numbers of dead whales caught in gear are reported on Mondays (the first day fishermen check their nets after the 1–2 day weekends) or following periods of bad weather in which the gear could not be worked (Lien, 1988). For example, 7 out of 10 humpback deaths which occurred during 1990 happened during the same week (Lien *et al.*, 1990a). For a time just prior to this week, a lucrative pulse market was available for capelin and fishermen were extremely busy with this fishery; additionally, weather was extremely bad and severely limited the amount of time that gear could be worked. Thus groundfish gillnets and codtraps were not checked; incidentally caught cetaceans were simply not detected within normal time limits. Another example occurred in 1988 when funding for the Entrapment Assistance Program did not become available until later in the fishing season. Mortality during the period before the program got underway was extremely high (Lien *et al.*, 1988).

Assistance given to free whales from fishing gear lowers resulting mortality. Prior to the Entrapment Assistance Program, mortality of humpbacks caught in fishing gear in Newfoundland and Labrador was estimated at 50% (Perkins and Beamish, 1979; Lien, 1980). During the first several years of the program mortality of humpbacks was from 26 - 28% (Lien, 1980; Lien and Aldrich, 1982). During this period, fishermen often saw the Entrapment Assistance Program only as a means of 'saving whales'; animals were commonly left in the gear, and without assistance, died. Later, when fishermen became more familiar with the program, and realised benefits through the assistance it provided in removing whales from gear, more of them co-operated with the program. Average humpback mortality from entrapment from 1987–1990 was 11%.

Impact on populations

The present levels of mortality resulting from incidental entrapment in inshore fishing gear in Newfoundland and Labrador probably only seriously affect one large cetacean species: the endangered right whale. Although only a single right whale has been reported entrapped in fishing gear, it died (Lien *et al.*, 1984); only five sightings of right whales have been made in Newfoundland and Labrador in the past decade (Lien *et al.*, 1989b). Fishing gear is believed to be a serious threat to the rare right whale in the western North Atlantic (Kraus, 1990; NOAA, 1990).

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Incidental Catches of Harbour Porpoises (*Phocoena phocoena*) in the Gulf of St. Lawrence and the St. Lawrence River Estuary, Québec, Canada

Pierre-Michel Fontaine and Cyrille Barrette

Département de Biologie, Université Laval, Québec, P.Q. Canada G1K 7P4

Mike O. Hammill and Michael C.S. Kingsley

Fisheries and Oceans Canada, C.P. 1000 Mont-Joli, P.Q. Canada G5H 3Z4

ABSTRACT

Incidental catches of harbour porpoise by commercial fisheries in the Estuary and Gulf of St. Lawrence, Canada were examined. Two questionnaires, one in 1989 and one in 1990, were sent to all active fishermen, asking for information on the number of porpoises caught during the previous season, gear type and mesh size, location and time of catch. Out of 968 questionnaires sent in 1989 and 731 in 1990, 33% and 18% respectively were returned completed. In both years, 29% of the fishermen said they had caught one or more porpoises during the previous year. The 316 responses to the first questionnaire indicated that 623 porpoises were caught during the 1988 fishing season for a mean of 1.97 (SD=6.3) porpoises per fisherman; the 135 responses to the second indicated that 326 animals were caught (mean 2.41; SD=10.9). Catches were mainly in gillnets set for cod (*Gadus morhua*), in July, near shore, but some porpoises were caught in all months from April through November. On average, for both surveys combined, 7% of fishermen said they had caught other cetaceans and 49% said they had caught seals. A total of 148 porpoise carcasses were retrieved from fishermen in 1989. The mean length of males was 135cm (SD=14.8) (*n*=64) including some large specimens (9>160cm).

KEYWORDS: INCIDENTAL CAPTURE; FISHERIES; NORTH ATLANTIC; HARBOUR PORPOISE; PINNIPEDS; WHITE-SIDED DOLPHIN; WHITE-BEAKED DOLPHIN; MINKE WHALE; WHITE WHALE.

INTRODUCTION

The development of commercial fisheries has led to increased competition between marine mammals and man for marine resources (Duguy and Hussenot, 1982). Monofilament drift or set nets and marine mammals are often present in the same areas resulting in large incidental catches, particularly among the phocoenidae, in many fisheries around the world (Ohsumi, 1975; Gaskin, 1984; Northridge, 1984).

The harbour porpoise (*Phocoena phocoena*) is one of the smallest cetaceans, with an adult length of about 1.55m and weight of around 52kg (Gaskin *et al.*, 1974). Found in northern temperate coastal regions, it appears to be particularly susceptible to capture in commercial fisheries (e.g. see IWC, 1992). In Canada, incidental catches of harbour porpoise by commercial fisheries have been examined off the east coast of Newfoundland and in the Bay of Fundy (Gaskin, 1984; Lien, 1987; Lien *et al.*, 1987). However, little is known about by-catches in what might be a separate population (Gaskin, 1984) occupying the Estuary and the Gulf of St. Lawrence. In a preliminary study on by-catch, Laurin (1976) visited 36 fishing communities in the Estuary over a three-year period and mentioned that some fishermen caught up to 15 animals during a fishing season. However he was unable to estimate the total by-catch in the St. Lawrence region. The objective of our study was to obtain more information on the incidental catch of harbour porpoises in the Estuary and northern Gulf of St. Lawrence.

MATERIAL AND METHODS

Questionnaires

The study area encompassed the Estuary and the northern Gulf of St. Lawrence, including the Magdalen Islands, a total area of some 71,370 n.miles^2 centered around 49°N, 63°W (Fig. 1). Questionnaires were sent to all active fixed-gear fishermen registered with the Department of Fisheries and Oceans Canada (DFO), Division of Statistics and Data Processing. A fisherman was considered active if he had landed fish at least once during the fishing season. Questionnaires were sent to fishermen during the winter of 1989 and during the summer of 1990 in order to obtain data for the 1988 and 1989 fishing seasons, respectively. Fishermen were asked how many porpoises they had caught during the previous season, the month of capture, the type of fishing gear used and were asked to indicate the location of capture on a map included in the questionnaire. They were also asked to report observations of harbour porpoises and of incidental catches of other cetaceans and seals. Information on fish tonnage landed in the area was obtained from the DFO.

Retrieval of carcasses

In 1989, we initiated a carcass retrieval program. Fishermen in the three main fishing harbours were contacted and offered a $40 retrieval fee paid per specimen in order to alleviate losses due to damaged nets and handling. The program started on 20 May, and was stopped, because of freezer space limitations, on 20 August after 148 specimens had been received. Each carcass was examined for evidence of net scars, and fresh cuts or wounds to ensure that no animal had been intentionally hunted for the purpose of collecting the fee. At the same time, information on the date, location and type of fishing gear used as well as the fisherman's name and address were obtained. Carcasses were frozen immediately and dissected later in the laboratory. Necropsies were done according to the standard method of the American Society of Mammalogists (1961). Ovaries were sectioned manually in 2mm slices and sexual maturity of the females was established by the presence of either a corpus albicans or

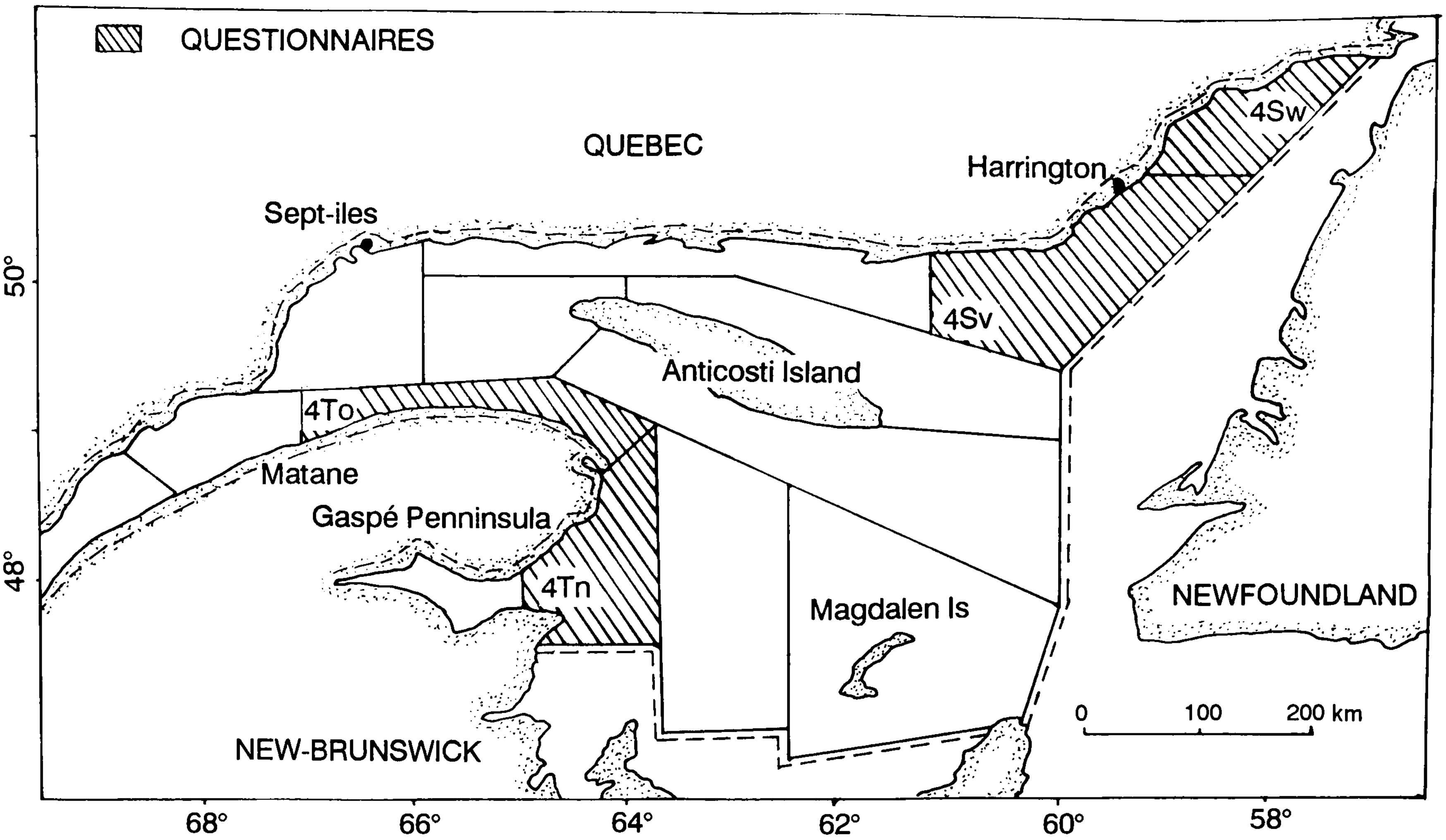

Fig. 1. The dotted line encloses the study area. Hatching shows the regions of high catches reported from the questionnaire. Abbreviations identify the North-west Atlantic Fisheries Organisation division of the area.

corpus luteum (Perrin and Donovan, 1984). Differences between means and frequency distributions of porpoise catches were examined using Student's *t*-test and the chi-square goodness of fit test.

RESULTS

Questionnaires

Out of the 968 questionnaires sent in 1989 and 731 in 1990, 33% and 18% respectively were returned completed (Table 1). The lower response rate in 1990 may be due to the questionnaires having been sent during the summer fishing season, whereas in 1989 they were sent in the winter, a time of reduced activity for fishermen. In both years, 29% of the respondents said they had caught one or more porpoises during the previous fishing season. In 1989, 42% reported that they had caught porpoises during their life. Results from the first questionnaire indicated that 623 porpoises were caught during the 1988 fishing season, with a mean of 1.97 (SD=6.3) porpoises per fisherman. The survey showed that 326 animals were caught in 1989, for a mean of 2.41 (SD=10.9) porpoises per fisherman (Table 1). There was no significant difference in mean catch per fisherman between years (t=-0.65, α>0.05).

Regional differences in bycatches were examined by dividing the study area into 14 regions following Northwest Atlantic Fisheries Organisation (NAFO) divisions. The distribution of porpoise captures did not follow the distribution that would be expected if proportional to the fish tonnage landed in the same regions (chi^2=897, df=13, p<0.0001, in 1988; chi^2=5,326, df=13, p<0.0001, in 1989). For instance, four regions consisting of the Gaspé Peninsula and the lower North shore (Fig. 1), were the source of 66% in 1989 and 72% in 1990 of the incidental catch reported, but accounted for only 39% and 41% of fish tonnage landed in 1988 and 1989 respectively.

Similarly, the monthly distribution of incidental catches did not follow the monthly distribution expected if proportional to the fish tonnage landed (chi^2=87, df=7, p<0.0001, in 1988; chi^2=32, df=7, p<0.0001, in 1989). For instance, for both years together, 80% of incidental catches were made in June-July-August, while only 51% of total fish tonnage landed occurred at that time (Fig. 2).

Table 1

Results from the questionnaires for the two fishing seasons and the program of carcass retrieval.

	Questionnaire		Carcass retrieval
	1989	1990	1989
Questionnaires sent (Active fishermen)	968	731	
Questionnaires received completed	316 (33%)	135 (18%)	
Fishermen who caught or delivered porpoises	93 (29%)	36 (29%)	36
Harbour porpoises reported or received	623	325	148
Harbour porpoises per fisherman (Mean±SD)	**1.97±6.3** [a]	**2.41±10.9** [a]	
Extrapolation of the number of by-catches	1907	1762	

[a] Inter year differences were non significant. (t=-0.65, α >0.05)

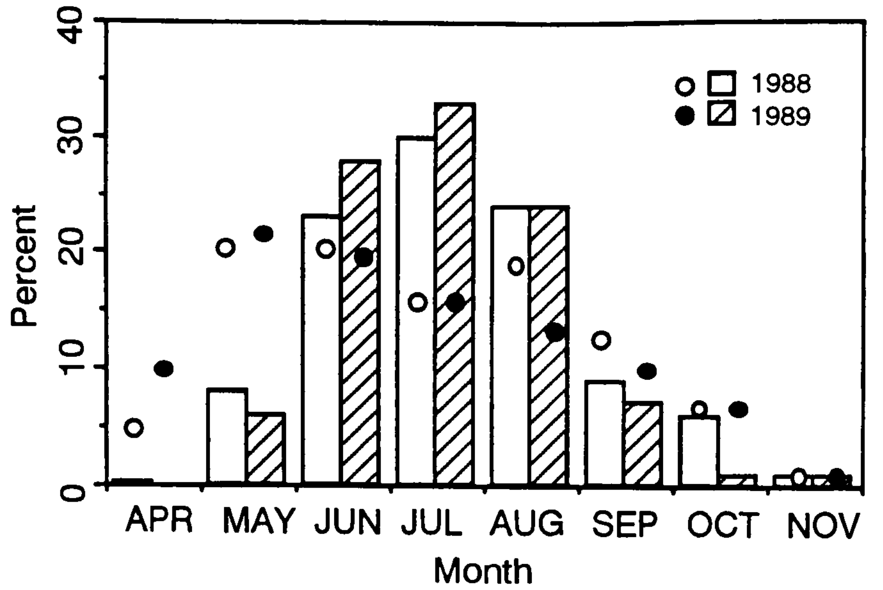

Fig. 2. Monthly distributions of incidental catches (bars) reported in the questionnaires and of fish tonnage landed (dots) for the two fishing seasons, both expressed as a monthly percentage of the annual total.

Almost all porpoises were caught in monofilament gillnets. Gillnets set on the bottom to catch cod (*Gadus morhua*) were responsible for 72% and 89% of the cases during the 1988 and 1989 fishing seasons, respectively. Next in importance were gillnets set for herring (*Clupea harengus*), salmon (*Salmo salar*), lumpfish (*Cyclopterus lumpus*) and mackerel (*Scomber scombrus*). Other types of fishing gear such as cod traps and herring traps, accounted for very few catches (Table 2).

Table 2

Type of gear responsible for the incidental catches of harbour porpoises as determined from the questionnaires for the two fishing seasons and from the program of carcass retrieval.

Type of gear and mesh size	Questionnaires 1989-1990	Retrieval Program 1989
*Cod 14-21cm	72%-89%	95%
*Herring 7cm	11%- 3%	5%
*Salmon 14cm	4%- 5%	0%
*Lumpfish 34cm	4%- 3%	0%
*Mackerel 5-10cm	3%- 0%	0%
Cod trap	3%- 0%	0%
Others	3%- 0%	0%

* Monofilament gillnets.

The number of porpoises captured, as well as the tonnage of fish landed by fishermen was related to the size of their boats. Boats greater than 14m in length made up 7% of the registered fleet during the two fishing seasons. However, they caught 38% of the fish in the two years ($chi^2=376$, df=1, $p<0.0001$) and 28% of the porpoises reported ($chi^2=202$, df=1, $p<0.0001$).

Fishermen were asked if they caught seals: 58% in 1988 and 40% in 1989 replied that they had at some time in the past. Fishermen that had caught porpoises were more likely to have caught seals: 83% of the fishermen who caught porpoises in 1988 ($n=92$) and 63% in 1989 ($n=36$) also caught seals. Whereas, of those who had not caught porpoises, only 42% ($n=161$) and 31% ($n=94$) said they caught seals in 1988 and 1989 respectively. The pinniped species caught were grey seal (*Halichoerus grypus*), harbour seal (*Phoca vitulina*) and harp seal (*Phoca groenlandica*).

Fishermen were also asked if they had caught other cetaceans in their nets: 10% in 1989 and 4% in 1990 responded positively but in many cases only indicated that they had caught unidentified whales. Several species were identified including the Atlantic white-sided dolphin (*Lagenorhyncus acutus*), white-beaked dolphin (*Lagenorhyncus albirostris*) and minke whale (*Balaenoptera acutorostrata*). White whales (*Delphinapterus leucas*) were also listed as having been caught in the past, but none were caught in 1988 or 1989.

Retrieval program of carcasses

Gillnets were implicated in all 148 carcasses obtained, 95% of which were set to catch cod and 5% were set to catch herring (Table 2).

Ten fishermen who returned the questionnaire for the 1989 season also supplied porpoises in the same season: 34.4% of the porpoises that they said they had caught were delivered to us.

More males (53%) than females (47%) were in the sample, but the sex ratio did not differ significantly from unity and is similar to that for other bycatch samples (Clausen and Andersen, 1988; Read, 1989). The mean length of males was 135 ±11.4cm ($n=76$), and the mean length of females was 142 ±14.8cm ($n=68$). Our sample included some very large specimens: nine females (14%) were more than 160cm long. Fifty three percent ($n=66$) of the females were sexually mature, and 58% of these were lactating.

DISCUSSION

The quality of information derived from questionnaire surveys depends on sample size, the bias of non-respondents and the accuracy of the data provided (e.g. Usher and Wenzel, 1987; Lien *et al.*, 1994). In this study, we contacted all registered fishermen in our study area, and the number of respondents was quite high. Estimating non-respondent bias is more difficult. Here, we have assumed that both respondent and non-respondent bias was similar. Previous studies of incidental catches in commercial fisheries have used telephone or mail surveys of fishermen (Smith *et al.*, 1983; Lien, 1987). We used mail surveys because they are more cost effective for contacting a large number of people. We also believe that these surveys may be more accurate, particularly the results from our 1989 winter sample when fishermen were less active and therefore felt less pressured to respond. We believe that those who took the time to answer, did so carefully. Lien *et al.* (1994) examined the accuracy of results based on 'memory recall' surveys and found that results were more accurate when the number of animals caught was low. In our study, most fishermen (93% in 1989 and 76% in 1990) said they caught less than 10 porpoises, making it likely that the answers to our questionnaires were accurate.

The fact that the ten fishermen who returned questionnaires and carcasses returned only 34.4% of the total number of animals that they said they had caught in that year could be due to: (1) in some cases too much effort would have been required to disentangle the carcasses; (2) the carcass retrieval program was cancelled before the end of the fishing season; and (3) in some areas, particularly along the North Shore and parts of the Gaspé peninsula, harbour porpoises are still used locally for food.

The absence of a significant difference in mean catch per fisherman between years indicates that either the questionnaire yielded a reliable estimate of the bycatch or, if a bias was present, then the bias was consistent from year to year. Our overall average of 2.07±8.6 porpoises per fisherman per year is higher than the average Lien (1987) found along the eastern coast of Newfoundland ($\bar{x}$=1.4), but is much lower than reported for the Bay of Fundy ($\bar{x}$=5.5) by Read and Gaskin (1988). The Bay of Fundy is a smaller area with a high density of porpoises during the summer (Read and Gaskin, 1988) and may not be comparable to areas like Newfoundland or Québec.

Each active fisherman on our list (around 850) is the owner of a boat and can be considered to represent one crew. Lien (1987) estimated the number of crews in Newfoundland and Labrador to be 2,300 and the number of harbour porpoises taken incidentally per year to be 1,800–3,000 (0.81–1.4 porpoises per crew per season). Our study area is geographically and climatically similar to Lien's and it is interesting to note that our estimates (1.15 – 2.07 porpoises per crew per season) are similar to his.

Our questionnaire results showed that a minimum of 623 and 326 porpoises were caught accidentally in the northern Gulf and Estuary during commercial fishing in 1988 and 1989, respectively. Extrapolating the mean number of porpoises caught per fisherman returning questionnaires to the total number of active fishermen, results in an estimate of 1,907 and 1,767 porpoises caught in our study area in 1988 and 1989 respectively. This extrapolation assumes that all non-respondents expended similar fishing effort and caught similar numbers of porpoises to the respondents in our surveys. At this time, we are unable to verify these assumptions. However, owing to the similarity in the results between the two surveys and the high response rates, particularly to the first questionnaire (33%), we believe that the actual number of captures is closer to our higher estimate of 1,907 animals than our lower estimate of 1,767.

In evaluating the impact of incidental catches, the effect on the population of losing lactating females should not be neglected. Lactation in *P. phocoena* lasts for at least nine months (Read, 1990). During the fishing season, young of the year would be no more than five or six months old and, even if they are not captured with their mother, would be unlikely to survive. In our sample, only four calves were caught compared to 20 lactating females. We consider it necessary to increase our estimate of the total by-catch by 13% to account for mortality of orphaned calves.

Both the questionnaires and the carcass retrieval program agreed with Laurin's (1976) results, showing that a disproportionate number of animals are caught along the lower North Shore of the St. Lawrence and around the Gaspé Peninsula (Fig. 1). Differences between the spatial and temporal distribution of fish tonnage landed and porpoise catches, suggest that there is movement of harbour porpoise into the northern Gulf and Estuary during June, July and August.

Gillnets set for groundfish were responsible for most of the incidental catches in our area, as is true in the Bay of Fundy (Read and Gaskin, 1988) and Newfoundland (Lien, 1987). Such nets are usually set to capture cod. It is not surprising that porpoises become entangled given that they, as well as cod, feed on capelin (*Mallotus villosus*) and herring (Lilly, 1987; Fontaine, 1992). Many fishermen believe that porpoises are caught soon after the nets are set. However, Read and Gaskin (1988) failed to catch porpoises in an experiment in which the nets were retrieved immediately after being set. Four fishermen in the same area captured a total of 0–6 porpoises with similar nets set at the same time but left in place for the normal period of 24 hours. It would thus appear that most entanglements occur while nets are at the bottom.

The disproportionately high catches by large boats (>14m) may be due to greater fishing effort, but unfortunately, information on effort is not available. Alternatively, porpoises may be more susceptible to entrapment by large boats due to the use of different fishing techniques. For example, a single long net like those set by larger boats is more likely to catch porpoises than the same length of net broken up into short units (Ohsumi, 1975).

Changes in size distribution of porpoises have been used as an indicator of population status (Clausen and Andersen, 1988; Read and Gaskin, 1988). Our proportion of females greater than 160cm (14%) was much higher than that found by Read (1989) in the Bay of Fundy (5%) and by Clausen and Andersen (1988) in Danish waters (7%). Unfortunately, there are no historical data for the St. Lawrence area to compare with our sample on size distribution. However, the greater proportion of large specimens reported in other populations subjected to heavy catches, might suggest that the St. Lawrence population has been less affected than those in Danish waters and the Bay of Fundy (Clausen and Andersen, 1988; Read and Gaskin, 1988). It could also mean that the population in our study area is isolated from the one in the Bay of Fundy as suggested by Gaskin (1984). Despite the difficulty in ageing harbour porpoises (Watts and Gaskin, 1989), age distributions would be a better index of population status because they may be independent of ecological factors that may affect body size (Fontaine, 1992).

Fishermen reporting that they had caught porpoises were more likely to have caught seals as well. Both harbour porpoises and seals are associated with coastal regions and forage for similar food resources (Boulva and McLaren, 1979; Lilly, 1987; Benoit and Bowen, 1990; Murie and Lavigne, 1991; Sergeant, 1991; Fontaine, 1992). Fishermen tend to have a more negative feeling towards seals than towards porpoises (Read and Gaskin, 1988). Seals are caught much more often and cause more damage to the nets. Seals are also an intermediate host of the codworm (*Pseudoterranova decipiens*) which affects the commercial value of cod (Malouf, 1986).

Incidental catches of other cetaceans do not seem to occur frequently in comparison with those of harbour porpoises or seals. Fishermen were unable to identify reliably the various mysticetes encountered, so it is difficult to list the species taken or to estimate how frequently each species was caught. The questionnaires also indicated that white whales had been captured accidentally in the past, but not during the recent fishing seasons. We do not believe that commercial fishing affects white whales in the Gulf of St. Lawrence because fishing is concentrated downstream of the area currently occupied by this population (Michaud *et al.*, 1990).

CONCLUSION

This study indicates that there is a substantial incidental catch of harbour porpoises in Québec waters in the Gulf of St. Lawrence. Given our lack of knowledge on harbour porpoise abundance in this area, it is difficult to assess the impact of such catches. However, research is currently underway to obtain information on porpoise abundance, along with information on incidental catch of porpoises from the west coast of Newfoundland and in the southern Gulf of St. Lawrence.

Our estimate of incidental catches in the northern Gulf (probably around 1,900) could be more accurate with better information on fishing effort and the variability of this parameter between fishermen. Obtaining this information and attempting to reduce the incidental take of harbour porpoise will be achieved most effectively by working with the fishing industry. It is, after all, with the cooperation of fishermen that we have been able to identify and to document the initial problem. As a first step, it would be important to provide fishermen with more information about the problem and its consequences.

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SC/O90/G47

Coastal Fisheries and Cetacean Mortality in Portugal

Marina Sequeira

Instituto da Conservação da Natureza, Divisão de Investigação e Estudos Ecológicos, R. Filipe Folque, 46–3°, 1000 Lisboa, Portugal

and

Carlos Ferreira

Instituto Português de Investigação Marítima, Departamento de Tecnologia da Pesca, Av. Brasília, 1400 Lisboa, Portugal

ABSTRACT

Considerable numbers of cetaceans are killed incidentally every year during fishing operations on the Portuguese coast. Although a small number of marine mammals are caught by trawlers and fishing traps, the highest mortality rates occur in the gillnet fishery. The common dolphin (*Delphinus delphis*) and the harbour porpoise (*Phocoena phocoena*) have been the major victims and the numbers of cetaceans caught are particularly high in the central areas of the Portuguese coast. However there is little reliable biological information available on the incidental taking of cetaceans on the Portuguese coast, and there is an urgent need for a monitoring programme there.

KEYWORDS: INCIDENTAL CAPTURE; FISHERIES; NORTH ATLANTIC; COMMON DOLPHIN; HARBOUR PORPOISE; STRIPED DOLPHIN; BOTTLENOSE DOLPHIN; MANAGEMENT

INTRODUCTION

Fishing zones

The Portuguese continental shelf covers a maritime area of *ca* 28,000km^2 (about 600km long between 37° and 42°N). As the Portuguese coast is almost devoid of island protection it is exposed to strong northwestern Atlantic influences, and is thus hardly propitious to fishing activities involving complex gear that has to remain at sea for long periods.

However, the Algarve coastline in Southern Portugal is sheltered from the dominant northwesterly winds and thus provides better conditions for bottom anchored fixed gear close to the coastline. Until quite recently this included fixed traps for tuna (*Thunnus thynnus*) and sardine (*Sardina pilchardus*).

The Portuguese coast can be divided into three fishing zones: northern, central and southern (Fig. 1).

Northern zone

The northern zone is about 200km long and stretches from the Minho river south to Mira. It includes 51 harbours with 37 fishing fleets that operate exclusively at sea (the remaining fleets operate essentially in freshwater and estuarine areas).

Central zone

The central zone spans almost 350km between Tocha and Azenha do Mar with 51 harbours and 34 fishing fleets operating at sea.

Southern zone

The southern zone extends about 160km between Odeceixe and Cape S. Vicente and includes 36 fishing harbours, most of them situated along the southern facing shoreline.

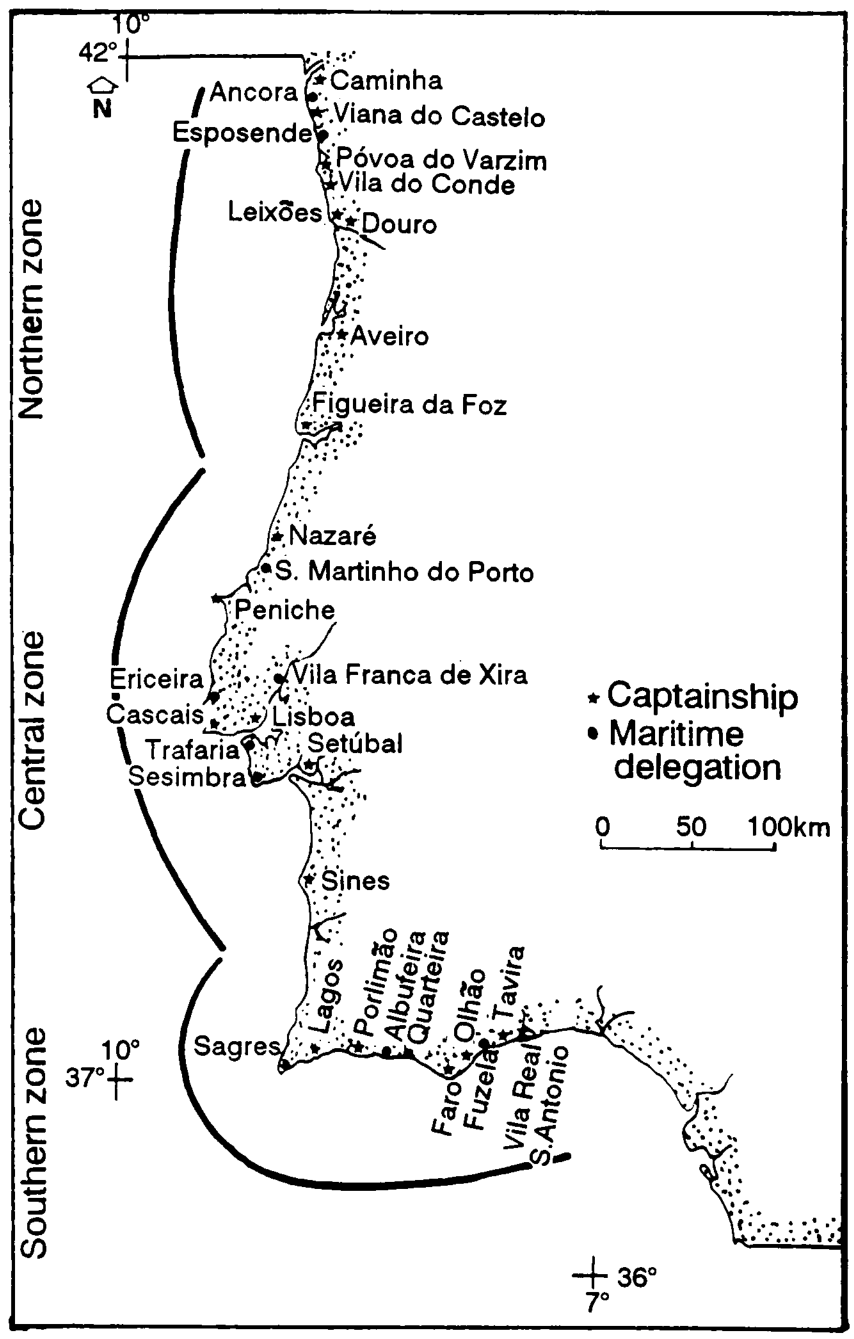

Fig. 1. Fishing areas, harbours and captainships.

Auctions

As many fishermen still do not report their total catches at the official auctions, the official data for the artisanal fisheries may represent a substantial underestimate. In addition, although this is no longer the case, in 1984 up to 50% of the artisanal fishing ports on the Portuguese coast did not have official auctions (Costa and Franca, 1982; 1985; Franca and Costa, 1984; Table 1).

Table 1

Fishing harbours (H) with official auctions (A) in 1984 (in Costa and Franca, 1982, 1985; Franca and Costa, 1984).

Zone	H	A	Zone	H	A	Zone	H	A
Northern	34	17	Central	34	17	Southern	36	18

Fleet

Depending on the fishing areas being exploited, the boats registered on the Portuguese coast are grouped into several categories (Table 2), based on overall length (m), gross registered tonnage (GRT), engine power (Kw) and length of fishing trip (days) as defined by national legislation.

Boats may obtain licenses to use up to a maximum of five of the different types of fishing gear allowed in Portuguese waters.

Local fishing boats with weather decks can operate up to six n.miles from the coast within the captain's jurisdiction area from the port of registration; awning deck boats are allowed to operate up to 30 miles from the coast and in areas of adjacent captainships (Duarte, 1990).

The areas allowed for the coastal fishing boats are established according to the registration port and type of fishery. Whenever technical and security requirements are fulfilled these boats can operate within EEC fishing areas. The Portuguese coastal fishing fleet includes boats using almost all types of gear, but the average size of the vessels decreases towards the South (Duarte, 1990).

As would be expected distant water vessels have comparatively higher GRT and longer trips; although they may operate in any fishing area, they are not allowed to fish within 12 n.miles of the coast (Duarte, 1990).

The geographical distribution of the fleet by number of boats, GRT, engine power and age is given in Appendix Table 1.

Table 2

Classification of the Portuguese fishing fleet.

	Local fisheries	Coastal fisheries	Distant-water fisheries
Length(m)	up to 9m	>9m	-
GRT	-	up to 100	>100
Engine power	up to 75Kw (awning deck) up to 45Kw (weather deck)	25Kw (minimum)	-
Length of trip	-	established according to the fishing area	15 days minimum

Fishermen

Data available for 1982–88 indicate that the number of fishermen registered has not changed substantially, with most of them operating in the coastal fleet (Appendix Table 2).

Only the most important coastal fisheries, that potentially may have incidental catches of marine mammals, are reviewed in this report. Technical data and information on by-catches associated with the activities of the Portuguese distant-water fisheries proved very difficult to obtain.

There are no accurate estimates of the number of cetaceans killed by any of these fisheries, nor any information on the impact of these mortalities upon the different populations. However, the information obtained so far suggests that trawling operations account for a considerable part of the overall cetacean mortality in active gear occurring in Portuguese waters.

Legislation

In 1981, national legislation was passed that protected all marine mammals in Portuguese continental waters. This made the killing of all cetaceans technically illegal and many fishermen no longer report their incidental by-catches as they are afraid of the legal consequences.

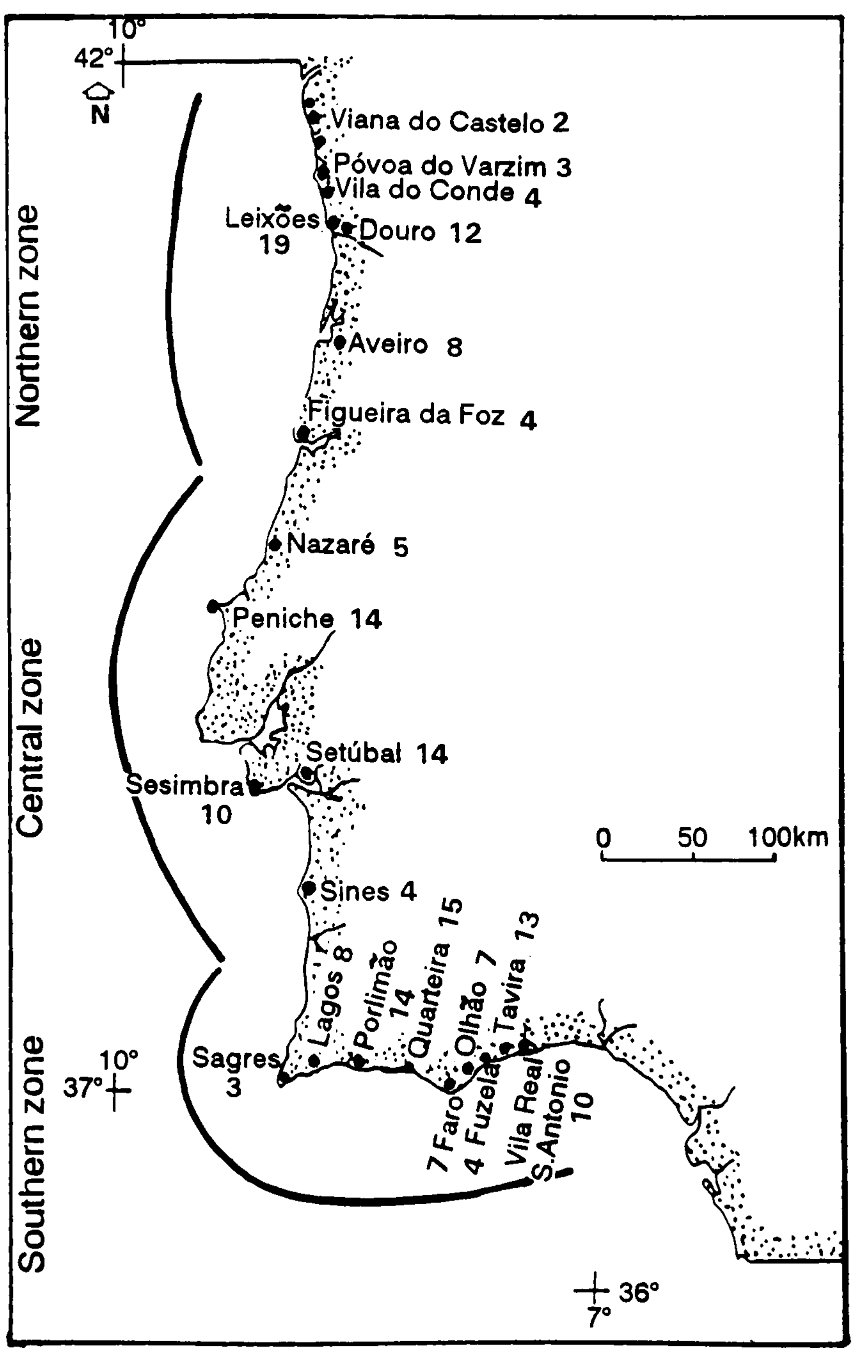

Fig. 2. Numbers of licenses issued in 1991 for purse seining fishing.

FISHING METHODS

Purse seine nets

Location of ports

Although this activity is scattered all along the coast, there are seven primary ports: Leixões, Portimão, Peniche, Setúbal, Quarteira, Douro and Tavira (Fig. 2).

Target species

The main target species are pelagic fishes such as the sardine (*Sardina pilchardus*), mackerel (*Scomber scombrus*), Spanish mackerel (*Scomber japonicus*), horse mackerel (*Trachurus trachurus*), blue whiting (*Micromesistius poutassou*), snipe fish (*Macrorhamphosus* spp.) and anchovy (*Engraulis encrasicholus*) (Costa and Franca, 1982; Pestana, 1989). Purse seines are also used in Azorean and Madeiran waters to catch small pelagic fish that are used as live bait for thunnids.

Area of operation

Purse seines are used in the coastal waters on the Portuguese continental shelf.

Vessels and crew

Wooden boats are used which are not able to keep fish on board for long periods of time. They therefore operate close to harbour and return immediately after fishing.

Purse seine nets may be operated by two main types of boat depending on their GRT and engine power: the larger and more powerful *traineiras* that operate seine nets all year round; and the *cercadoras* which may also use other types of fishing gear besides seine nets. The characteristics of the vessels operating in 1987 are given in Table 3.

Table 3

Characteristics of the purse seiners in mainland Portugal: age, GRT and engine power, as registered in 1987 (GEPP, 1987).

Age	GRT	Engine power
Max. 53.0yrs	Max. 42.2	Max. 189.87Kw
Min. 2.0yrs	Min. 1.4	Min. 7.44Kw
Mean 16.0yrs	Mean 18.3	Mean 83.61Kw

According to the Fisheries Planning Division national baseline (GEPP, unpubl.), there were 179 boats licensed to use seine nets from mainland Portugal in 1991. In addition, an undetermined number of boats operate small seine nets illegally along the Portuguese coast.

Crews comprise entirely Portuguese fishermen and their number is often higher than strictly necessary, with an adverse effect on economic profitability.

Gear

Seine nets capture shoaling fish by surrounding them laterally and ventrally, thereby preventing their escape by swimming under the net into deeper water. With only a few exceptions, these are surface nets equipped with buoys on the floatline. The minimum legal mesh size for seine nets is set at 18mm, with net length and height dimensions established according to the GRT of the boat as shown in Table 4. However, many boats still use illegal nets which are longer than allowed.

Table 4

Maximum length (L) and depth (D) of seine nets related to GRT of the fishing boats using them.

GRT	L	D	GRT	L	D	GRT	L	D
<20	300	60	20-49	700	120	≥50	800	150

Operations

The shoals are located visually or with the help of sounding lines and fishing is usually carried out at night with lights. The method used by most purse seiners has changed rapidly in recent years from most fishing ports (with the exception of Peniche and some areas in the Northern zone); the practice of fishing continuously in areas close to the shoreline, where the net reaches the bottom when closing is now widespread. Purse seiners often use buoys with several types of light sources scattered all over the fishing area to aid fishing (Costa and Franca, 1982; 1985; Franca and Costa, 1984). This often results in high mortalities of immature forms of demersal species, which has a deleterious effect on the main stocks.

Economics and history

Data relating to the economic aspects of the purse seine fishery in Table 5 refer to prices obtained at fish markets and include both fresh and frozen fish sales.

Landings

Data available on seine net landings at individual harbours suggests marked differences between the catch levels for the three zones (Table 6).

Effort

In 1991, the 179 licensed boats (Appendix Table 3), each operated only one net. The fishing effort for the purse seiners (CPUE) is expressed as tonnes per boat and the data for 1980–1988 (Pestana, 1989) are summarised in Table 7.

Table 5

Official auction sales (thousands of escudos) for the purse seine fishery (INE, 1988, 1989).

	1987				1988			
Area	Marine fish	Crustaceans	Molluscs	Other	Marine fish	Crustaceans	Molluscs	Other
Northern zone	1,948,858	4	935	21	2,096,556	37	2,964	16
Central zone	2,388,474	18	9,482	88	3,015,974	6	9,929	126
Southern zone	1,174,627	8	19,929	84	1,652,819	69	33,186	17
Total	5,511,959	30	30,346	193	6,765,366	112	46,079	159

Table 6

Seine net landings (tonnes) in mainland Portugal, 1987 and 1988 (INE, 1988, 1989).

Area	1987			1988		
	Fish	Molluscs	Other	Fish	Molluscs	Other
Northern zone	45,986	3	-	52,173	9	-
Central zone	38,741	23	4	38,321	19	2
Southern zone	21,849	41	2	24,218	61	-
Total	106,576	67	6	114,712	89	2

Table 7

Number of boats and CPUE for the purse seine fishery (Pestana, 1989).

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988
No. boats	211	193	184	196	192	192	198	208	208*
CPUE	427	557	521	399	441	582	496	411	450*

* Preliminary data only.

Interactions with cetaceans

There are no official records of cetacean mortality in seine nets on the Portuguese coast. However, as in other oceanic areas, it is likely that some marine mammals are caught by the purse seine fleet.

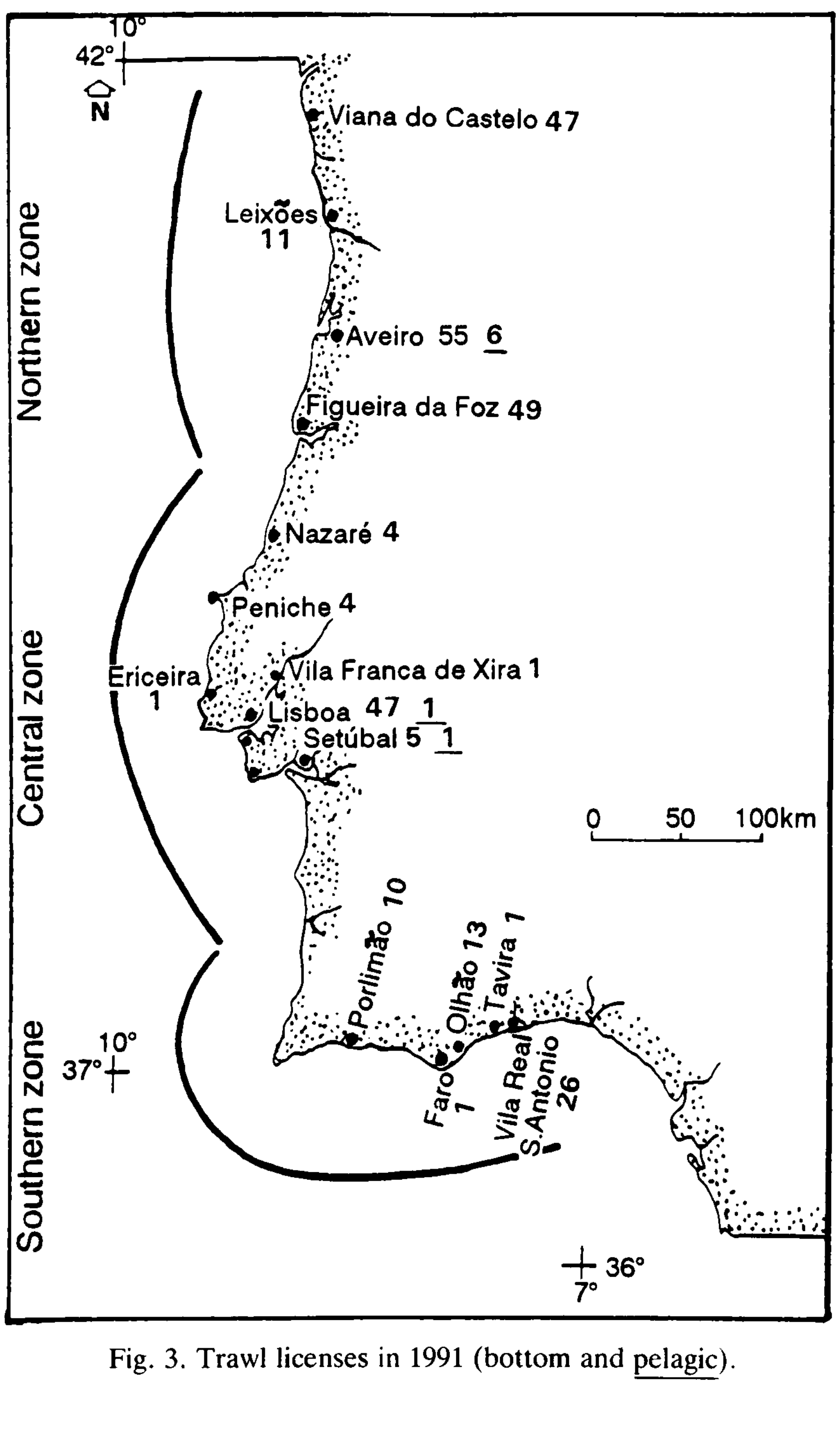

Fig. 3. Trawl licenses in 1991 (bottom and pelagic).

Trawls

Location of ports

The most important ports are Figueira da Foz, Aveiro, Viana do Castelo and Lisboa (Fig. 3).

Target species

The Portuguese trawl fishery is directed mainly to bottom-living or demersal species and catches include the horse mackerel, blue whiting, mackerel, Spanish mackerel, hake (*Merluccius merluccius*), megrim (*Lepidorhombus bosci* and *L. whiffiagonis*), monkfish (*Lophius piscatorius* and *L. budegassa*), cephalopods (octopus and squids) and the Norway lobster (*Nephrops norvegicus*).

Area of operation

Although national legislation prevents trawlers operating within 6 n.miles of the coast, trawlers occasionally fish illegally within that distance.

The areas in which boats are allowed to trawl are related to their individual GRT. Boats under 120GRT are allowed to operate within 12 n.miles of the shore, whereas those above 180GRT are only allowed to operate more than 18 n.miles offshore.

Vessels and crew

According to information provided by the General Directorate of Fisheries (Direcção-Geral das Pescas, 1986), the trawling fleet had almost 120 active trawlers in 1985, with 80 catching fish and 40 taking crustaceans. All of them used bottom trawls. The vessels were between 18–35m, 50–250GRT, with engine power ranging between 294–1,103Kw.

However, some of the trawlers fishing for crustaceans were smaller, with almost 29% of the boats aged 20 years and over and only 24% of them under 10 years old. A summary of information for the registered trawling fleet in 1990 is given in Table 8. More than half the vessels are now made of steel and almost 80% are stern trawlers. The crew is usually larger than necessary.

Gear

The bottom trawl is the most widespread type used on the Portuguese coast. Codend mesh size varies according to the target species. For each mesh size there is a minimum percentage of target species fixed by legislation and a maximum percentage of protected species that may be caught (Appendix Table 4).

Operations

Since the fishing areas are comparatively close to the shore, trips are typically one day long, although some boats may be capable of remaining at sea for up to three weeks. The catch may be landed at another port, for economic reasons.

Table 8

Age, GRT and engine power of trawlers (Cardador, *pers. comm.*).

Age	GRT	Engine power
Max. 64.0yrs	Max. 259.3	Max. 1083.3Kw
Min. 1.0yrs	Min. 18.0	Min. 178.4Kw
Mean 20.0yrs	Mean 142.7	Mean 481.16Kw

Trawlers operating along the Portuguese coast use only one net, although the Portuguese fleet operating in West Africa regularly uses outriggers. All vessels have radar, sounders and other navigation equipment, but many fishermen still ignore the echo-sounders when locating the shoals. The skippers go directly towards the traditional fishing grounds, where they throw the nets and tow for between 2 and 4 hours, depending on the target species. Fishing depth varies with local topography and target species, up to a maximum of 700m.

Economics and history

Total earnings from trawling operations in 1987 and 1988 are given in Table 9.

Landings

As in the purse seine fishery, the total landings from trawlers (Table 10) differ by zones.

Effort

The potential of the Portuguese trawling fleet is not fully realised, mainly because ships capable of trips of up to three weeks operate regularly for under 200 days per year, with individual trips averaging under two days. In addition, these ships do not fully utilise their bilge capacity and waste up to 30% of their gross income in fuel consumption (Direcção-Geral das Pescas, 1986).

In 1991, there were 283 boats licensed to use trawls, some of them operating in CECAF, NAFO and ICSEAF areas. Only eight boats were licensed to use pelagic trawls (at Aveiro, Lisboa and Setúbal).

Interactions with cetaceans

The official numbers of cetaceans reported caught during trawling operations are certainly underestimates, mainly because there are no observers on board to monitor the by-catches.

Official reports refer to only 18 dolphins found dead in trawl nets (17 common dolphins, *Delphinus delphis*, and 1 harbour porpoise, *Phocoena phocoena*). Twelve were recorded in 1980, when the killing of cetaceans along the Portuguese coast was still allowed and marine mammals could be sold at local fish markets. When these captures became illegal in 1981, the fishermen ceased reporting by-catches and the official records obtained since refer only to six common dolphins drowned in nets. Five of these were accidentally caught by the pelagic trawl of the Portuguese Fisheries Institute's own research vessel, in 1985 and 1987, suggesting that many more cetaceans may be caught every year by the whole trawling fleet. This mortality possibly involves a few tens of cetaceans killed every year.

Discussion

Trawling operations certainly contribute to the overall mortality of cetaceans recorded on the Portuguese coast. The mortality rates for the different species and the associated impacts on the cetacean populations need to be assessed as a matter of urgency. Furthermore, the fishing areas regularly exploited by trawlers should be carefully monitored. This might be accomplished by placing biologists on board selected trawlers.

Fishing traps

Location of ports

Of the two major types of fishing traps widely used on the Portuguese coast, basket traps and pots, the former predominate in the northern and central zones while the latter are particularly important in the southern zone (Fig. 4).

Target species

This fishery is especially aimed at octopus and crustaceans.

Table 9

Total earnings (thousands of escudos) from trawlers (Table 10) show differences for the three zones in Fig. 1.

	1987				1988			
Area	Marine fish	Crustaceans	Molluscs	Other	Marine fish	Crustaceans	Molluscs	Other
Northern zone	2,134,836	17,105	566,064	102	2,307,220	19,011	387,045	113
Central zone	1,685,551	35,596	128,084	161	1,759,546	19,253	85,959	665
Southern zone	948,268	1,946,905	144,941	32	1,194,714	2,835,319	195,895	64
Total	5,511,959	1,999,606	839,089	295	5,261,480	2,873,583	668,899	842

Table 10

Landings of the trawl fleet (tonnes) by zone and group of species in mainland Portugal, 1987 and 1988 (INE, 1988, 1989).

	1987				1988			
Area	Fish	Crustaceans	Molluscs	Other*	Fish	Crustaceans	Molluscs	Other*
Northern zone	21,217	19	2,074	2	18,899	20	1,291	2
Central zone	10,836	37	428	1	8,480	9	242	3
Southern zone	4,644	1,643	491	-	4,389	2,348	533	-
Total	36,697	1,699	2,993	3	31,768	2,377	2,066	5

* Diadromous fishes and lamprey.

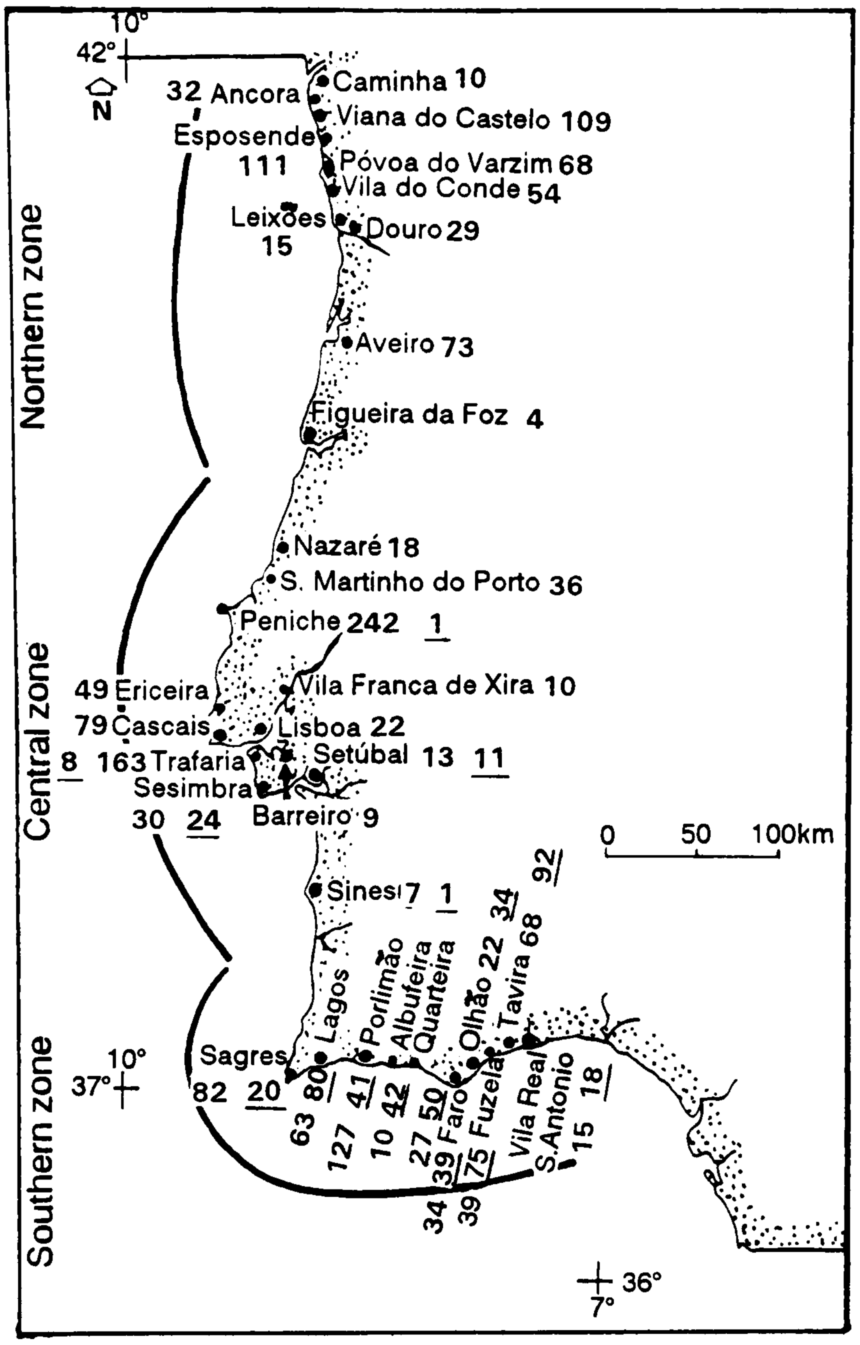

Fig. 4. Licenses for traps and pots in 1991.

Area of operation
Current legislation prohibits the use of traps within 0.5 n.miles of the coastline. For boats >5GRT this distance is increased to one mile.

Vessels and crew
These boats are typically built of wood and 6–20m long, with no refrigeration, and therefore unable to keep their catch on board for long periods. The crew consists of 2–8 Portuguese fishermen and in most cases is larger than strictly necessary.

Gear
Current legislation does not allow the use of traps made entirely of synthetic materials. The minimum mesh size allowed is 30mm and all parts in the trap must be sewn to each other and to the supporting structure by natural yarn without any anti-decay treatments. The traps are set out singly or in groups along a main line, according to specific legislation. Wire baskets are set out in groups of 13 to 100 units, with an average number of 30 to 40 traps per group (Costa and Franca, 1985). The traps are usually baited with sardines, although other species such as the common mackerel and horse mackerel may be used (Franca and Costa, 1984).

Pots are sheltered circular clay traps, widely used to catch octopus. These traps are always set in groups along a line anchored to the bottom. Pots used in shallow waters are typically 21cm high with openings 10cm wide, while pots used in deep waters are 32cm high with openings 13cm wide (Costa and Franca, 1982).

Operations
No boat is allowed to use more than 1,000 pots.

Economics and history
Reliable information on landing prices and earnings by the fishermen are difficult to obtain and are not readily available from the official fisheries statistics.

Total landings
There is no detailed information available on catches with fishing traps since these are included together with other gear in the official statistics for artisanal fisheries.

Effort
There were 1,670 boats licensed to use either basket traps or wire baskets in August 1991, and 546 boats had licenses to fish with pots (Appendix Table 3).

Interactions with cetaceans
The minke whale (*Balaenoptera acutorostrata*) is the only species known to become occasionally entangled in Portuguese fishing traps. In the three cases reported, the whales were caught in the wire leaders of the basket traps. All were dead when found by the fishermen.

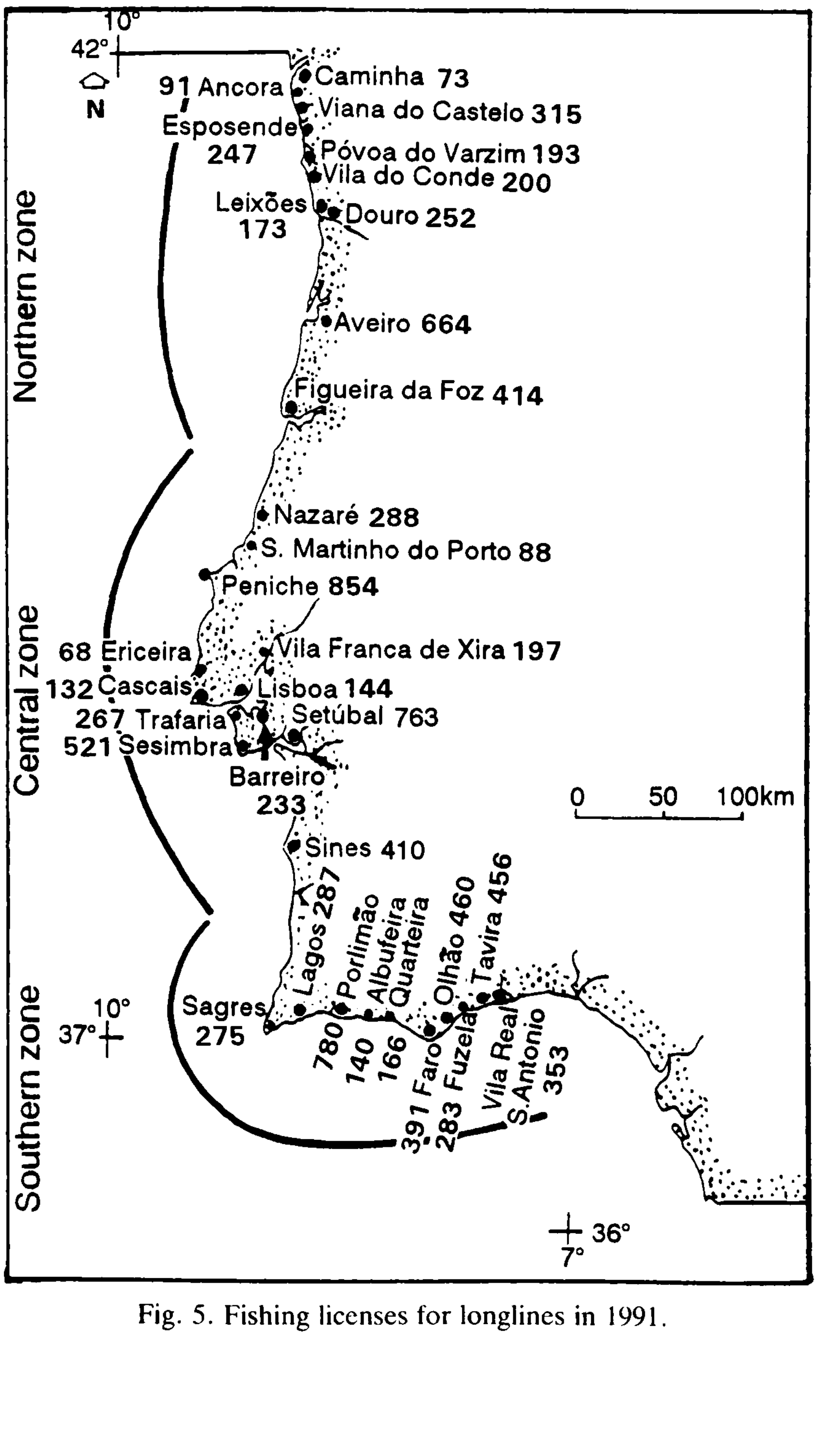

Fig. 5. Fishing licenses for longlines in 1991.

Discussion
Due to their intrinsic characteristics (bottom set fishing gear) most types of fishing traps currently used on the Portuguese coast are unlikely to cause high mortality of cetaceans. Nevertheless, special attention should be paid to the areas with higher rates of primary productivity and richer marine faunas. These include the oceanic areas adjacent to the Tejo and Sado estuaries and close to the Nazaré deep canyon in the central zone, where cetacean strandings and sightings have been frequently reported (Sequeira, 1988; Sequeira and Teixeira, 1990 and Sequeira *et al.*, 1992).

Longlines

Location of ports
This fishery operates all along the Portuguese coast but is concentrated especially in the northern and central zones (Fig. 5).

Target species
Longlines are regularly used to capture seabass (*Dicentrarchus labrax*), Atlantic pomfret (*Brama brama*), European conger (*Conger conger*), pout whiting (*Trisopterus luscus*), sargos and bream (*Diplodus* spp.), gilthead seabream (*Sparus aurata*), black seabream (*Spondyliosoma cantharus*), pandoras (*Pagellus* spp.), soles (*Solea* spp.), black scabbardfish (*Aphanopus carbo*), sharks and thunnid species.

Area of operation
The use of longlines is comparatively widespread within the Portuguese exclusive economic zone (EEZ), although target species may differ markedly between the areas fished.

Vessels and crew
Boats used for longlining are usually built of wood and most lack adequate means of maintaining the fish on board for extended periods. Trips are typically one day long and may end in a different port. Only a small minority of these boats fish exclusively with longlines.

There is a special longliner fleet for the black scabbardfish (*Aphanopus carbo*) at Sesimbra; its main characteristics in 1984–88 are shown in Table 11.

Gear
Longlines consist of groups of interconnected lines either set at the bottom or drifting, each line bearing a large number of baited hooks. For the capture of pelagic species such as tuna and swordfish, drifting longlines are used. In recent years, bottom longlines for black scabbardfish were developed at Sesimbra in the central zone. In this type of fishery the main line may have 3,600 to 4,000 hooks and the gear may spread for 6 to 8km (Martins *et al.*, 1989).

Operations
Longlines are usually set at dawn and stay in the water for periods ranging from a few hours up to a few days (Leite, 1990). However, longlines set to capture the black scabbardfish are set and hauled at dawn. The duration of individual hauls is usually between 40 and 65 hours (Martins *et al.*, 1989).

Economics and history
Among the Portuguese artisanal fisheries, longlines were of only limited importance in the northern zone in 1983–84, behind gillnets, purse seines and trawls. The types used in this area are either bottom set longlines or drifting bottom longlines. According to Franca and Costa (1984) longlines came in third place in the central zone, far behind gillnets and fishing traps. Longlines are most popular in the small harbours to the south of Sines and are used by almost all the artisanal fishing fleet operating there permanently. Two different types of lines are used, depending on the target species.

The longline fishery was of some economic importance in 1982 in the areas around Portimão in the southern zone. At nearby Quarteira, Ferragudo and Luz, longlines were used only when catches obtained with other gear went very low (Costa and Franca, 1982). Again, two types of lines are used in the southern zone, depending on the target species.

There are no readily available economic data for the longline fishery since it is included with other artisanal gear in the official statistics. Nevertheless, the high selectivity of this gear and the quality of the fish captured make it of some economic importance.

Total landings
There are no detailed statistics for longline fisheries since they are included with other gear in the artisanal fisheries statistics. Nevertheless, black scabbardfish landings at Sesimbra can be obtained for 1984–88 and are shown in Table 12.

Table 11

Characteristics of the longliner fleet for black scabbardfish in 1984-88 (Martins *et al.*, 1989).

Year	No. of boats	Mean values: GRT	Engine power (Kw)	Length overall (m)
1984	15	16.6	95.53	11.2
1985	23	16.1	84.43	11.2
1986	28	16.1	87.04	11.3
1987	23	18.0	99.32	11.8
1988	27	20.1	107.89	12.4

Table 12

Black scabbardfish landings at Sesimbra (tonnes) in 1984-88 (Martins *et al.*, 1989).

Year	1984	1985	1986	1987	1988
Landings(t)	613	947	2,241	2,593	2,602

Table 13

Total landings, fishing effort and CPUE for the black scabbardfish longline fleet at Sesimbra (Martins *et al.*, 1989).

		Fishing effort		CPUE	
Year	Landings(Kg)	Boats	Fishing days	Kg/boat	Kg/day
1984	403,986	15	2,170	26,932.4	186.2
1985	795,676	23	3,092	34,594.6	257.3
1986	1,722,736	28	5,662	61,526.3	304.3
1987	2,419,496	23	5,082	105,195.5	476.1
1988	2,594,716 *	27	4,691	96,108.6	553.1 *

* Estimated data only.

Effort

Fishing effort for the black scabbardfish at Sesimbra in 1984–88 was estimated in terms of number of boats and fishing day units (Table 13). There were 10,056 boats licensed to use longlines in 1991 (Appendix Table 3). According to Martins *et al.* (1989) individual trips average two days fishing.

Interactions with cetaceans

Although there are no published records of cetacean entanglement in longlines in Portugal, this does not necessarily mean that entanglement does not occur.

Discussion

The impact of longline fisheries on cetacean populations needs to be determined, especially in the areas most heavily fished.

Gillnets

Location of ports

Gillnets are widely used all along the Portuguese coast from Caminha to Vila Real de Santo António. The number of boats licensed to use this type of gear is higher in the northern and central zones (Fig. 6).

Target species

The main target species of the gillnet fishery are allis shad (*Alosa alosa*), flatfishes (Pleuronectidae), hake (*Merluccius merluccius*), pouting (*Trisopterus luscus*), monkfish (*Lophius* spp.), seabass (*Dicentrarchus labrax*), seabreams (Sparidae) and cuttlefish (*Sepia officinalis*).

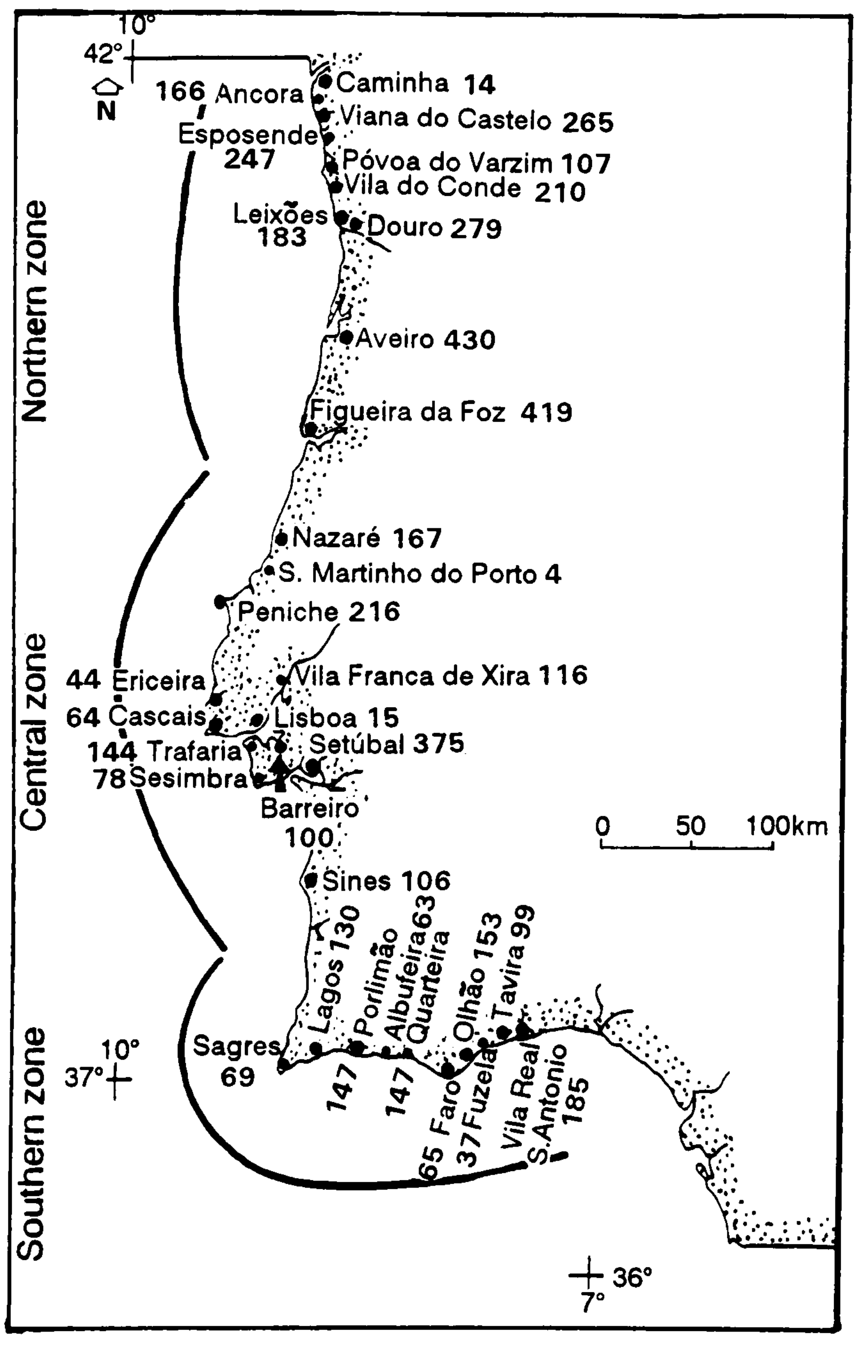

Fig. 6. Number of gillnet licenses in 1991.

Area of operation

Anchored gillnets can only be set out if at least 0.25 n.miles from the coast. Between 0.25 and 1.0 n.miles, only boats >5GRT or <10m may fish with anchored gillnets. Within 1–2 n.miles from the coast any boat may operate provided they use their nets in waters at least 20m deep.

Vessels and crew

Boats operating with gillnets are built mostly of wood and are unable to keep the catch for long periods on board. The composition of the Portuguese gillnet fleet in 1989 is shown in Table 14.

Table 14

The Portuguese gillnet fleet in 1989 (Cardador, pers. comm.)

Area	Boats	Power (Kw)	Length (m)	GRT
Northern zone	913	75.64	10.32	15.25
Central zone	1,422	63.89	9.17	14.26
Southern zone	994	44.75	8.97	10.55

Gear

Gillnets are among the most important fishing gear currently being used on the Portuguese coast and include both gillnets (*sensu strictu*) and trammel nets. Although gillnets maybe anchored or drifting, the use of drifting trammel nets is forbidden. Anchored gillnets are the most common at many fishing settlements in Portugal. Usually they are set out in fleets[1], while drifting gillnets are set out individually (Costa and Franca, 1985). The characteristics of gillnets vary with the harbours but they are generally made of synthetic monofilament, while trammel nets are made from synthetic multifilament. The minimum mesh sizes allowed for gillnets are shown in Table 15.

Table 15

Minimum gillnet mesh sizes allowed.

Type of net	Minimum mesh size (mm)
Gillnet bottom set	80
Trammel net bottom set	100 (at lint)
Drifting gillnet for small pelagic fish	36
Drifting gillnet for large pelagic fish	100

The use of bottom set gillnets with mesh sizes of 60–80mm is also allowed, but only in certain areas and periods. This applies also to trammel nets with lint mesh sizes of 80–100mm. Individual boats are not allowed to exceed a maximum length of gillnets depending on their GRT (Table 16). All nets or groups of nets must be set at least 0.25 n.miles apart and cannot exceed 4km, up to the maximum length allowed (Table 16). The maximum depth allowed is 10m for anchored and drifting gillnets and 2m for trammel nets.

[1] **Fleet** means any number of nets joined end to end and operated as a complete outfit.

Table 16

Maximum lengths of gillnets allowed per boat.

Type of net	GRT of vessel	Maximum length of net (m)
Gillnet bottom set	≤5: weather deck	1,500
	≤5: Awning deck	3,000
	5-9	4,000
	10-19	7,000
	20-39	10,000
	≥40	13,000
Trammel net bottom set	≤10GRT	1,500
	≥10GRT	3,000
Drifting gillnet for small pelagic fishes		300

Operations

Drifting gillnets are used by a comparatively large number of small fishing boats and are set seasonally, while anchored gillnets are mainly operated from larger ships and are set all year round. Nets are usually set for 6–24 hours. According to current legislation anchored gillnets may not be set for longer than 24 hours in consecutive 36 hour periods, except that (1) in the southern zone they may not be used for more than 12 hours in consecutive 24 hour periods and (2) if the mesh size is <100mm they may be set up to a maximum of 72 hours in consecutive 96 hour periods, provided they are in areas deeper than 300m (this latter provision also applies to trammel nets with lint mesh sizes >110mm).

Economics and history

There are no details readily available at this stage.

Total landings

There are no reliable data for gillnets since they are included with other artisanal gear in the official statistics. Nevertheless, data provided by Cardador (pers. comm.) indicate that total landings in 1989 were: northern zone – 15,714 tonnes; central zone – 12,915 tonnes; and southern zone – 5,776 tonnes. These figures may be overestimates, as many boats have licenses to operate more than one type of gear simultaneously.

Effort

In 1991, there were 4,844 boats licensed to use gillnets (Appendix Table 3).

Interactions with cetaceans

There are no accurate estimates of the total number of cetaceans killed in gillnets set along the Portuguese coast, mainly because fishermen do not report them as they fear legal sanctions from the authorities. Therefore, most marine mammals caught are simply thrown back into the sea. Trying to obtain detailed information on by-catches directly from the fishermen has proved to be difficult. Regular recording of cetacean by-catches has been attempted since 1977 and 132 cases of entanglement have been reported with 59 specimens killed in gillnets. The existing data indicate that incidental takes of common dolphins are substantial, particularly in the central zone. Other cetaceans regularly caught in these nets include the striped dolphin *S. coeruleoalba*, the harbour porpoise and the bottlenose dolphin *T. truncatus*.

The harbour porpoise is particularly vulnerable in the coastal areas around Aveiro where the continental shelf is wider, thus allowing a large number of gillnets to be set close to the shore. Data from early naturalists refer to the harbour porpoise as a very common species on the Portuguese coast (du Bocage, 1863; Nobre, 1895; Nobre, 1935), a situation that has changed drastically since then following a pattern similar to that of other Western European countries (Lindstedt and Lindstedt, 1989; IWC, 1991a; b). According to Teixeira (pers. comm.) most harbour porpoise sightings in recent years are of single animals or small groups. Furthermore, the stranding surveys initiated in 1977 suggest a substantial decrease in the abundance of *P. phocoena* relative to other species (Sequeira and Teixeira, 1988; 1990), and many of the stranded animals had net marks around the head and flippers.

Discussion

It seems possible that large numbers of cetaceans, particularly common dolphins and harbour porpoises, are dying in gillnets but lack of information does not allow an adequate assessment of the true mortality rates. As this mortality may be threatening some populations, both mortality and population size must be monitored as a matter of urgency.

In order to obtain accurate information on the numbers of cetaceans killed in gillnets, it may not be practical to use on-board observers, as the number of boats using gillnets is extremely high and gillnets may be often used to complement the main gear. Some useful information on by-catches may be obtained from questionnaire schemes run simultaneously with environmental awareness campaigns amongst fishermen. Such a campaign should lead to increased cooperation from fishermen and to all cetaceans being found dead in gillnets being reported to the scientific authorities.

In addition to assessing the impacts of gillnets, staff from the Fisheries and Environmental Departments must cooperate with fishermen to find out ways of reducing incidental captures. For example, the license assignment scheme could be used to control the number of boats allowed for each zone, especially in heavily fished areas where the impact of gillnets on cetaceans is most important. Further studies of gear technology and action on the modification and replacement of gillnets by other types of fishing gear should be developed, bearing in mind that longlines and traps may have comparatively low impacts on cetaceans and other marine fauna.

Gillnetting is currently one of the most important fishing activities on the Portuguese coast, and makes an important contribution to income. It is thus extremely important that fishermen are involved and consulted at all stages about any proposed modifications to reduce the negative impact of their activities on cetaceans. This should be seen as the best way to ensure better law enforcement and the avoidance of unnecessary social clashes.

CONCLUSIONS AND RECOMMENDATIONS

Although it is known that some cetaceans are caught during fishing operations, detailed information on the incidental mortality of marine mammals in Portuguese waters is still lacking. More than half of these deaths are probably caused through entanglement in gillnets, with trawl incidents accounting for only a few tens of specimens killed per year. The impact of incidental mortalites upon the relevant cetacean populations is unknown. Urgent assessments are needed, including detailed studies on gear technology and estimates of abundance and population trends for all the species on the Portuguese coast.

In order to assess these mortalities and to reduce their impact on the population of cetaceans, it is recommended that:

(1) accurate information on current takes of cetaceans must be collected for all the fisheries operating in the Portuguese EEZ – fisheries causing high levels of mortality should be monitored continuously, through on-board observer programmes;
(2) the numbers and distribution of gillnets currently used on the Portuguese coast must be monitored and scientific staff from the Fisheries and Environmental Departments must cooperate with the fishermen involved to develop programmes of gear modification and the replacement of gillnets by other types of fishing gear in the most critical areas;
(3) studies must be developed for those species most affected by gillnets (including the harbour porpoise and the common dolphin) that include identification of stocks, assessment of abundance, seasonal distribution, population size and current trends.

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APPENDIX 1

Appendix Table 1(a)

Number of boats in the Portuguese fishing fleet by GRT classes (Duarte, 1990).

GRT	Local No. GRT (sum) Kw (sum)	Coastal No. GRT (sum) Kw (sum)	Distant water No. GRT (sum) Kw (sum)	GRT	Local No. GRT (sum) Kw (sum)	Coastal No. GRT (sum) Kw (sum)	Distant water No. GRT (sum) Kw (sum)
0-1.9	5,051 3,492 8,996			50-99.9		189 12,644 50,911	
1-1.9	4,899 6,690 19,986	11 20 166		100-249.9		174 26,877 93,835	7 1,345 3,529
2-4.9	1,611 4,784 21,002	16 54 351		250-499.9		2 513 1,914	38 14,612 28,056
5-9.9	367 2,364 11,252	225 1,784 9,675		500-999.9		2 1,359 1,191	14 10,699 13,317
10-24.9	6 66 217	573 9,179 45,705		> 1000			44 63,889 74,703
25-49.9		386 13,105 63,409		TOTAL	11,934 17,396 59,156	1,578 66,535 217,158	103 90,515 119,60

Appendix Table 1(b)

Number of boats in the Portuguese fishing fleet by age classes (Duarte, 1990).

	Local	Coastal	Distant water		Local	Coastal	Distant water
0-5 years				**16-20 years**			
No.	297	104	10	No.	792	126	9
GRT	521	6,708	5,001	GRT	996	8,032	15,980
Kw	2,694	24,040	12,457	Kw	35,89	29,692	20,253
6-10 years				**>20 years**			
No.	1,242	194	14	No.	7,686	949	73
GRT	1,997	10,240	21	GRT	11,196	32,795	61,811
Kw	9,051	45,017	100	Kw	33,580	130,357	72,287
11-15 years							
No.	1,917	205	7	Total	11,934	1,578	103
GRT	2,686	8,760	6,023		17,396	66,535	90,515
Kw	10,243	38,072	9,851		59,156	267,157	119,606

Appendix Table 2

Number of fishermen registered in 1982-88 (GEPP, 1990).

Fleet	1982		1983		1984		1985		1986		1987		1988	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Local fisheries	11,664	37.04	12,349	37.03	12,352	36.36	11,961	36.36	12,761	36.72	11,777	33.06	13,526	36.84
Northern zone	5,448	46.71	6,231	50.46	6,058	49.04	5,884	49.19	5,996	46.99	3,712	31.52	5,985	44.25
Central zone	4,343	37.23	3,878	31.40	3,882	31.43	3,520	29.43	3,893	30.51	4,785	40.63	3,914	28.94
Southern zone	1,873	16.06	2,240	18.14	2,412	19.53	2,557	21.38	2,872	22.51	3,280	27.85	3,627	26.82
Coastal fisheries	17,044	53.13	18,047	54.11	19,021	56.00	18,432	56.02	19,736	56.80	21,244	59.63	20,631	56.20
Northern zone	6,002	35.21	8,818	48.86	6,834	35.93	6,638	36.01	7,003	35.64	6,353	29.90	7,246	35.12
Central zone	6,152	36.09	6,046	33.50	7,340	38.59	6,656	36.11	7,154	36.25	7,918	37.27	7,102	34.42
Southern zone	4,890	28.69	3,183	17.64	4,847	25.48	5,138	27.88	5,549	28.12	6,973	32.82	6,283	30.45
Distant water fisheries	2,781	8.83	2,957	8.87	2,596	7.64	2,507	7.62	2,251	6.48	2,605	7.31	2,555	6.96
Northern zone	2,016	72.49	2,566	86.78	2,345	90.33	2,278	90.87	1,968	87.43	279	10.71	2,288	42.27
Central zone	714	25.67	354	11.97	242	9.32	219	8.74	269	11.95	2,326	89.29	267	30.73
Southern zone	51	1.83	37	1.25	9	0.35	10	0.40	14	0.62	0	0.00	0	26.99
TOTAL	31,489		33,353		33,969		32,900		34,748		35,626		36,712	
Northern zone	13,466	42.76	17,615	52.81	15,237	44.86	14,800	44.98	14,997	43.16	10,344	29.03	15,519	42.27
Central zone	11,209	35.60	10,278	30.82	11,464	33.75	10,395	31.60	11,316	32.57	15,029	42.19	11,283	30.73
Southern zone	6,814	21.64	5,460	16.37	7,268	21.40	7,705	23.42	8,435	24.27	10,253	28.78	9,910	26.99

Appendix Table 3

Number of fishing liecnses for different types of gear in mainland Portugal in 1991.

		Trawls*		Traps			
Harbour	Seine nets	Bottom	Pelagic	Baskets	Pots	Longlines	Gillnets
Northern							
Caminha				10		73	14
Ancora				32		91	166
Viana do Castelo	1	47		109		315	265
Esposende				111		125	247
Póvoa do Varzim	3			68		193	107
Vila do Conde	4			54		200	210
Leixões	19	11		15		173	183
Douro	12			29		252	279
Aveiro	8	55	6	73		664	430
Central							
Figueira da Foz	4	49		4		414	419
Nazaré	5	4		18		288	167
São Martinho				36		88	4
Peniche	14	4		242	1	854	216
Ericeira		1		49		68	44
Cascais				79		132	64
Lisboa		47	1	22		144	15
Vila Franca Xira		1		10		197	116
Barreiro				9		233	100
Trafaria				163	8	267	144
Sesimbra	10			30	24	521	78
Setúbal	14	5	1	13	11	763	375
Sines	4			7	1	410	106
Southern							
Sagres	3			82	20	275	69
Lagos	8			63	80	287	130
Portimão	14	10		127	41	780	147
Albufeira				10	42	140	63
Quarteira	15			27	50	166	147
Faro	7	1		34	39	391	65
Olhão	7	13		22	34	460	153
Fuzeta	4			39	75	283	37
Tavira	13	1		68	92	456	99
V. Real S. António	10	26		15	28	352	185
Total	179	275	8	1,670	546	10,056	4,844
%	1.02	1.56	0.04	9.50	3.11	57.21	27.56

* Includes the fleet operating in CECAF, ICSEAF and NAFO areas.

Appendix Table 4(a)

Cod end minimum mesh size for trawls.

Minimum mesh size (mm)	Target species allowed	Minimum percentage of target species	Maximum percentage of protected species allowed
65	All	-	100
Adjacent to mainland			
(a) 55	Norway lobster (*Nephrops norvegicus*)	30 (b)	60 (including 30 of hake) (c)
	Deepwater pink shrimp (*Parapenaeus longirostris*) Red shrimp (*Aristeus antennatus*) and Giant red shrimp (*Aristaeomorpha foliacea*)	30	50
40	Blue whiting (*Micromesistius poutassou*) Mackerel (*Scomber scombrus*) Spanish mackerel (*S. japonicus*) Herring (*Clupea harengus*)	50	10
20	Sardine (*Sardina pilchardus*) Eel (*Anguilla anguilla*)	50	10
16	Sprat (*Clupea spratus*) Anchovy (*Engraulis encrasicholus*) Sandeels (Ammodytidae)	50	10
25	Snipe fish (*Macroramphosus* spp.)	85	5
Adjacent mainland east of Cape Sta. Maria			
40	All but the protected species listed in Appendix Table 4(b)	90	10

(a) Norway lobster may be captured with selective trawl nets. This type of gear must have an upper cod end with 65mm and a lower cod end with 55mm minimum mesh sizes, separated by an horizontal panel. Under these circumstances, the maximum percentage of protected species allowed is 100%.
(b) 25% between 1 January and 31 March.
(c) This percentage is estimated only after the third haul of the trawl net.

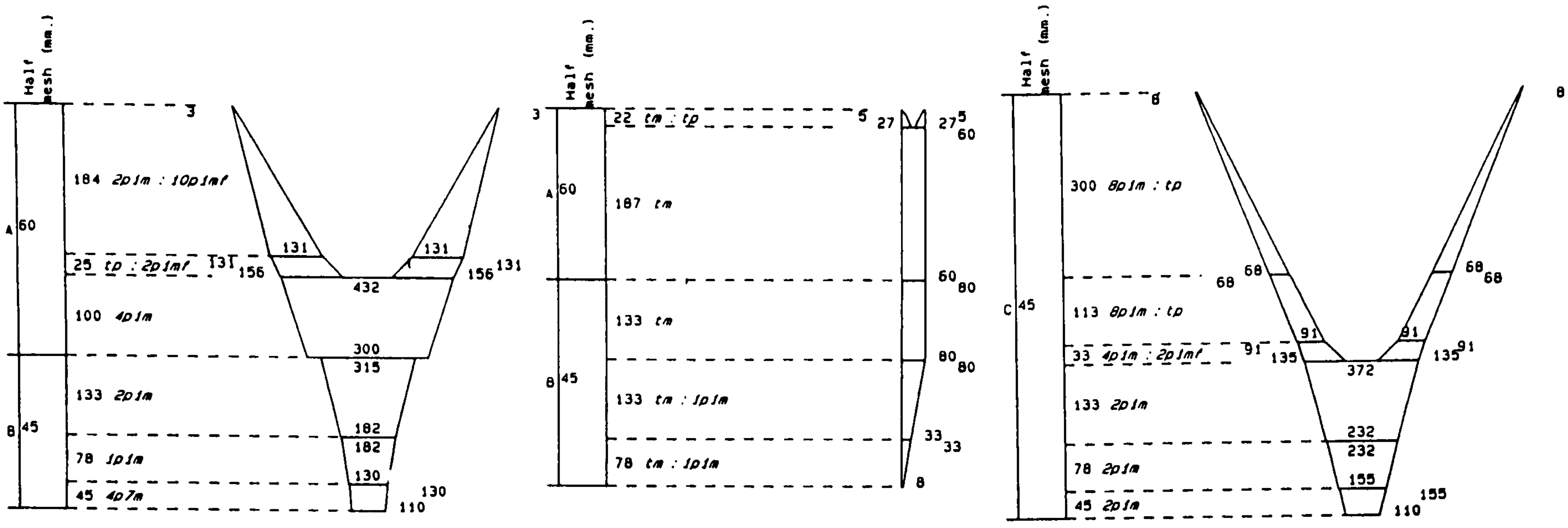
Appendix Table 4(b)

Minimum landing sizes for protected species in Portuguese waters. (a) To be established as defined under EC legislation.

Species	Minimum length (mm)	Species	Minimum length (mm)
Hake (*Merluccius merluccius*)	27	European ling (*Molva molva*)	63
Plaice (*Pleuronectes platessa*)	25	Allis shad and twaite shad (*Alosa* spp.)	30
Witch flounder (*Glyptocephalus cynoglossus*)	28	Mullet (*Mugil* spp.)	20
Lemon sole (*Microstumus kitt*)	25	Sea trout (*Salmo trutta*)	25
Common sole (*Solea vulgaris*)	24	European flounder (*Platichthys flesus*)	25
Turbot (*Psetta maxima*)	30	Anglerfish (*Lophius piscatorius*)	(a)
Brill (*Scophthalmus rhombus*)	30	European anglerfish (*Lophius budegassa*)	(a)
Megrins (*Lepidorhombus* spp.)	20	Cuttlefish (*Sepia* spp.)	(a)
Common dab (*Limanda limanda*)	23	European eel (*Anguilla anguilla*)	(a)
Saithe (*Pollachius virens*)	35	Little sole (*Dicologlossa cunesta*)	15
Spanish bream (*Pegellus bogaraveo*)	25	Blue ling (*Molva dyterygia*)	70
Red mullet (*Mullus surmuletus*)	15	Gilthead seabream (*Sparus aurata*)	19
Bass (*Dicentrarchus labrax*)	36	Black seabream (*Spondyliosoma cantharus*)	23
Conger eel (*Conger conger*)	58		

APPENDIX 2

SOME KINDS OF FISHING GEAR USED OFF MAINLAND PORTUGAL



I.N.I.P.	Ref: FGAV011	TRAWL 61.50m/83.50m	1 Boat
Instituto Nacional de Investigacao das Pescas	Date: JAN88	Type: Bottom 4 panels	550HP to 650HP
Copyright du logiciel: CENTRE NATIONAL DE LA MER/INFREMER		Species: Octopus	Twine area: 153.51 m2
		From: Euroredes	

Fig. 1. Trawl (61.55m/83.50m) for octopus. Type: bottom, four panels. Twine area: 153.51m^2.Boats: 550–650HP.

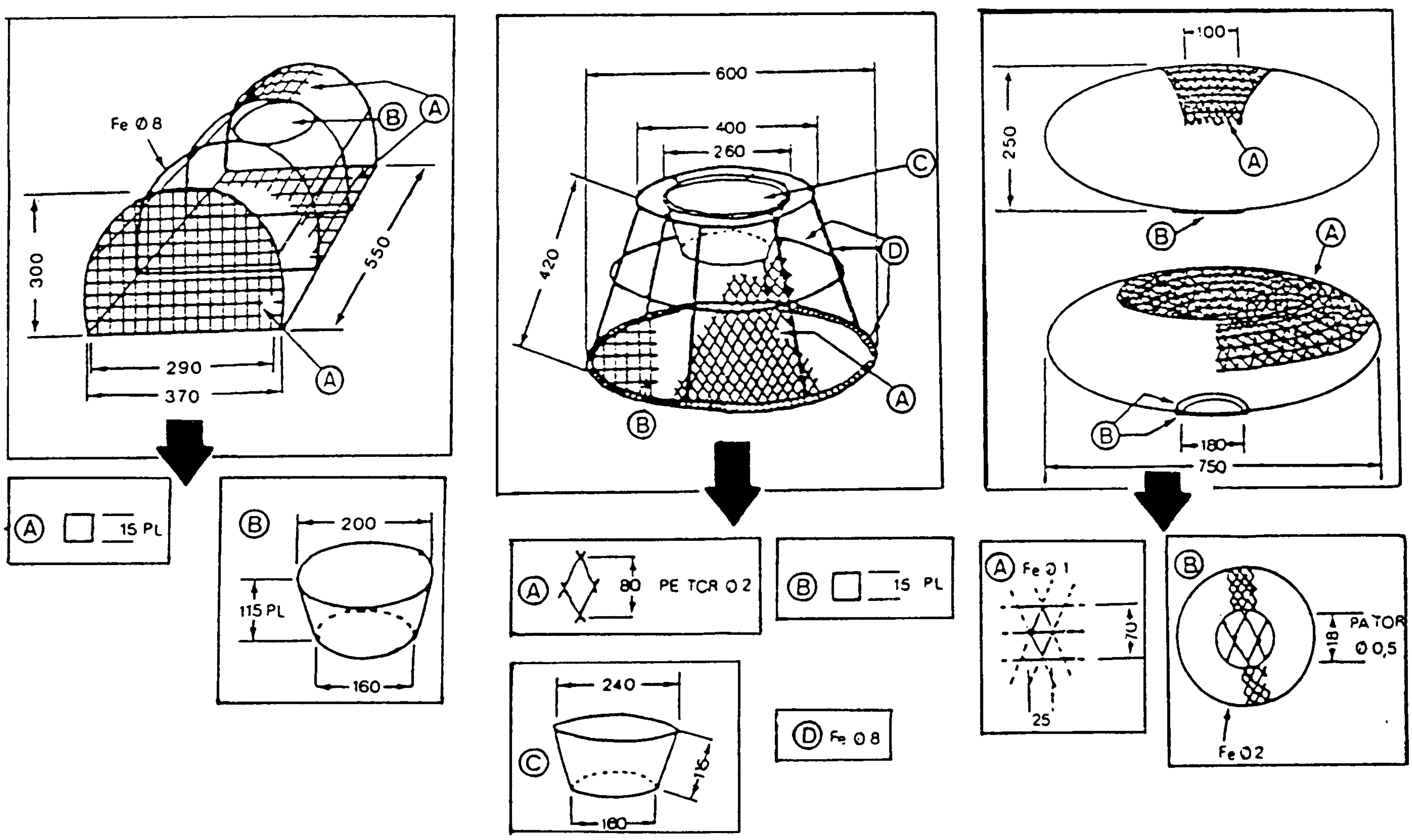


Fig. 2. Traps for octopus.

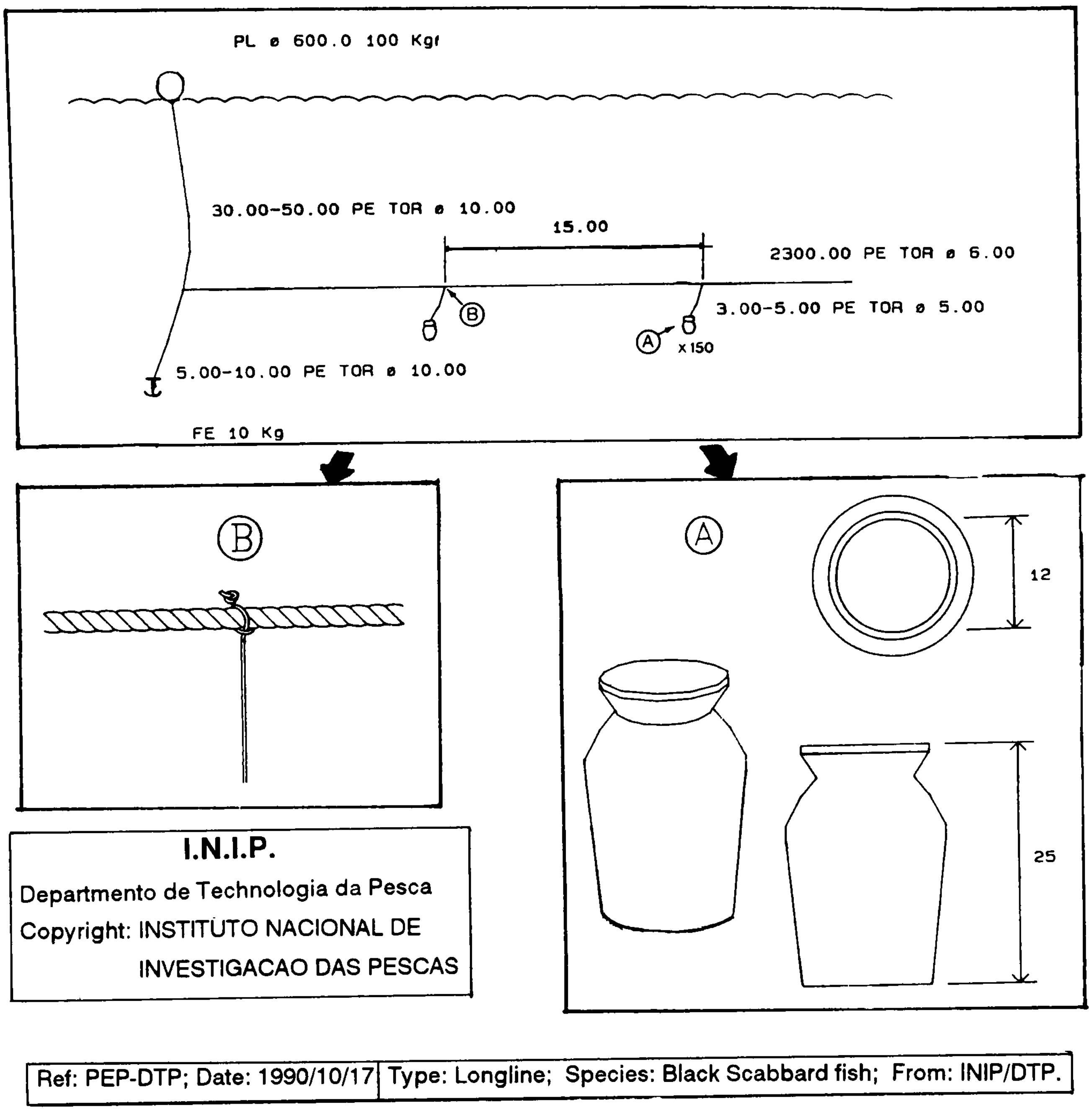


Fig. 3. Pots for octopus.

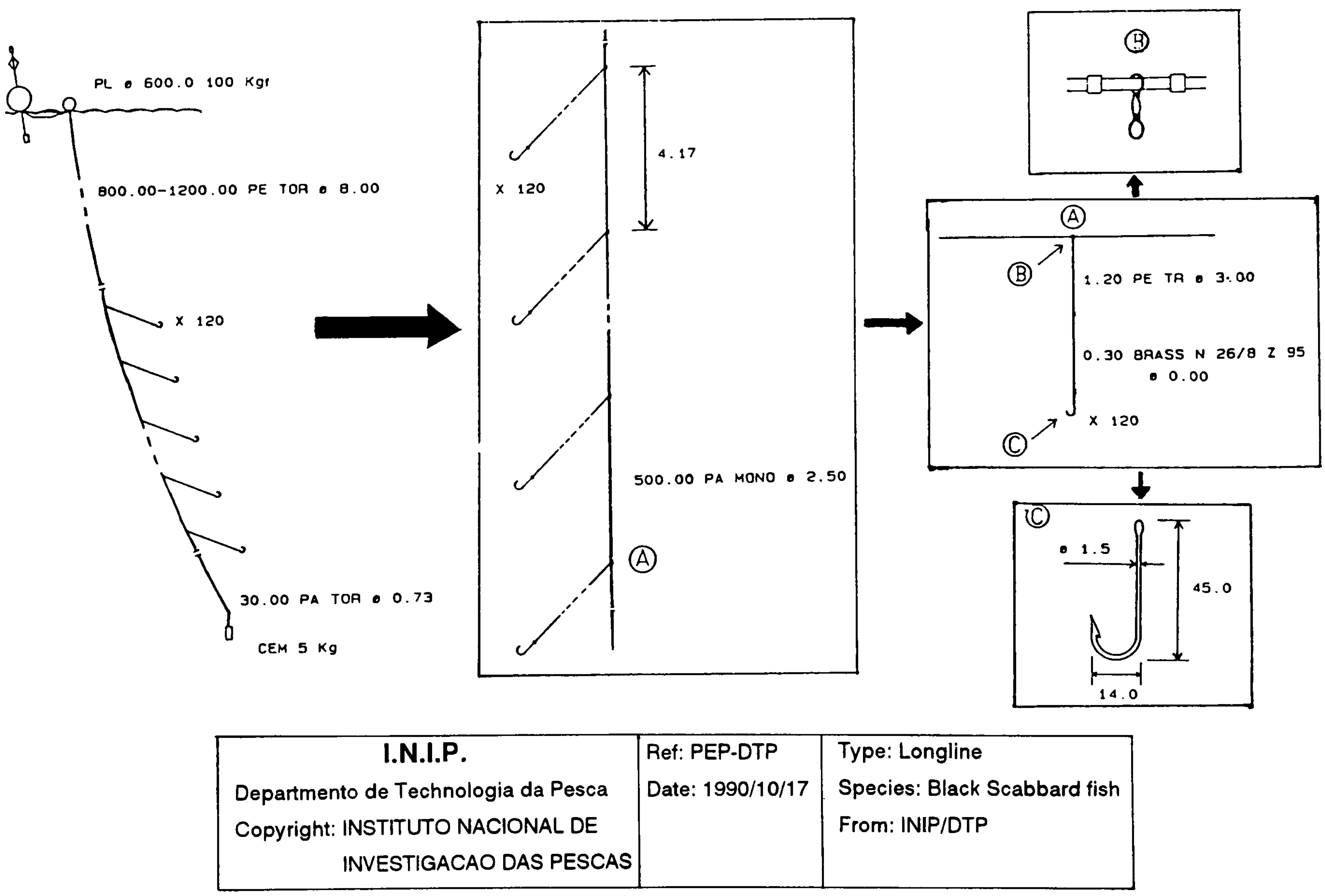


Fig. 4. Longline for black scabbard fish.

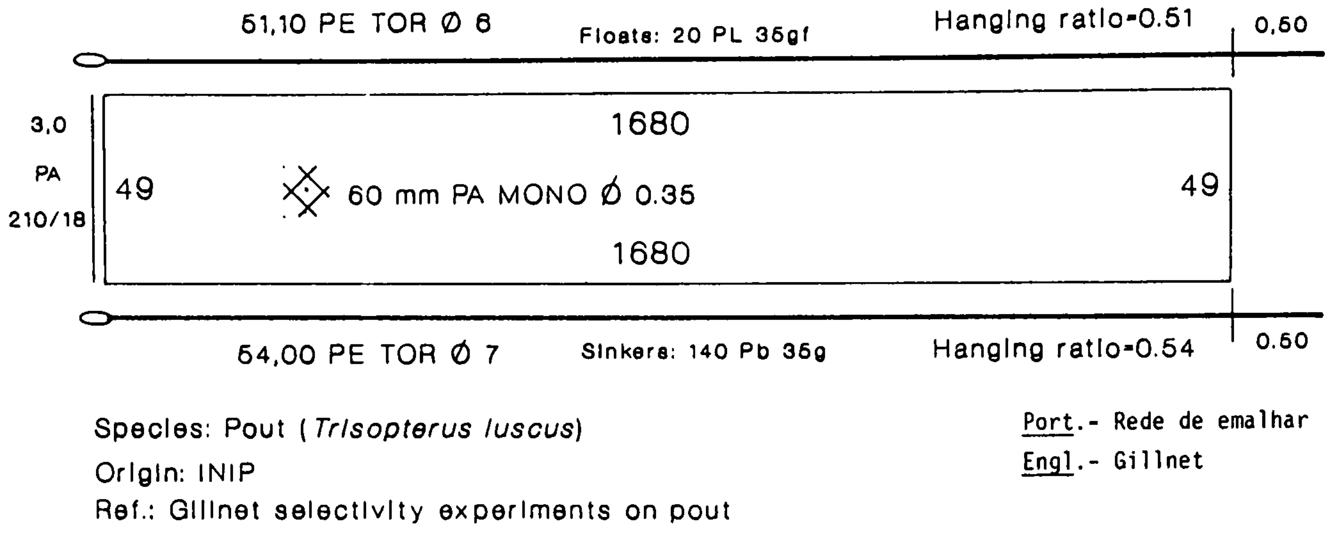


Fig. 5. Gilnet for pout.

SC/O90/G57

Incidental Catches of Harbour Porpoises (*Phocoena phocoena*) in Danish Waters, 1986–89

Carl Chr. Kinze

Zoological Museum, University of Copenhagen, Universitetsparken 15, DK-2100 Copenhagen Ø, Denmark

ABSTRACT

Incidental catches of harbour porpoises (*Phocoena phocoena*) were studied for the years 1986–89 by means of a salvage programme, an interview survey and a small scale reporting scheme. Data were obtained on 152 animals. Most were taken in large-mesh gillnets (mesh size 70–120mm) set for cod, turbot, lumpfish and plaice, throughout Danish waters. An estimated maximum take of 750 porpoises from a single harbour in northern Jutland (Hanstholm) indicates a considerable total take. The catch consists mainly of subadult animals. Behavioural reactions of the porpoises to presence of fishing gear are discussed and may indicate that the animals have a capability of learning to avoid net entanglement.

KEYWORDS: INCIDENTAL CAPTURE; HARBOUR PORPOISE; BEHAVIOUR; FISHERIES; NORTH ATLANTIC

INTRODUCTION

There have been bycatches of harbour porpoises in nets in Danish waters since at least the 19th century (Melchior, 1834; Tauber, 1892). They were formerly of minor importance compared to a directed fishery that operated at several sites (see review by Kinze, 1994). The directed catch, which was estimated to be 97% of the total take (Tauber, op. cit.), ceased temporarily in 1892. It resumed during both world wars, in 1916–19 and 1941–44. Bycatches have occurred continuously throughout the period. Since the Second World War, the Baltic stock of the harbour porpoise has experienced a marked decline, and incidental catches in monofilament nets have been identified as a major threat to the population (Andersen, 1982).

Clausen and Andersen (1988) studied porpoises caught incidentally in Denmark during 1980–81. My studies began in 1986 (Kinze, 1987; 1989a). The aims of the present study were to determine (1) which fishing gear catches porpoises, (2) the sex and age distributions of the catches; (3) the timing of the catches relative to seasonal life history cycles of the porpoise and (4) to compare the findings with those of Clausen and Andersen (1988).

Although the Danish Fisheries Research Institute has recently (1993) carried out a survey to estimate cetacean bycatches, the results are preliminary (Larsen, 1995) and are discussed by Lowry and Teilmann (1994).

MATERIALS AND METHODS

Information on incidental catches was compiled from three sources: (1) a salvage programme to collect stranded and incidentally caught animals (run by the Zoological Museum of Copenhagen and yielding data on size, age, sex, date and type of fishing gear involved); (2) an interview survey at four fishing ports in western and northern Jutland (Hvide Sande, Thorsminde, Thyborøn and Hanstholm, Fig. 1) providing information on fishing gear and rough estimates of take; and (3) a small scale reporting scheme involving one vessel (from Hanstholm) and giving exact information on incidental catches.

Information on the Clausen and Andersen results came from their (1988) paper and their raw data in the archives of the Zoological Museum.

RESULTS

Numbers and season

Records of 152 incidental catches were compiled. The salvage programme collected 94 incidentally caught specimens between January 1986 and December 1989. The single-vessel survey out of Hanstholm recorded an incidental catch of 58 porpoises between April 1988 and August 1989 (47 during the one-year period May 1988 – April 1989). Complete data on fishing effort were not available, but the catches seemed to occur year round, with the possible exception of the winter months December – February. The salvage programme collected the bulk of the specimens during the spring quarter (March-May), while the single-vessel survey recorded greater numbers taken during the summer months, especially in August (Table 1).

Table 1

Incidental catches of harbour porpoises by months.

Month	Collected 1986/89	Special survey	Collected 1980/81
January	2	0	2
February	1	0	1
March	13	0	-
April	25	8	-
May	8	3	-
June	7	14	-
July	10	7	-
August	5	26	2
September	6	0	42
October	9	0	30
November	7	0	59
December	1	0	13
Total	94	58	149

Sex and age distributions

Of the 94 specimens collected in the salvage programme, 52 were males. Of 55 specimens of known sex recorded in the single-vessel survey, 34 were males. Thus males made up 57.7% of the catches of known sex. Age was determined for the specimens from the salvage programme; in this sample there was a preponderance of immature animals (76.5% less than 3 years old, Fig. 2).

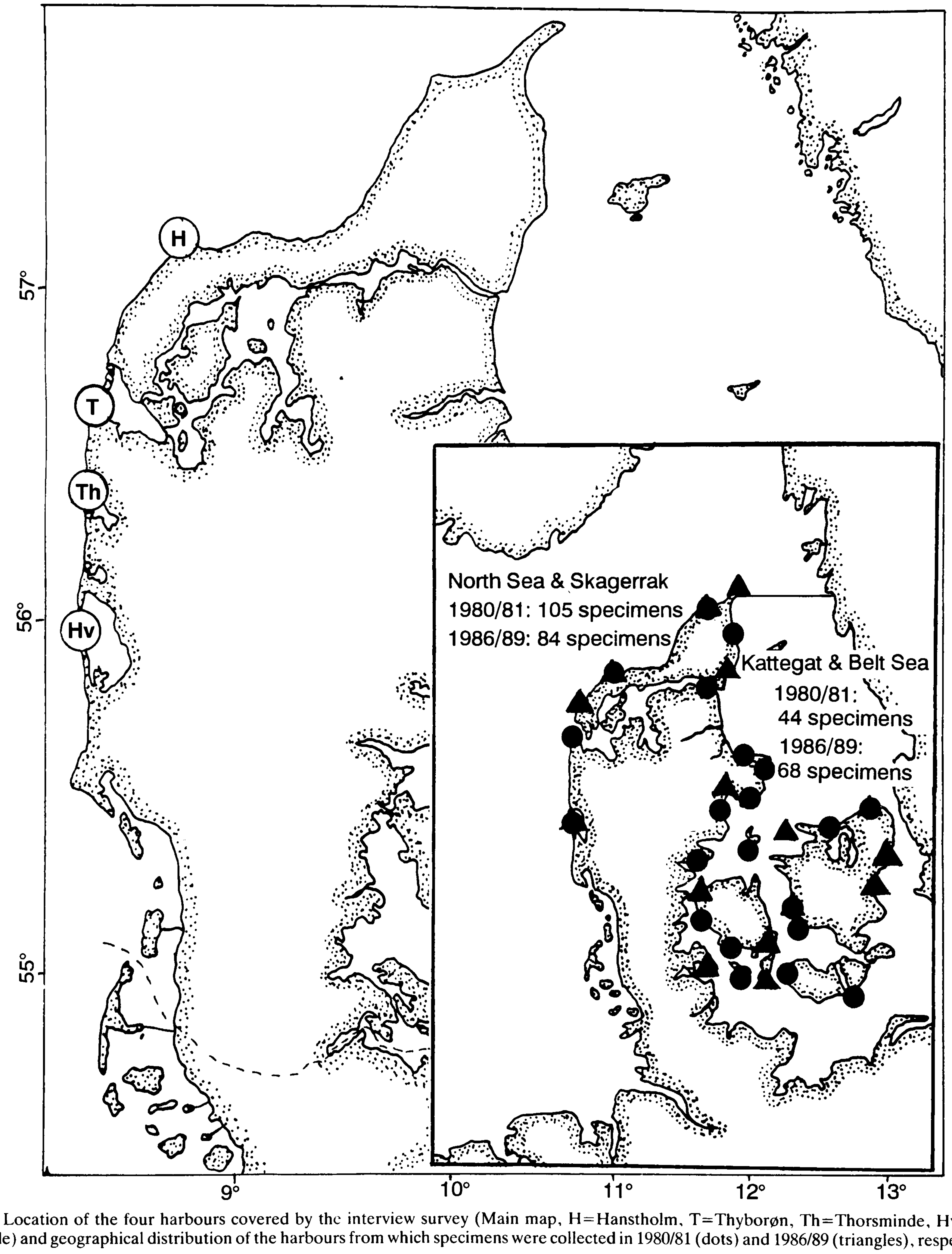


Fig. 1. Location of the four harbours covered by the interview survey (Main map, H=Hanstholm, T=Thyborøn, Th=Thorsminde, Hv=Hvide Sande) and geographical distribution of the harbours from which specimens were collected in 1980/81 (dots) and 1986/89 (triangles), respectively.

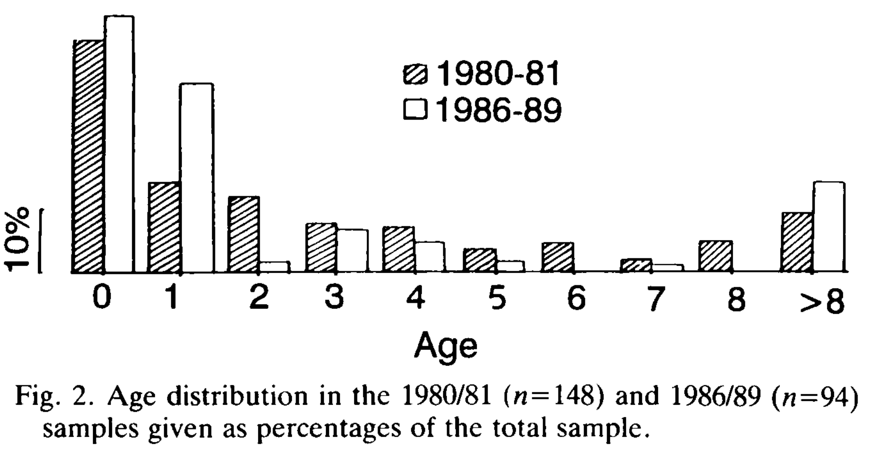


Fig. 2. Age distribution in the 1980/81 (n=148) and 1986/89 (n=94) samples given as percentages of the total sample.

Fishing gear

Of 152 animals recorded from the salvage programme and in the single-vessel survey, 147 were caught in large-mesh gillnets of 50–135mm mesh (Table 2). These nets were targeted on turbot (mesh size 110–135mm), lumpfish (70–120mm), plaice (65–90mm) and cod (50–85mm). The collected specimens nearly all came from cod and lumpfish nets. Incidental catches in cod nets occurred in all Danish waters during all or most of the year, while lumpfish nets caught porpoises only in Danish inner waters in the spring.

The interview survey revealed that in North Sea waters, incidental catches occurred mainly in cod nets (50% of the 'yes' answers) and turbot nets (33%) and to a lesser extent in plaice nets (17%). The single-vessel survey off Hanstholm documented a take in turbot nets. Only five of the collected specimens were not taken in gillnets. Of these, four were taken in trawls (Table 2). None were reported taken in trawls in the interview survey; 13 of 15 'no' answers were by trawlermen.

Table 2

Distribution of incidental catches by fishing gear.

Gear	1986/89	%	1980/81	%
Gillnets	89	95	111	75
Cod	22		90	
Lumpfish	34			
Plaice	11		21	
Other Flatfish	3			
Salmon	3			
Unspecified	16			
Trawls	4	5	28	19
Other	1		10	6
Total	94		149	

Size of the catch

Interviews with fishermen yielded the following rough estimates:

Maximum reported catch per vessel per season – 100–200
Maximum reported catch per cruise – 50
Maximum reported catch per day – 25
Maximum reported catch per net set – 8

The monitored vessel out of Hansholm caught 47 porpoises during a one-year period. There are about 15 vessels fishing with the same gear out of Hansholm. If an annual take per boat of about 50 porpoises is assumed, this means that the annual take for this port alone can be roughly estimated at about 750 animals.

Comparison with the 1980/81 data set

Clausen and Andersen (1988) reported on specimens collected from September to February, while the present study was based on specimens collected year round (1986–89). The 1980/81 sample included 105 specimens from the northern North Sea and the Skagerrak and 44 from Danish inner waters; for the present study the figures were 84 and 68, respectively (Fig. 1). In both samples there were more males than females. The age distributions were also similar, with age classes 0–2 accounting for 62.8% and 76.5% of the earlier and later samples, respectively (Fig. 2). The more recent sample had a higher proportion of age class 1 animals. The distribution of net types was also similar, with large-mesh cod nets accounting for the bulk of the catch (Table 2).

Clausen and Andersen's (1988) estimate of an annual incidental catch of 3,000 and my rough estimate of 750 for a single port agree in that they both indicate that large numbers may be taken.

DISCUSSION

Impacts

The results presented here and those of Clausen and Andersen (1988) indicate that large numbers of harbour porpoises have been taken incidentally in Danish waters for at least the period in question. However, the numerical estimates must be considered preliminary, because they are based on small samples of the fisheries. The porpoises are taken mainly on the bottom, in large-mesh gillnets. The entangled animals are predominantly immature, and males slightly outnumber females.

Since the present study has been completed, the Danish National Forest and Nature Agency has established a reporting system for incidental catches; 92 harbour porpoises were reported in 1991 and 119 in 1992 (Larsen, 1993: 1994). In addition, the Danish Fisheries Research Institute placed observers on 51 fishing trips in 1993, who reported a total of 117 harbour porpoises taken in cod and turbot nets (Larsen, 1995). Relatively crude extrapolation from this confirms the results of our study that several thousand harbour porpoises may be taken by Danish vessels each year (but see Lowry and Teilmann, 1994).

This apparently large incidental catch may be having a severe impact on the population(s). Unfortunately, our knowledge of the stock identity of harbour porpoises in this region is poor; it is thought likely that there may be several populations in the North and Baltic Seas (e.g. Kinze, 1985; 1990; Yurick and Gaskin, 1987; IWC, 1992). Similarly, there are few estimates of population size, apart from in the Lofoten-Barents Sea, the northern North Sea (Børge and Øien, 1994) and some Danish and German waters (Heide-Jørgensen *et al.*, 1993). Fortunately, this issue is being addressed and a multi-national survey in the North and Baltic Seas was carried out in summer 1994, although the results are not yet available.

Apart from the numbers caught, the age and sex compositions of the catch are important in assessing likely impact on populations. Certain life stages may be relatively more vulnerable to entanglement. The end of the weaning period (at eight months of age, according to Møhl-Hansen, 1954) and the onset of the lumpfish fisheries may co-occur in Danish waters; this may lead to frequent entanglements of newly weaned, inexperienced calves. It may also put accompanying adult females at risk if they try to rescue their calves. The 1986/89 data set includes as least one case of a presumed cow-calf pair caught in the same net.

The possibility of higher catches of specific age classes due to age-related segregation must also be taken into account. Subadult males are thought to segregate from other age/sex classes in offshore Canadian waters (Gaskin and Blair, 1977) and may be caught incidently in disproportionate numbers. On the other hand, females frequenting more inshore shallow-water calving grounds may in effect avoid fishing operations during the calving season.

Entanglement

An early study of the echolocation abilities of the harbour porpoise found that it could not detect thin nylon monofilament threads (Møhl and Andersen, 1973). However, this study was conducted on captive animals in an artificial environment with conditions little resembling those in the wild. More recent work has shown that harbour porpoises and other species should be capable of detecting monofilament nets at a considerable distance and even under severe weather conditions (Au and Jones, 1991).

Even though monofilament nets are theoretically detectable by porpoises, the echo from fish in a net may mask the return from the monofilament webbing and therefore be dangerous to inexperienced animals. Pence (1986) found the knots in a net to give the best echo; therefore small-mesh nets (with more knots) should be more easily detected than large-mesh nets. Most incidentally entangled porpoises in Denmark are taken in large-mesh nets; the animals typically have 'mesh-marks' on the head.

As noted in IWC (1994) several modifications of gillnets have been attempted but have yielded inconclusive results. Silber (1989) tested net modifications on free-ranging harbour porpoises and found higher frequency of avoidance for the nets with the best passive acoustic properties but was unable to achieve complete deterrence. The position of the net in the water column has an influence on entanglement; for example Piatt and Nettleship (1987), who found off Newfoundland that most animals were caught at 10–20m while Lindstedt and Lindstedt (1989) found highest catches of harbour porpoises in Swedish waters at 20–60m. Virtually all Danish gillnets are set in water shallower than 60m; even bottom nets are well within the diving depth of the harbour porpoise (maximum dive time about six minutes and maximum depth about 80m – Gaskin *et al.*, 1974).

A feature of the data presented here is the high proportion of sub-adult animals. One explanation is that entanglement may be related to experience of the animals and their behaviour around gillnets. Although all age-classes may be attracted to gilled fish in the nets (Gaskin, 1984), younger, less-experienced adults may be more vulnerable to entanglement (i.e. the age structure of the catch may not be representative of the population). An alternative explanation may be that the large proportion of young animals in the catches reflects segregation and immigration of young animals from other areas. This does not seem likely, however, because size distributions are similar in neighboring waters of Sweden, Norway and Britain (Lindstedt and Lindstedt, 1989; A. Bjørge, pers. comm.; S. Northridge, pers. comm.). Ostensibly unselected samples taken in drive fisheries or shot at sea in Baltic and Greenland waters have a larger proportion of older porpoises (Møhl-Hansen, 1954; Hammond, 1987; Kinze, 1989b).

Changes in body length distribution over time have been detected in incidental catches in Canadian waters (Read and Gaskin, 1988); this might be accounted for by learning on the part of the porpoises. Initially a gillnet fishery there caught animals of all size classes. After 10 years, the relative numbers of smallest and largest animals had declined. All mammals have a pronounced ability to learn by experience (Ewer, 1968), and a process of learning to avoid nets or to avoid entanglement should be expected to occur in harbour porpoises as a response to exploitation. If the porpoises learn by experience, one might expect decline in relative frequency of the smallest calves (because they are being kept out of the nets by their mothers) and the the largest (oldest) animals (because they have learned to avoid the nets).

Some porpoises may learn to avoid nets through direct experience of entanglement with subsequent escape or release. Others may learn indirectly through hearing distress calls from entangled individuals (Amundin and Amundin, 1971). In addition, harbour porpoises have an acute sense of taste (Kuznetsov, 1979), and glandular secretions, urination, or defecation of entangled animals could deter the approach of conspecifics; this is thought to occur in white whales, *Delphinapterus leucas*, in the White Sea (Yablokov *et al.*, 1972).

Young mammals spend a relatively greater proportion of time in exploration than adults do (Ewer, 1968). Recent studies of behaviour of the harbour porpoise in Danish waters (Kinze, 1988; 1990) found that subadults approached a research vessel very readily, while adults, especially those accompanied by calves, kept their distance.

All types of fishing gear seemingly have sufficient acoustic return to make them detectable by harbour porpoises. However, some gear may exclude the possibility of learning on the part of the porpoises, either because they remove all the animals in the area, or because the fishing operation is very complex and unpredictable from the animal's perspective.

Pair trawls may be less selective than gillnets, because members of all age classes may by chance be in the path of the mouth of the net when the fishing vessel turns or when the net falls. This may account for differences in size distribution found in animals caught in cod nets and in trawls (Clausen and Andersen, 1988). However, such gear accounts for only a minor fraction of the total incidental catch.

CONCLUSION

Considerably more information is needed before the impact of the incidental catches in Danish waters can be assessed; the available data indicate that large numbers of harbour porpoises, mainly subadults are taken in Danish fishing gear, mostly in various types of gillnets. The existing monitoring and reporting systems need strengthening and the 1994 multi-national survey results should be examined in conjunction with further studies on stock identity.

ACKNOWLEDGEMENTS

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SC/O90/G34

A Review of the Passive Fishing Nets and Trap Fisheries in the Mediterranean Sea and of the Cetacean Bycatch

Antonio Di Natale

Aquastudio, via Trapani 6, 98121 Messina, Italy.

and

Giuseppe Notarbartolo-di-Sciara

Tethys Research Institute, Via G. Giusti 5, 20154 Milano, Italy

ABSTRACT

Cetacean mortality in passive fishing gear in the Mediterranean has not previously been the subject of a systematic study. Data on passive fishing nets and traps are here presented for the majority of the principal national Mediterranean fisheries, including geographic information, a description of vessels, crew, gear, operations, economics and history, total landings, effort, interaction with cetaceans and, in addition, occasional bycatches of the endangered monk seal. Although data on total bycatch, species composition and CPUE are lacking, it is well-known that cetaceans are incidentally caught in great numbers in fisheries in this region. Pelagic driftnets are responsible for the greatest proportion of the cetacean bycatch, although catches in coastal gillnets and traditional tuna traps also occur. Many of these fisheries are illegal but continuing. Recommendations for the conservation of cetaceans in the Mediterranean are made.

KEYWORDS: MEDITERRANEAN; INCIDENTAL CAPTURE; FISHERIES; MANAGEMENT; FIN WHALE; SPERM WHALE; MINKE WHALE; CUVIER'S BEAKED WHALE; PILOT WHALE - LONG-FINNED; RISSO'S DOLPHIN; STRIPED DOLPHIN; COMMON DOLPHIN; BOTTLENOSE DOLPHIN; ROUGH-TOOTHED DOLPHIN; KILLER WHALE; MONK SEAL

INTRODUCTION

Fishing is deeply rooted in the Mediterranean tradition and has formed an important component of local coastal economies since ancient times. As a consequence, the density of small-scale artisanal fishing operations in the Mediterranean is among the highest in the world (Northridge and Di Natale, 1991). Passive fishing nets are perhaps the most widespread gear used and this has led to the evolution of a large number of technological variants, sometimes extremely specialised and almost species-specific. This includes the use of pelagic driftnets for the capture of swordfish (*Xiphias gladius*), first recorded during the 2nd Century BC by the Roman historian Oppianus (Sisci, 1988).

Such high fishing pressure is inevitably a cause of conflict with marine mammals: one pinniped species, the almost extinct monk seal (*Monachus monachus*); and about 20 cetacean species. The most common cetaceans in the Mediterranean are: the fin whale *Balaenoptera physalus*, the sperm whale *Physeter macrocephalus*, Cuvier's beaked whale *Ziphius cavirostris*, the long-finned pilot whale *Globicephala melas*, Risso's dolphin *Grampus griseus*, the common dolphin *Delphinus delphis*, the striped dolphin *Stenella coeruleoalba* and the bottlenose dolphin *Tursiops truncatus* (Cagnolaro *et al.*, 1983; Di Natale, 1987). Apart from the recent survey to estimate the population size of striped dolphins in the western Mediterranean (Forcada *et al.*, 1994), little is known about their population size.

Of the many types of passive fishing nets used in the Mediterranean, the following are the most important in terms of their interactions with marine mammals: (1) bottom gillnets and trammels; (2) traditional tuna traps and (3) surface pelagic driftnets. Although interactions with these have directly and indirectly led to the near extinction of the monk seal (Ronald and Duguy, 1979), until a few decades ago cetaceans appear to have been little affected. This scenario was drastically changed after World War II mainly by two technological innovations; the use of synthetic net filaments and the introduction of power engines in fishing boats, which has enabled the development of large pelagic driftnet fleets.

PEOPLE CONTACTED

The following persons were contacted and provided information on national fisheries in Mediterranean waters: M. Balilli, D.E. Gaskin, F. Gorica, S. Memia, E. Hajderi (Albania); M. Adjal, G. Kadari, F. Zenasni (Algeria); M. Hadjichristophorou (Cyprus); A. Ezzat (Egypt); B. Lliorzou, J. Maigret (France); A. Aguilar (Gibraltar); E. Lefkathitou, S. Tselas, G. Tserpes, P. Megalofonou (Greece); A. Ben-Tuvia, M. Ben-Yami, M. Ton (Israel); N. Miyabe (Japan); N.K. El Kebir (Libya); L. Attard, J. Manduca, R. Sisci (Malta); J. Maigret (Monaco); A. Fahfuhi, A. Lamrini, A. Srour (Morocco); G. Plotoaga (Romania); A. Aguilar, J.L. Cort, J. Mejuto Garcia, J.M. de la Serna Ernst (Spain); K. Ben Mustafa, M. Fundun-Ktari, S. Najal, J. Zaouali (Tunisia); F. Aksiray, F. Altunel, M. Demir, M. Salih Celikkale, J. Tanyolac (Turkey); M. Ivashin, Y. Mikhalev, L. Popov, A. Rovnin, A. Yablokov (USSR); V. Alegria Hernandez (Croatia); R.C. Griffiths, J. Majkowski, M. Savini (FAO Fisheries Department); P. Miyake (ICCAT); J.C. Rey Salgado (EEC Direction General XIV).

LITERATURE REVIEW

Most of the available information concerning Mediterranean traditional tuna traps and surface pelagic driftnets is reported in ICCAT-SCRS[1] documents (Anon., 1990; 1993; In press). Coastal gillnet fisheries are poorly

[1] International Commission for the Conservation of Atlantic Tunas.

described and there have been no reviews updating the report of Dremière and Nédélec (1977). However, Di Natale *et al.* (1990) present an overview of all fishing activities in Italy, including traditional tuna traps, surface pelagic driftnets and coastal gillnets. This supplements the review of artisanal fishing gear, including gillnets, of Di Natale (1988). Although French Mediterranean artisanal fisheries were reviewed by Farrugio (1988), the information is incomplete. It is of concern that no regular monitoring or quantitative description of the environmental impact of passive fishing nets in the Mediterranean has been made (Northridge and Di Natale, 1991).

This lack of regular extensive monitoring is also true for the specific problem of the interactions between cetaceans and fisheries. Anecdotal evidence of cetacean incidental captures in fishing gear in the Mediterranean is contained in several stranding reports from France (e.g. Duguy, 1985; 1986; 1987; 1989) and from Italy (e.g. Anon., 1987; 1988a; 1989); early incidental catches are reported by Di Natale (1987), Mangano (1984), Mojo and Cavallaro (1972), Podestà and Magnaghi (1989); information was reviewed by Di Natale and Mangano (1982; 1983a; 1983b; 1983c) and Duguy *et al.* (1983). A summary of such incidents recorded along the Italian coasts between 1986 and 1989 is given by Notarbartolo-di-Sciara (1990). More recent, general reviews are provided by Scialabba (In press), Northridge and Di Natale (1991), Northridge *et al.* (1991) and Di Natale (1990b). Di Natale (1990a; b; 1992), Di Natale and Mangano (1990), Di Natale *et al.* (1993; In press; In press-a; b) explore in more detail the situation in Italy.

SYNOPSIS OF THE FISHERIES

Overview

The only Mediterranean countries that do not seem to have any fisheries in which passive nets cause cetacean mortality are Libya and Monaco.

Traditional tuna trap data are available for Italy and Tunisia; although Libyan and Croatian tuna traps exist, no cetacean accidental captures have been reported. Other coastal traps set for smaller pelagic schooling fishes are found in several Mediterranean countries (Italy, Romania, Turkey and ex-Yugoslavia), but there are no data on whether cetacean bycatches occur.

Pelagic driftnet data are reported here for Algeria, France, Greece, Italy, Malta, Morocco, Spain and Turkey. Albania*, Cyprus and ex-Yugoslavia presently do not have driftnet fleets.

The information on coastal gillnet fisheries provided by Dremière and Nédélec (1977) for Bulgaria, Cyprus, Egypt, France, Israel, Romania, Spain, Tunisia, Turkey and ex-Yugoslavia, is now obsolete. We were only able to obtain updated information for Algeria, France, Greece, Italy, Spain and Tunisia.

No recent information could be obtained for: Albania* (gillnets), Bulgaria (all fisheries), Cyprus (gillnets), Egypt (all fisheries), Gibraltar (all fisheries), Israel (all fisheries), Lebanon (all fisheries), Malta (gillnets), Morocco (gillnets and tuna traps), Romania (all fisheries), Spain (tuna traps), Syria (all fisheries), Tunisia (driftnets), Turkey

* It is believed that 'a few' boats have started to use driftnets in Albania after contact with Italian fishermen but no details are available.

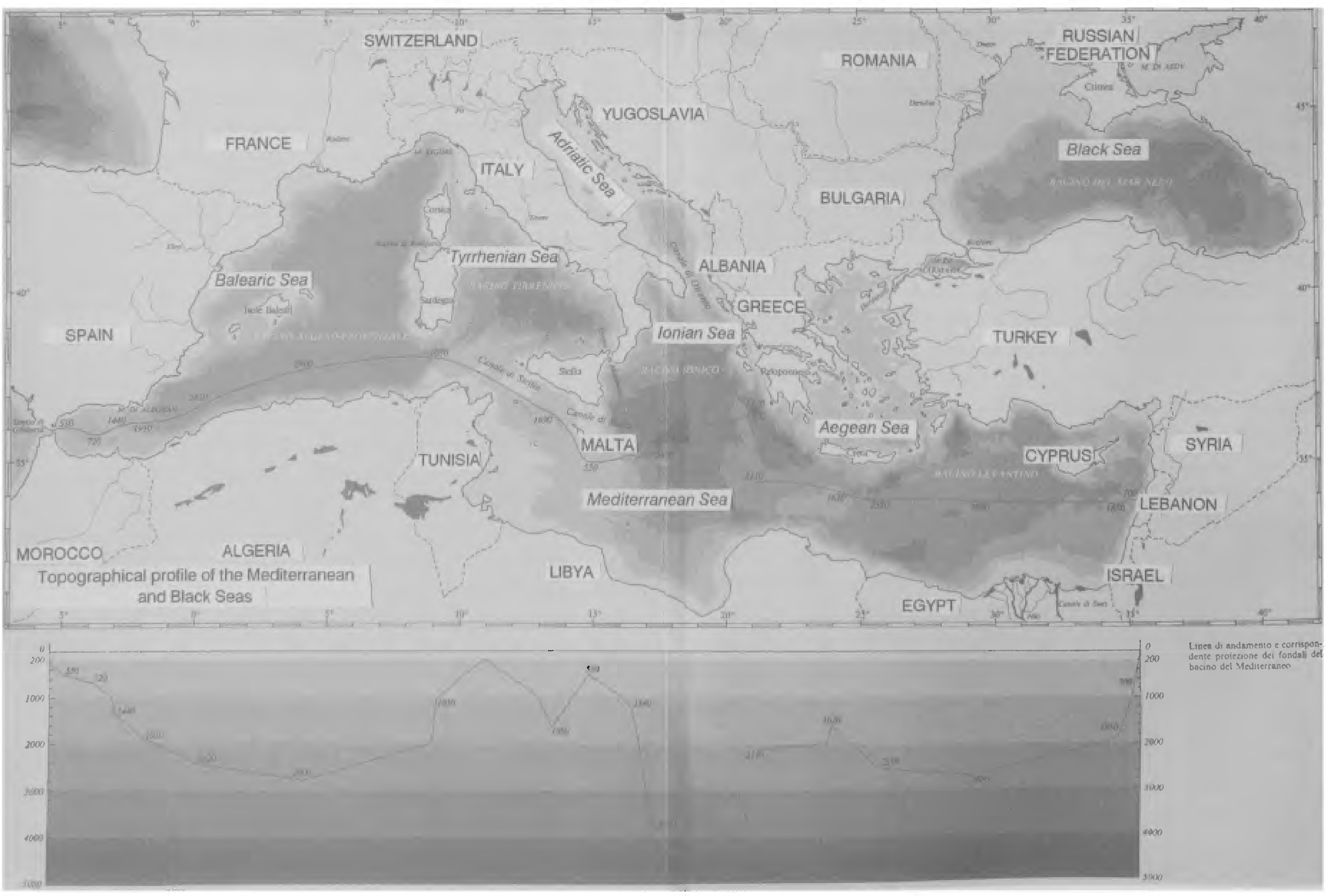

Fig. 1. Sea floor profile and topography of the Mediterranean and Black Seas.

(gillnets), USSR (all fisheries), and ex-Yugoslavia (gillnets and tuna traps). We suspect, however, that fishing activities in Albania, Egypt, Gibraltar, Lebanon and Syria are not important with respect to cetacean incidental captures.

To our knowledge, no driftnetting in the Mediterranean is being carried out by countries from outside the region (Anon., 1990; 1993).

The following fisheries are described in more detail: (A) Algerian gillnet; (B) Algerian surface pelagic driftnet; (C) French Mediterranean gillnet; (D) French Mediterranean surface pelagic driftnet; (E) Greek gillnet; (F) Greek surface pelagic driftnet; (G) Italian gillnet; (H) Italian surface large pelagic driftnet; (I) Italian surface small pelagic driftnet; (J) Italian traditional tuna trap; (K) Maltese surface pelagic driftnet; (L) Moroccan Mediterranean surface pelagic driftnet; (M) Spanish Mediterranean gillnet; (N) Spanish Mediterranean surface pelagic driftnet; (O) Tunisian gillnet; (P) Tunisian traditional tuna trap; (Q) Turkish surface pelagic driftnet.

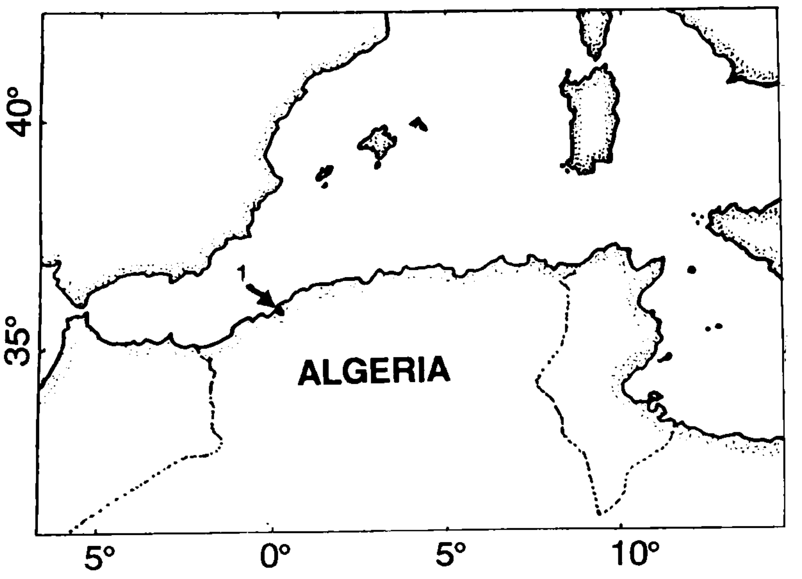

Fig. 2. Position of the Algerian harbour in which the experimental driftnet boat was located. (1) Oran.

(A) Algerian gillnet fishery

There is relatively little information for this fishery, with respect to ports, vessels, operation, catch and effort data or economics. The available information is summarised below.

Target species

European hake (*Merluccius merluccius*), common sole (*Solea vulgaris*) and other benthic species are taken.

Area of operation

The fishery is carried out in Algerian coastal areas, but not within 3 n.miles of the coast.

Gear

Although no detailed information is available, the gillnets used have a stretched mesh size from 20–30mm to 350mm.

Interactions with marine mammals

One or two dolphins (species not specified) are reported as 'commonly' taken but there are no estimates of the annual bycatch. An awareness campaign is being carried out by CERP (Centre d'Etudes de Recherche Appliquée et de Documentation pour la Pêche et l'Aquaculture, Bou-Ismail), because cetaceans are protected by the Algerian law. Occasionally a monk seal is entangled in gillnets (perhaps one per year).

(B) Algerian surface pelagic driftnet fishery (experimental)

Ports/operation area

The fishery is centred near Oran (1°16'W, 35°04'N; Fig. 2) and operates in coastal waters.

Target species

Swordfish (*Xiphias gladius*) and tuna-like fishes are targetted.

Vessels and crew

A wooden cabin vessel, 9m long, with a 10 tonne displacement, was used in an experimental fishery in 1990 with a crew of four Algerian fishermen. Since then, the fishery has expanded to ten vessels.

Gear

In the experimental fishery, a multifilament driftnet with a stretched mesh size of 37cm was used. The float size was 40cm and the spaces between floats were 5m. Beacons consisted of battery operated lamps and radio transmitters. The total net length was 2km and the net depth was 3m. It is assumed that the vessels now operating use similar gear.

Operations

Trips last from 12–15 hours. The net is set in waters less than 40m deep, usually during the night (0100–0200hrs) and retrieved the next morning after 8–9 hours soaking time.

Economics and history

The catch is typically kept fresh and landed daily; ex-vessel prices are about 10 US$/kg. The fish is sold fresh on the domestic market. A total annual landing of 400kg is reported from the experimental fishery. The expanded fishery is still relatively small.

Interactions with cetaceans

Although there are no official data, the common dolphin is potentially at risk of capture. Algerian law forbids the capture, trade and transportation of cetaceans.

This experimental driftnet fishery operated for a short time under the control of Algerian fishery scientists from 1990. Moderate commercial development of driftnetting followed and up to ten boats.

(C) French Mediterranean gillnet fishery

Ports/operation area

Vessels operate from ports found all along the French Mediterranean coasts, both on the mainland and in Corsica. All boats operate within the French Mediterranean coastal area, approximately within 18km of the coast.

Target species

A large number of benthic and pelagic species are targetted.

Vessels and crew

The fleet is heterogeneous. Boats have a wooden or fibreglass hull and range in length between 3 and 14m (Fig. 3c). There are no official data concerning the total number of vessels but it is thought that over 1,000 boats are in operation, crewed by 1–3 French fishermen, sometimes helped by Maghrebian fishermen.

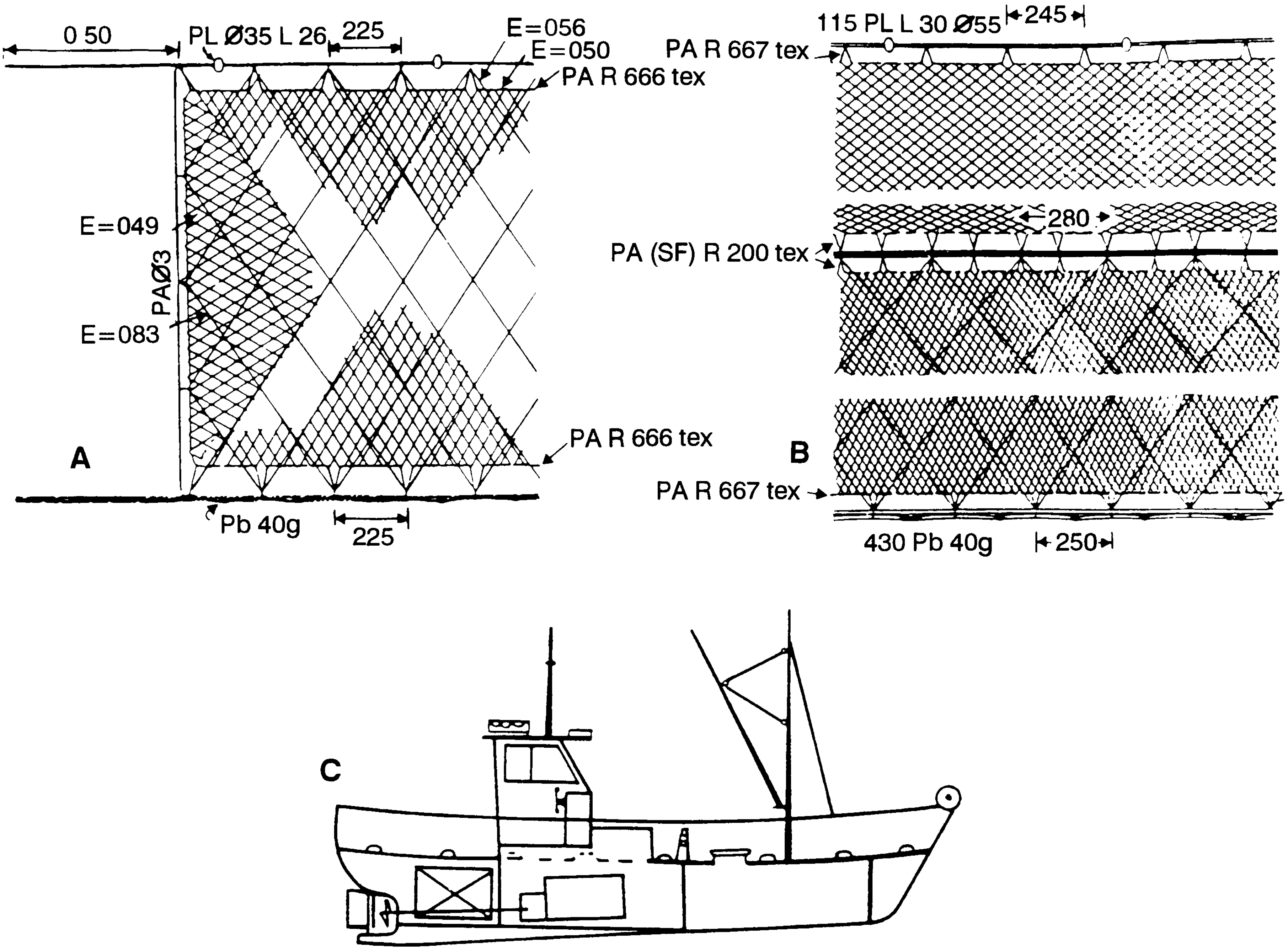

Fig. 3. (A) Typical technical features of the trammel gillnet (*trémail*) used in the French Mediterranean fishery; (B) technical features of a combined gillnet (trammel + gillnet) (*filet combinés*) used in French Mediterranean fishery; (C) typical French cabin boat, 11m long, 100hp, wooden or plastic, used in Mediterranean coastal gillnet fishery. (Drawings by Farrugio, 1988).

Gear

Trammels follow a traditional design, as in most Mediterranean countries. Combined nets are also used (Figs 3a and 3b). Monofilament and multifilament nylon or polyamide gillnets are used with a stretched mesh size of 25–80mm and a maximum length of 50m per panel. Net depth is reportedly 1.2m. Each boat typically uses 10–40 panels, but some reach a maximum of 50–200 panels.

Operations

Trammels and combined trammels are generally set during the night and retrieved the following morning. By contrast, the set gillnets used in the hake fishery are set in the morning and retrieved during the day. No other information is available.

Economics and history

Fish is normally kept fresh, landed daily and sold in the domestic market. No data on total landings or effort are available.

Interaction with cetaceans

Anecdotal reports concerning four striped dolphins, one common dolphin, four bottlenose dolphins, four Risso's dolphins and two minke whales (*Balaenoptera acutorostrata*) are given by Duguy *et al.* (1983). Two rough-toothed dolphins (*Steno bredanensis*) have been reported by Granier (1970) and Duguy and Cyrus (1973). Further information from the French Mediterranean stranding record is given by Duguy (e.g. 1985; 1986; 1987; 1989). Cetaceans are protected by French law.

Comment

This fishery is among the most important in the French Mediterranean but it is not yet adequately monitored.

(D) French Mediterranean surface pelagic driftnet fishery

Ports/operation area

Ports on the mainland coast (Gulf of Lions) and Corsica are used (Fig. 4) and the fishery is carried out in adjacent waters.

Target species

The swordfish (*Xiphias galdius*), albacore (*Thunnus alalunga*) and other tuna-like fishes are targetted.

Vessels and crew

In 1990, only 12 driftnet boats were thought to operate in the French Mediterranean, all with a French crew. Two large boats operated in the Gulf of Lions; the remaining 10 smaller vessels operate in Corsican waters (Anon., 1990). The number of large vessels has since increased to 10.

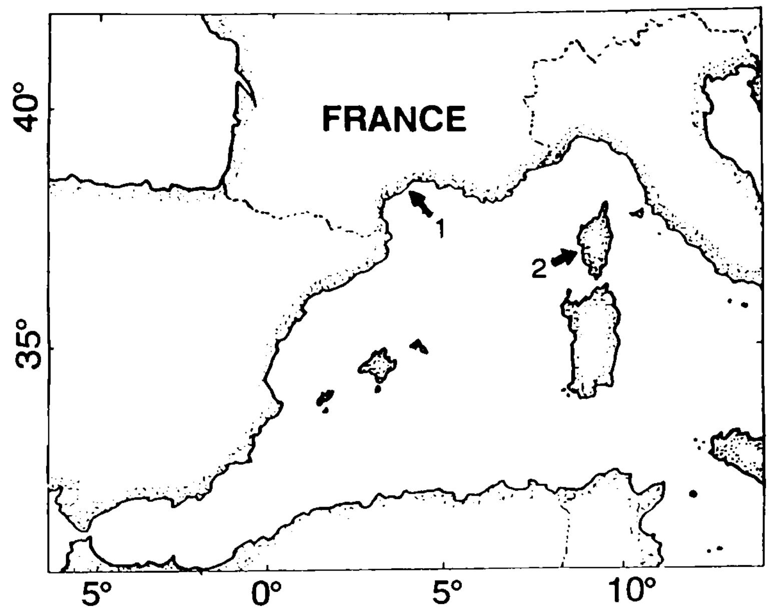

Fig. 4. Position of the French Mediterranean harbours in which driftnet boats are located. (1) *Gulf of Lions*; (2) Corsica.

Gear
Driftnets are made of nylon multifilament with a stretched mesh size of 36–42cm. In 1990, net length was 12–15km in the larger boats (Gulf of Lion) and 2.5–3km in the smaller (Corsica). Current European legislation forbids the use of driftnets greater than 2.5km. Nets are set in deep waters at sunset and retrieved before dawn the following morning. One of the boats operating in Corsica occasionally set the net on the bottom.

Interactions with cetaceans
Anecdotal information concerning four striped dolphins and one minke whale is given by Duguy *et al.* (1983). Additional information from the stranding record in the French Mediterranean is given by Duguy (1976; 1985; 1986; 1989). Sperm whales, long-finned pilot whales and Risso's dolphins are also suspected to be part of the bycatch. Cetaceans are protected by French law.

Comment
In March 1993, France, Italy and Monaco signed a Declaration to establish a marine mammal sanctuary in the Ligurian Sea. Unfortunately, although accepted by the French Ministry of the Environment, it has not been accepted (or enforced) by the Ministry of Fisheries. This is a matter of some concern (e.g. see Anon., 1994).

(E) Greek gillnet fishery

Ports/operation area
Ports are found all along the Greek mainland and islands coasts and operations occur in all Greek coastal waters.

Target species
A large variety of benthic and pelagic species are targetted.

Vessels and crew
Little information is available. The fleet is large (about 20,000 vessels) and heterogeneous. Most boats are small and their hull is wooden. The crew usually comprises 1–5 Greek nationals.

Economics and history
The catch is landed fresh, and sold on the domestic market. There are no data on gear, methodology or catch and effort.

Interactions with marine mammals
Smaller delphinid species (striped, common and bottlenose dolphins) are suspected to be part of the gillnet bycatch. Cetaceans are protected by the Greek law, but this appears to be weakly enforced. Unknown numbers of monk seals are known to be captured accidentally by gillnets (Northridge, 1984).

Comment
Given the socio-economic importance of this fishery, accurate monitoring of the marine mammal bycatch is strongly recommended, particularly with respect to the endangered monk seal.

(F) Greek surface pelagic driftnet fishery

Ports/operation area
The main ports are Kefallonia (Ionian Sea) and Kithyra (southwestern Aegean Sea) and operations take place in adjacent waters (Fig. 5). Small mesh driftnets are used everywhere, but mostly in eastern waters.

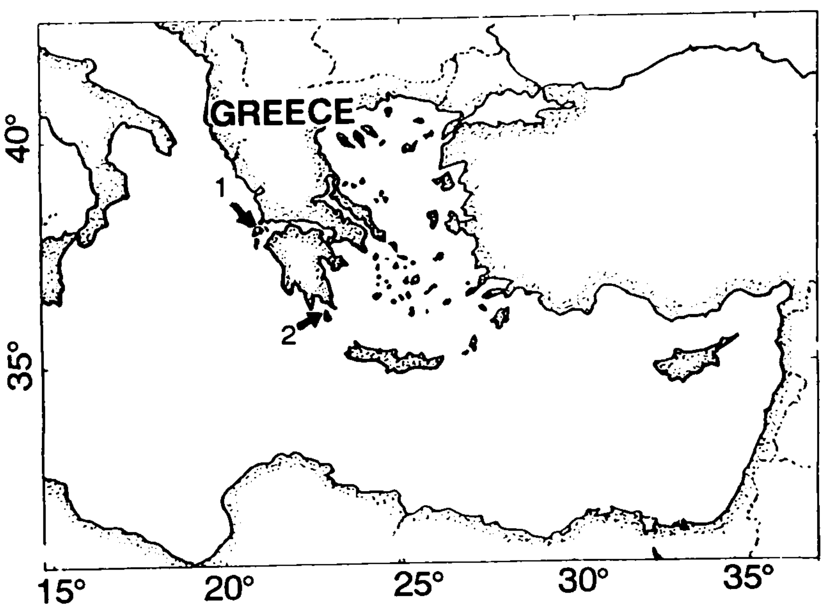

Fig. 5. Position of the Greek harbours in which driftnet boats are located. (1) Kefallonia; (2) Kithyra.

Target species
The target species is the swordfish (*Xiphias gladius*). Small driftnets catch small tunas.

Vessels and crew
In 1990, the fleet consisted of five 7–8m long wooden cabin cruisers with a crew of 2–4. The number of vessels using small mesh driftnets is unknown.

Gear
The nets are made of nylon polyfilament, with a stretched mesh of 36–42cm width, a maximum length of 3–5km (in 1990 – European legislation now makes nets of >2.5km illegal) and a depth of up to 28m. In small driftnets, stretched mesh size is around 8–9cm.

Operations
The fishery occurs in summer, when the weather is calm. The net is set before sunset and the soak time is approximately 4 hours. There are no data available for the small-scale fisheries.

Economics and history
Fish are landed fresh and sold on the domestic market with the ex-vessel price being about 8 US$/kg. Driftnetting began in 1989, with technology imported from Italy. No data are available for the small-scale fisheries.

Interaction with cetaceans
Although there are no official data, it is suspected that striped and common dolphins are caught. Cetaceans are protected by Greek law.

Comment
The swordfish fishery was started only after the Italians began operating in Greek waters and thus cannot be regarded as locally traditional. There are no monitoring programmes in effect. The Greek Government has not confirmed the existence of this fishery.

(G) Italian gillnet fishery (trammels)

Ports/operation area
Ports are found all along the Italian coasts and operations occur in Italian coastal and shelf waters.

Target species
Wrasses (Labridae), mullets (Mugilidae and Mullidae), rockfishes (Scorpaenidae), groupers and combers (Serranidae), dentexes and seabreams (Sparidae) and weevers (Trachinidae) are the principal target species.

Vessels and crew
The fleet is large (over 15,000 vessels) and heterogeneous. Boats may be made of wood, fibreglass or aluminium and are 4–16m in length. Crews are Italian and range in size from 1–4.

Gear
Most nets are made of nylon or polyammide polyfilament although a few nets are of nylon monofilament. The average mesh size (stretched) is 14–15mm (lower part of the net), 13–14mm (upper part) and 220mm (wall) long. Mesh size varies geographically. Panel length is highly variable from boat to boat; modal length is 350–400m. Each vessel usually carries 1–6 panels, although some can carry up to 20 panels. Most beacons are made of makeshift recycled plastic material. Nets are retrieved by hand or by net hauling gear (1- or 2-wheel).

Operations
Trips normally last between 3 and 5 hours. Nets are generally set on the bottom within a depth range of 5–200m. Nets are set in the afternoon and retrieved the following morning.

Economics and history
The catch is landed fresh (when it may be refrigerated) and marketed locally; prices vary between 7 and 21 US$/kg depending on prey species. There are no data on catch and effort.

Interaction with marine mammals
Although few entrapments are reported, this is probably because many go unreported rather than that they are rare. Bottlenose, Risso's and striped dolphins, and sperm whales are reportedly caught in gillnets, mostly in Sicily and Puglie. Cetaceans are used, removed or released by cutting the net; the proportion of live/dead bycatch is unknown. The bycatch is normally discarded. The Italian Ministry of Merchant Marine has funded research on this subject. The impact of this fishery on cetaceans is likely to be low. The once abundant (>40 years ago) monk seal, *Monachus monachus*, used to become commonly entangled in trammel nets. Rare reports of such occurrences still existed in the recent past in Sardinia.

Comment
More detailed research on the interactions between coastal cetacean species and fisheries should be carried out. Although cetacean mortality in this fishery seems relatively minor, fishermen's complaints and animosity towards cetaceans is common along the Italian coast, and may lead to directed mortality.

(H) Italian surface large pelagic driftnet fishery
The description of the fishery below refers mainly to the period before it was banned by the Italian Government on 30 July 1990. In 1991 the ban was lifted (see Discussion) and Aguilar and Silvani (1994) report that some 600–700 boats operate throughout the Mediterranean using illegal (>2.5km) nets. Most of the pre-ban information given below is thus probably still valid, although details are difficult to obtain.

Ports/operation area
The fishery took place out of more than 101 ports located along the western Italian coast (Tyrrhenian Sea), the coasts of Sicily and the Ionian coast of Calabria (Fig. 6). Our best estimate is that 20% of the fleet operated in all Mediterranean regions, 70% in Italian Seas (both coastal and offshore) and 10% only in Italian coastal areas.

Target species
Swordfish (*Xiphias gladius*) and albacore (*Thunnus alalunga*) are the targetted species.

Vessels and crew
The total number of vessels was about 800 just before the ban and is estimated now at about 650 vessels. The fleet was extremely heterogeneous, with no 'typical' vessel. All but one steel-hulled vessel had wooden hulls. Only about 40 smaller coastal boats lacked a cabin. About 5% of the vessels were less than 5m long, 15% were between 6 and

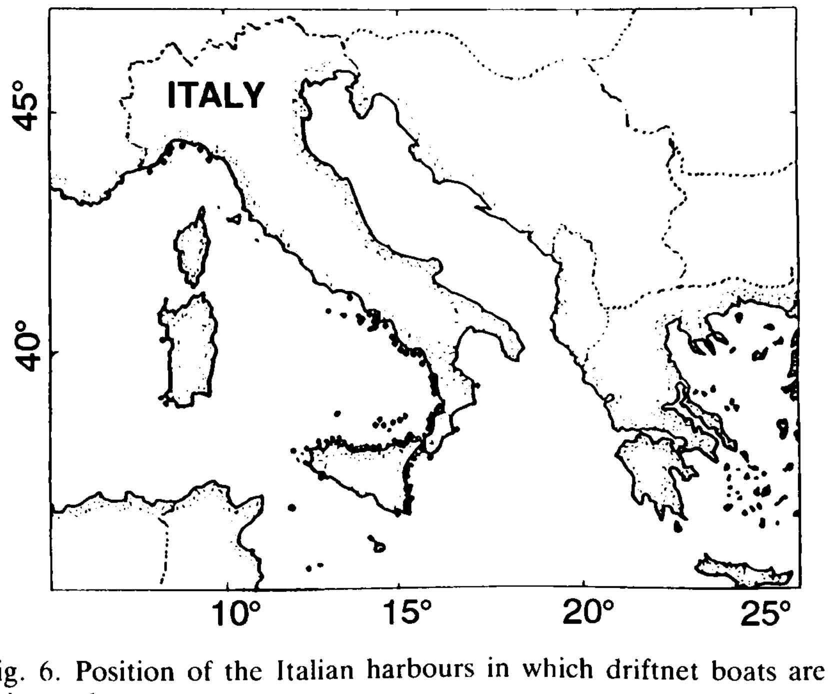

Fig. 6. Position of the Italian harbours in which driftnet boats are located.

12m, 65% were between 12 and 20m whilst the remaining 15% exceeded 20m. Most boats were between 20 and 40 GRT (range: 2–60 GRT). Crew number ranged from 2 to 6, almost all of whom were Italian (about 1% Tunisians). The fish capacity of each boat varied between 0.3 and 80 tonnes (modal value unknown). Half of the boats were not equipped with refrigeration facilities and landed the catch fresh, 40% put the catch on ice or in non-freezing refrigerators while 10% froze the fish on board.

Gear

Most of the nets were of nylon or polyamide twisted polyfilament. A few nylon monofilament nets were in use in the coastal fisheries. Mesh size (stretched) varied from 16–52cm, with most swordfish nets being from 36–42cm and albacore nets from 16–20cm. Twine size was between 48 and 60. Panel length ranged from 2 to 22.5km. Most nets were about 15km long, and 70–80 meshes (28–32m) deep. Each vessel carried only one panel. In spring some of the vessels operating in the southern area carried a larger mesh panel for swordfish and a smaller mesh panel for albacore. Driftnets were equipped with small floats, 10–15cm long and 5–6cm wide. Float spacing was variable, depending on mesh and twine size, and panel depth. Beacons were heterogeneous and largely makeshift, consisting of flashing lights, oil lamps, orange plastic inflatable buoys or black plastic flags (made of trashbags); different beacon types were often used on the same gear. Artisanal 3-wheel hydraulic hauling gear was commonly used, normally one per vessel (rarely two). In historic times driftnets were made of natural fibre (originally linen and later hemp and cotton). Synthetic fibres were introduced after 1950.

Operations

Fishing normally occurred between April and September in coastal and offshore waters (100 to >3,000m) and usually in deep (>1,000m) waters. Fishermen generally attended their nets during the night. Trip lengths ranged from 1 day in the coastal fishery to 2–5 days in the Italian offshore fishery or 8–20 days in further Mediterranean regions. The number of trips per vessel varied widely between 20 and 100 trips per year. Driftnets were usually set in a zig-zag pattern, beginning at 1700–1800hrs and ending at 2000–2100hrs. The soaking time was 3–4 hours. Nets were retrieved between 0100–0300 and 0700hrs or later. Catch size varied greatly, depending on geographic area, oceanographic conditions, weather conditions and moon phase; the mean catch was 96kg of commercial species per set.

Economics and history

The Italian driftnet fishery has a very ancient tradition, dating back to at least 177 B.C. (Sisci, 1988). Systematic research on this subject was initiated only in 1984 (Di Natale *et al.*, 1987); but between 1987 and 1990 the fleet increased by about 57% in the studied areas (Di Natale, 1990c). More recent data are reported by Di Natale *et al.* (1992). There is no official record of swordfish landings separated by gear (long line, driftnet or harpoon). Fish is sold fresh and frozen in the domestic market. A few tons are smoked and packed. Processors are capillarily distributed in most landing locations and in all major inland cities. Ex-vessel price ranged from 6.50 to 19.50 US$/kg, for a total ex-vessel value range of 30,000–300,000 US$/year.

Total landings

About 8,000 tonnes of swordfish and 1,700 tonnes of albacore (our unofficial estimate) are landed annually. Other commercial species comprise up to 1,800 tonnes.

Effort data

Catch per unit effort (CPUE) data exist only for 1985 and 1986 (C = catches in kg, E = (net length/100) × number of days fished). In 1985 the CPUEs were 1.04kg (swordfish) and 6.76kg (albacore). In 1986 they were 0.90kg (swordfish), 3.05kg (albacore).

Interaction with cetaceans

Several cetacean species are known or suspected to have been entangled in the Italian driftnets. These include: fin, minke, sperm, Cuvier's beaked and long-finned pilot whales and Risso's, bottlenose and striped dolphins. The many unidentified specimens on record may include the rarer common and rough-toothed dolphins. No official data on cetacean bycatches in driftnets exist. Although the stranding record provides some information, it heavily underestimates incidental mortality (Notarbartolo-di-Sciara, 1990). A conservative estimate of 10 cetaceans accidentally caught per vessel per season would mean a total annual bycatch in the Italian driftnet fishery of more than 8,000 cetacean specimens (mostly striped dolphins, but including at least 30 sperm whales). This estimate may be reduced in the light of more recent assessments based on observers data (Di Natale *et al.*, 1992). The uncertainty of the bycatch data and the lack of information on the sizes of the populations involved, makes it impossible to assess the impact of driftnetting on the local cetacean populations.

Cetaceans observed are usually entangled in the upper third of the net. Most cases involved passive entanglements although a few records of active entanglements (involving adult sperm whales entangled while attempting the rescue of a calf) have been reported. Cetacean removal techniques depended mostly on their size: the smaller species were brought on board to facilitate operations, and the tail and flippers were often cut to speed up removal. The larger whales were left entangled, dead or alive, and the entangling portion of the net was cut off from the main net. Very few specimens were disentangled and released alive. Most of the smaller specimens were found drowned, or were deliberately killed if found alive. Adults of the larger species (e.g. sperm whales) are always alive when the net is retrieved.

Cetaceans have been protected in Italian waters since 1980. Marketing of cetacean products is unlawful in Italy and thus the carcasses are generally discarded by the fishermen. However, occasionally dolphin meat is used as longline bait and there is a limited illegal market for dried dolphin fillet (*musciame*), considered a delicacy in Liguria and Tuscany. In 1989, three research projects were funded by the Ministry of Merchant Marine aimed at reducing cetacean bycatches. This included an observer programme and gear modification experiments. A 24 hour nationwide answering service, maintained by the Centro Studi Cetacei with the support of Europ Assistance, has been active since 1986 and has resulted in the rescue of several specimens: 8 sperm whales (33% of the total reported), 4 pilot whales and 3 striped dolphins were found entangled, rescued and released alive at sea by volunteers between 1986 and 1989 (Notarbartolo-di-Sciara, 1990).

Although there are no reports of monk seal entanglement in pelagic driftnets in Italian waters, Italian vessels have been seen fishing in Greek waters, where the monk seals barely survive (Aguilar and Silvani, 1994).

Comment
The current illegal fishery is a major cause for concern and enforcement is poor (see Discussion). However, an exception is the Sanctuary in the Ligurian Sea (see *Comment* under (D) above), where enforcement is strict and large scale driftnets banned.

(I) Italian surface small pelagic driftnet fishery

Ports/operation area
Vessels operate from ports all along the coast and operate in adjacent coastal waters.

Target species
Bullet tuna (*Auxis rochei*), little tuna (*Euthynnus alletteratus*), skipjack tuna (*Katsuwonus pelamis*), Atlantic bonito (*Sarda sarda*), chub mackerel (*Scomber japonicus*) and Atlantic mackerel (*Scomber scombrus*) are the target species.

Vessels and crew
This is an opportunistic small-scale fishery, for which there are no official data. The total number of vessels is unknown. The fleet is heterogeneous; most boats have wooden hulls, ranging in length from 4 to 14m. Crews comprise 2–3 Italian nationals.

Gear
About 90% of the nets are made of nylon or polyamide polyfilament; the remainder are nylon monofilament. Stretched mesh size ranges between 4 and 9cm. Panel length ranges from 0.2–1.5km and the depth is 3–8m. Each vessel carries only one panel. Beacons are makeshift recycled plastic bottles and containers, and pieces of styrofoam. Most nets are retrieved by hand; a few boats use artisanal 1-wheel hydraulic gear.

Operations
Trips are usually made daily, but vary considerably in length depending on the abundance and concentration of the target species. Nets are set mostly over the continental shelf. No other details are known.

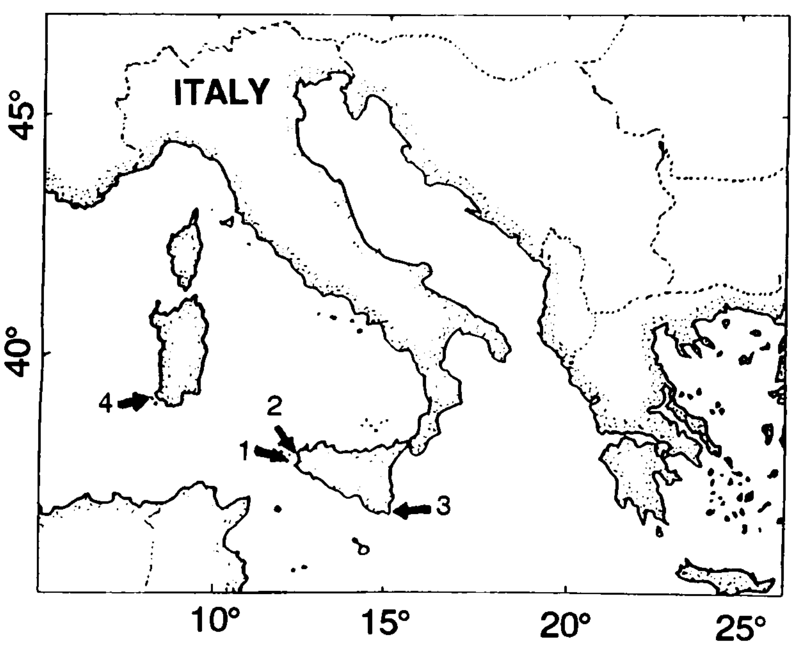

Fig. 7. Position of the Italian traditional tuna traps. (1) Favignana; (2) San Cusumano; (3) Porto Palo; (4) Carloforte.

Economics and history
With the exception of a small amount of mackerels canned in Southern Italy, fish is landed and sold fresh. The market is strictly domestic and processors are evenly spread along the coast and the landing locations. Ex-vessel prices range from 2 to 6 US$/kg. There are no catch or effort data.

Interaction with cetaceans
No official statistics exist and no scientific research or organised monitoring has ever been carried out. However, some species are known to have been involved including Risso's and bottlenose dolphins. The total number of incidental captures is thought to be low and the impact of the fishery on cetacean populations minimal. Entangled specimens are normally released alive at sea. In Liguria, Tuscany and off the smaller islands cetaceans are killed and filleted for the black marketing of *musciame*.

Discussion
Although we believe incidental mortality is probably low, a systematic investigation of this fishery should be carried out.

(J) Italian traditional tuna trap fishery

Ports/operation area
The main ports are San Cusumano, Favignana, Porto Palo di Capo Passero (all in Sicily) and Carloforte in Sardinia (Fig. 7) and operations are coastal and localised.

Target species
The bluefin tuna (*Thunnus thynnus*) is the target species.

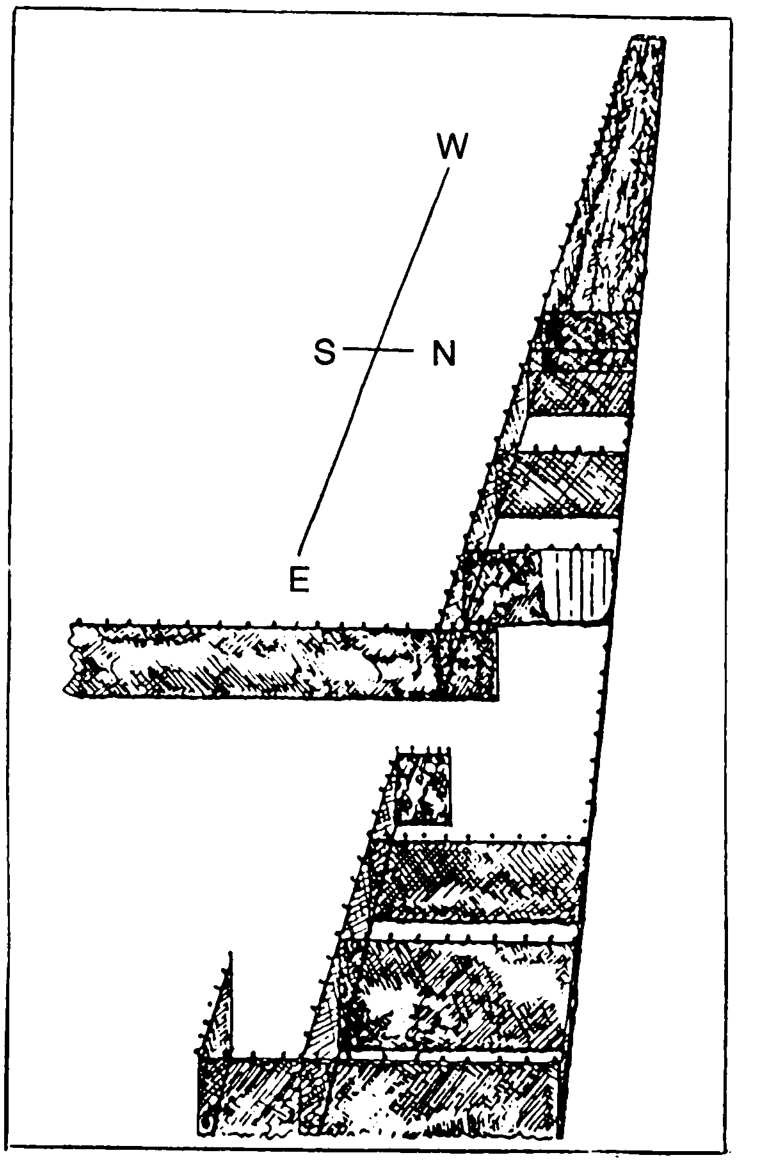

Fig. 8. Sicilian traditional trap (from: Sarà, 1983).

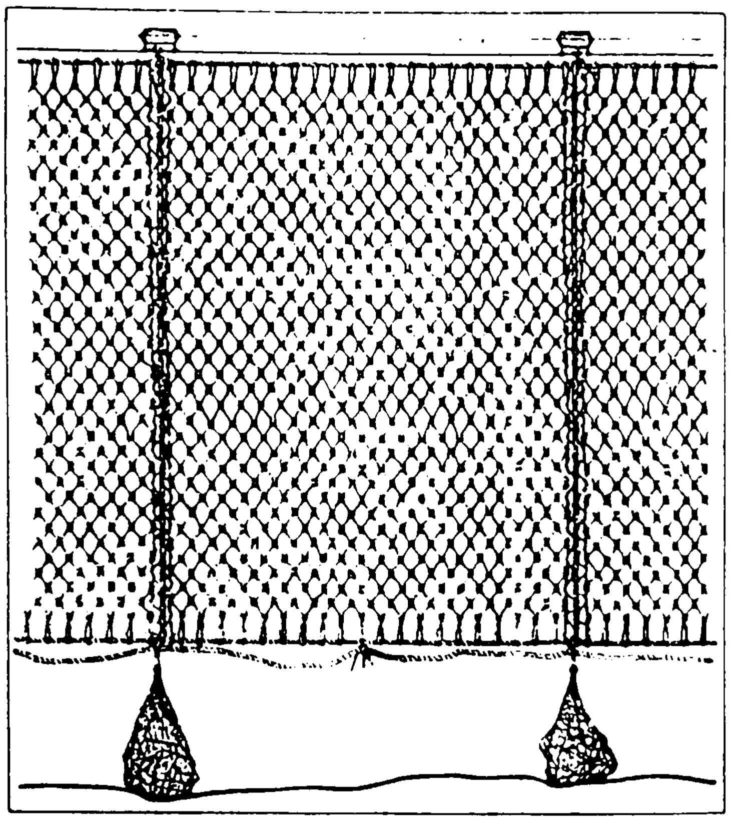

Fig. 9. Hanging scheme of the tuna trap in Favignana, Sicily (from: Sarà, 1983).

Vessels and crew
This is a land-based fishery using a number of support vessels towed in place by a motorboat. The boats used to carry the net and for all operations are typically made of wood. Crew numbers vary from 30 to 70. Fishermen are all Italian.

Gear
Nets are made of nylon or polyfilament polyamide with a stretched mesh size of from 20 to 120cm (Figs 8–10). Panel lengths and depths vary from trap to trap.

Operations
Tuna traps are usually set in May and retrieved at the end of June, in coastal waters shallower than 50m. The nets span from the sea surface to the bottom and are anchored in place. Fishing 'events' occur between 2–9 times per season, depending on the number of tunas entrapped. Each operation is concluded by the killing (*mattanza*) of all tunas entrapped in the last part of the trap, called the 'death chamber'.

Economics and history
This is one of the most typical Mediterranean fisheries and is of ancient origin. Up until the end of the 19th Century it was quite widespread along the coast of the Italian mainland and islands (Sarà, 1983; Consolo, 1987). Today several environmental and socioeconomic factors have strongly reduced its use and its activity is government supported as a national cultural heritage. Fish is sold canned, frozen (fillets for Japan), salted (ovaries, fillets and entrails) or fresh (for local consumption). The market is partly domestic and partly foreign (mostly Japan), but the relative proportions are unknown. Processing factories are located in the immediate vicinity of the tuna traps. Ex-trap price is about 4.5 US$/kg.

Total landings
About 250 tonnes/year of bluefin tuna and 1 tonne/year of swordfish are caught. The total catch has been increasing since 1985 after a serious decline in the previous decade.

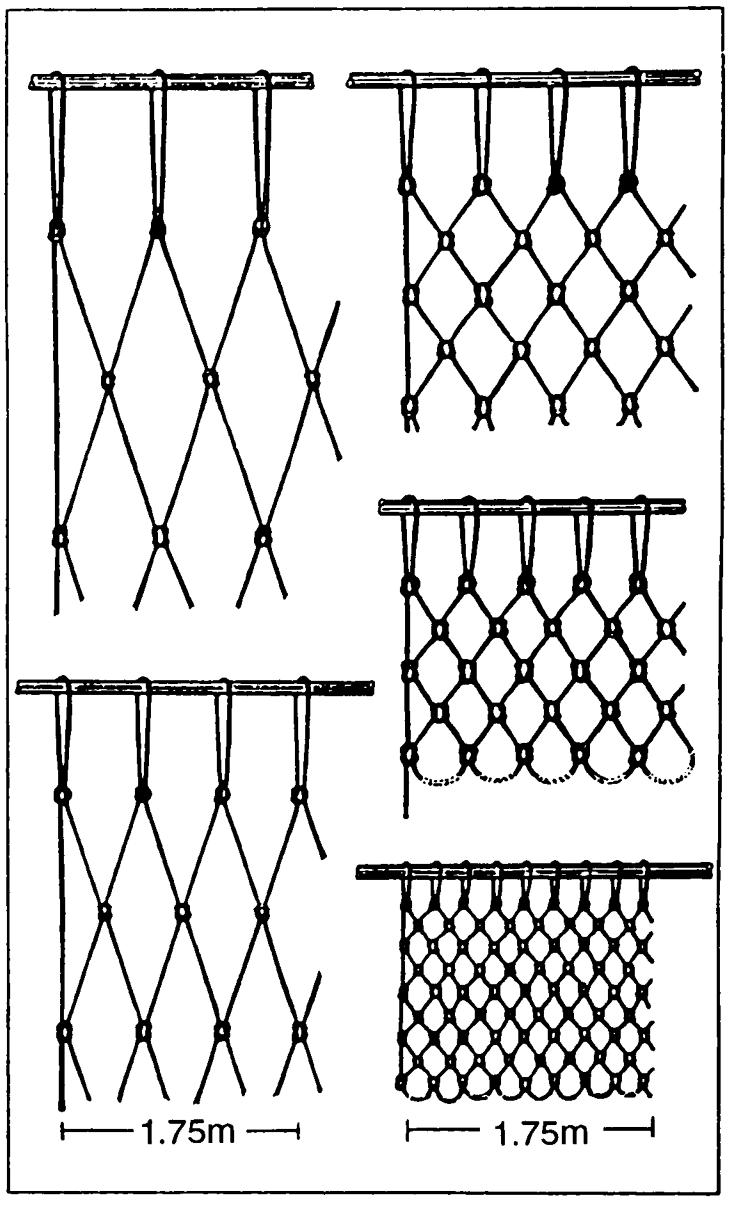

Fig. 10. Various meshes used in the tuna trap in Favignana, Sicily. The reference measure (*una canna*) is 1.75m (from: Sarà, 1983).

Effort data
1990 CPUE indices are available only for the two most important tuna traps (Favignana and San Cusumano). The total CPUE = 14,736, bluefin tuna = 14,694; swordfish = 42.2) where the catch is in kg and the effort is the total number of *mattanze*).

Interaction with cetaceans
One killer whale was captured in 1972 near Scopello, Sicily (Di Natale and Mangano, 1983a). Bottlenose dolphins are known to occur in the bycatch, although they are never reported. All cetaceans are alive when trapped and killed afterwards. The impact on cetacean populations is supposedly negligible.

(K) Maltese surface pelagic driftnet fishery

Ports/operation area
The two ports are Valletta and Marsaxlokk (Fig. 11) and operations occur throughout the Maltese Archipelago.

Target species
The swordfish (*Xiphias gladius*) is the target species.

Vessels and crew
In 1990, five wooden cabin cruisers, 12 to 16m long, crewed by 3–7 Maltese fishermen operated. We were unable to obtain more recent information.

Gear
Nets of 5–12km made of either nylon polyfilament or monofilament are used. They are equipped with radio transmitters as beacons. Mesh size (stretched) ranges from 20 to 42cm. A net-hauler is available on board.

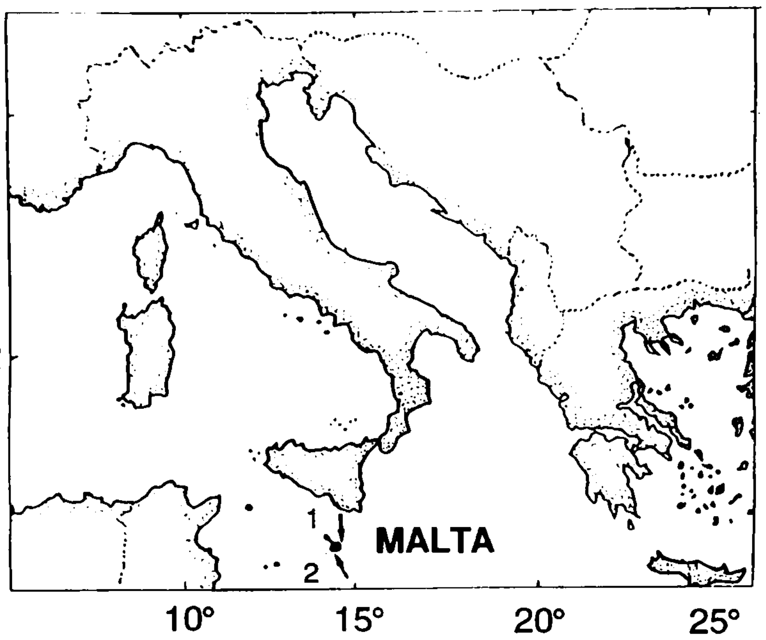

Fig. 11. Position of the Maltese harbours in which driftnet boats are located. (1) Valletta; (2) Marsaxlokk.

Operations
Fishing occurs in summer in water deeper than 200m. Trips last for 1–2 days. Nets are set at 1500–1900hrs and retrieved at 0200–0600hrs. The soaking time is thus 7–16 hours.

Economics and history
This fishery, which began in 1989, is likely to increase in the future. Fish is sold fresh on the domestic market. The 1990 ex-vessel price was about 6.20 US$/kg. No information on catch or effort is available.

Interaction with cetaceans
There are no official data but common, bottlenose and striped dolphins are potential bycatch species. Dolphins caught by other methods (harpoon and gun) are used as bait for shark longline fisheries.

Discussion
Information was gathered from three different sources, two of which refer to 1989 and one to 1990. It seems likely that some foreign boats may have reflagged with Maltese flags, with the purpose of creating a local swordfish industry in 1991, but we have been unable to obtain more recent information on this.

(L) Moroccan Mediterranean surface pelagic driftnet fishery

Ports/operation area
Aguilar and Silvani (1994) report that the main ports are Cabo de Agua, Nador, Al-Hoceima and Tangier. Operations occur in coastal waters and the Alboran Sea (Fig. 12).

Target species
Tuna-like fish species are targetted, as well as swordfish.

Vessel and crew
According to Anon. (1990), the fleet consisted of 30–40 wooden boats, all crewed by Moroccan and Spanish fishermen. More recently, Aguilar and Silvani (1994) stated that at least 200 vessels operate in the Alboran Sea for swordfish using variable length nets, many over 2.5km. Little operational or catch data are available. The fleet appears to have stabilised at this number since 1992.

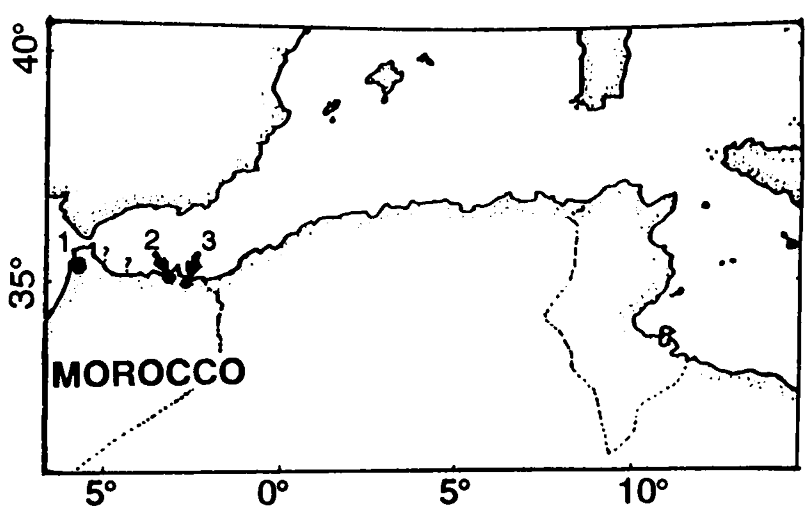

Fig. 12. Area of possible location of Moroccan Mediterranean driftnet boats. (1) Tangier; (2) Al-Hoceima; (3) Nador.

Interaction with marine mammals
No official data exist but it is thought that many stranded dolphins have died as a result of fishery interactions, including striped, bottlenose and common dolphins; monk seals are also found in the area (Aguilar and Silvani, 1994).

Discussion
A scientific programme to monitor the activities of this fleet was apparently established (Anon., 1990) but no regulations exist and no data have been published to our knowledge.

(M) Spanish Mediterranean gillnet fishery

Ports/operation area
Operations occur all along the Spanish Mediterranean mainland coast and on the islands from numerous ports, and extends over the continental shelf.

Target species
A large variety of benthic species are targetted in this fishery.

Other information
Apart from the fact that Spanish fishermen are involved, there is very little information on this fishery. The catch is largely sold fresh on the domestic market although a small part is exported to France.

Interaction with cetaceans
Anecdotal reports concerning 1 common dolphin and 1 bottlenose dolphin are given by Duguy *et al.* (1983). Cetaceans are protected under Spanish law.

Discussion
Although this fishery activity is rather widespread along the Spanish Mediterranean coast, there is a paucity of information available. This should be remedied.

(N) Spanish Mediterranean surface pelagic driftnet fishery
In October 1990, the Spanish government banned the use of swordfish driftnets. Thus the fishery described below is now illegal but still continues to some extent (Aguilar and Silvani, 1994).

Ports/operation area
The boats are based in Algeciras and Tarifa and fish in that area and the Alboran Sea (Fig. 13).

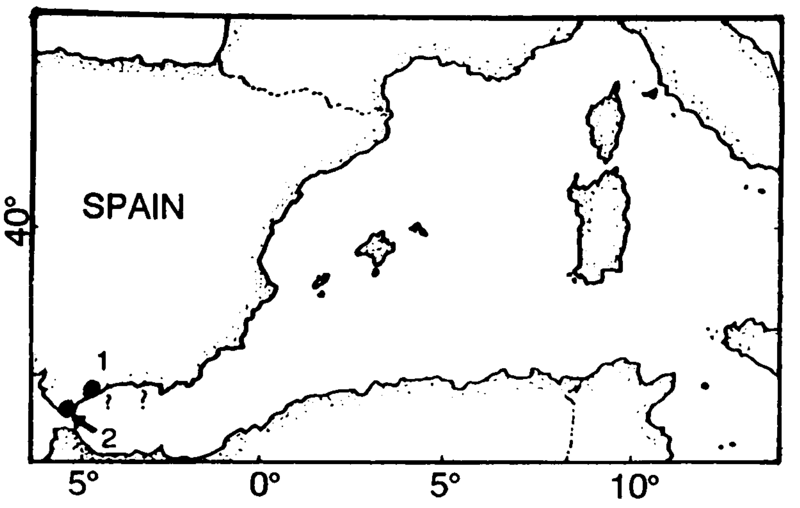

Fig. 13. Area of possible location of Spanish Mediterranean driftnet boats. (1) Algeciras; (2) Tarifa.

Target species
Swordfish (*Xiphias gladius*) and tuna-like fishes are targetted.

Vessels and crew
About 30 wooden boats operate most of which are 15m long. The crew comprises 4–5 Spanish fishermen. Spanish driftnet boats, legally operating in the Atlantic, encroach illegally into the Mediterranean Sea on an irregular basis. The number of vessels appears to be slowly decreasing.

Gear
Little data exist but panels are up to 5km long. Each vessel carries only one panel.

Operations
Operations take place from July to September.

Economics and history
Fish is sold mostly fresh on the domestic market. Refrigerated or frozen fish is exported to France and Italy. Ex-vessel prices range between 5 and 10 US$/kg.

Interaction with cetaceans
Only bottlenose dolphin bycatches are reported in the literature (Duguy *et al.*, 1983), but many more species are suspected to be involved. As a measure to reduce bycatches, observers had occasionally been placed on board driftnet vessels by the Instituto Español de Oceanografia (Anon., 1990).

Discussion
Spanish pelagic driftnetting in the Mediterranean is not considered in official Spanish reports, since these fishermen are considered 'pirates'.

(O) Tunisian gillnet fishery

Ports/operation area
Vessels operate from all along the coast and throughout Tunisian coastal waters.

Target species
A large variety of benthic species are targetted.

Vessels and crew
The total number of vessels is unknown. The fleet is apparently heterogeneous, but all boats have a wooden hull. Crews are all Tunisian.

Gear
The nets are made of polyamide monofilament and the panel length is about 100m. Each vessel carries 20–30 panels. Stretched mesh sizes are reported to be between 44–250mm. Little other operational information exists.

Interaction with cetaceans
One bottlenose dolphin was reported entangled in November 1980 in a trammel net north of Tunis (Ktari-Chakroun, 1981). No other information is available.

Discussion
There is no monitoring of this fishery. Gillnetting is widespread among Tunisian fishermen and interactions with cetaceans, particularly bottlenose dolphins are considered common. Local fishermen see dolphins as competitors and try to kill them when possible (K. Ben Mustapha, pers. comm.). In recent years large mesh driftnetting appears to have developed rapidly. It is reported that the Government is intending to introduce a total ban, largely to protect cetaceans and the monk seal.

(P) Tunisian traditional tuna trap fishery

Port/operation area
The fishery operates out of Sidi Daoud (Fig. 14) and occurs in the Gulf of Tunis.

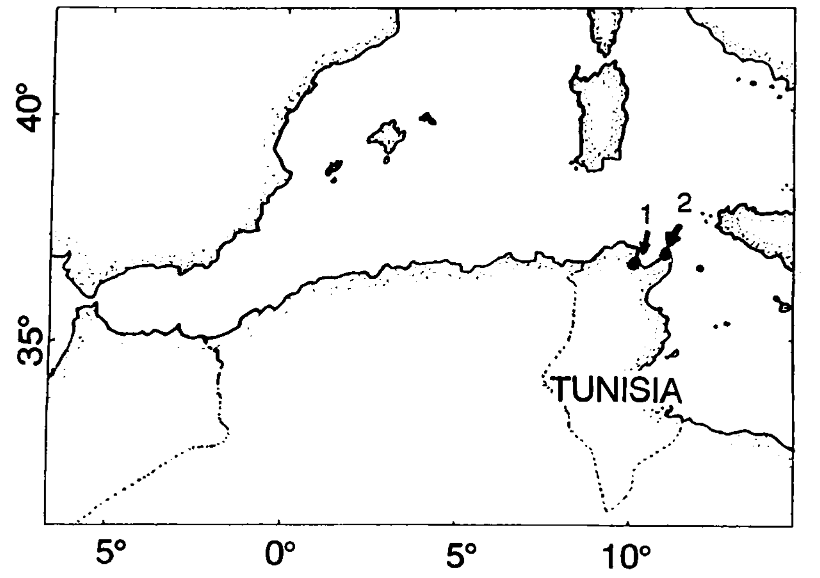

Fig. 14. Location of the Tunisian traditional tuna trap. (1) Tunis; (2) Sidi Daoud.

Target species
The bluefin tuna (*Thunnus thynnus*) is the target species.

Vessels and crew
This is a land-based operation using a number of support vessels, all crewed by Tunisian fishermen. The net is towed in place by a motorboat.

Economics and history
The only available information is that 83 tonnes of tuna were landed in 1988 (Anon., 1990). No official monitoring of the fishery exists.

Interaction with cetaceans
A minke whale and a common dolphin were captured, respectively, in May 1976 and in June 1980 (Ktari-Chakroun, 1980; 1981). Both animals, alive when trapped, were killed by the fishermen.

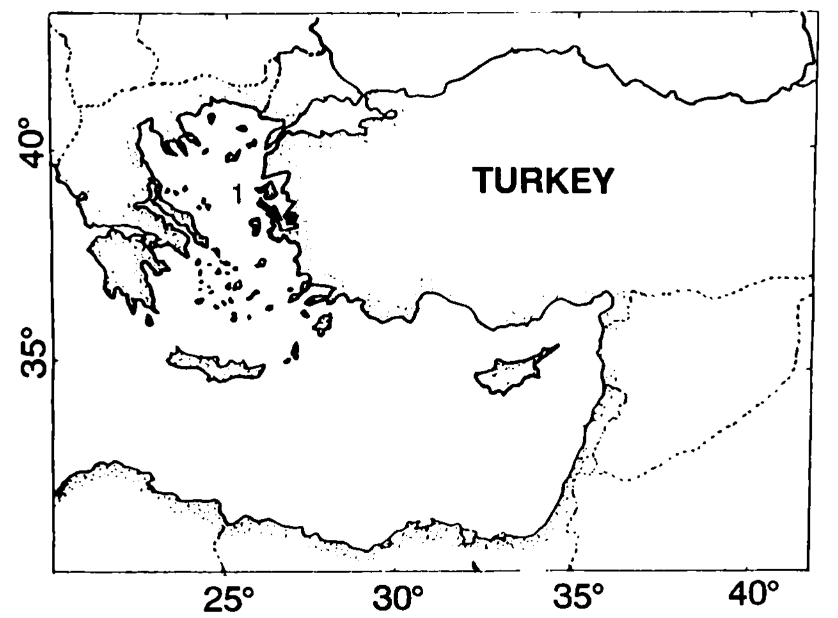

Fig. 15. Position of the Turkish area in which driftnet boats are located. (1) Izmir.

(Q) Turkish surface pelagic driftnet fishery

Ports/operation area
Vessels operate in the eastern Aegean Sea from Izmir and the Aegean coast south of it (Fig. 15).

Target species
The swordfish (*Xiphias gladius*) is the target species.

Vessels and crew
The fleet consists of 14 wooden boats, one about 16m long and the rest 7–8m long. The boats are crewed by 2–4 Turkish fishermen. In 1990 there was an Italian instructor.

Gear
The nets used are made of nylon polyfilament, with a stretched mesh size of 42cm. The smaller boats use a net 2–3km long and 28m deep whilst the larger boat uses a net 10km long and 30m deep. Only the largest vessel has hydraulic hauling gear.

Operations
The smaller boats make 50–70 trips per year, whereas the larger vessel made only 12 trips in 1990. Nets are set at 1800–1900hrs and retrieved at 0200–0400hrs. The fishing season lasts from February to June. The fishery is strongly limited by the typical summer meteorological conditions of the area (*meltemi* winds).

Economics and history
The Turkish swordfish driftnet fishery began in the mid 1980s (exact date unknown) and has increased since technology was imported from Italy in the late 1980s. Fish are sold fresh on the domestic market and 557 tonnes were landed in 1988. The fishery appears to have stabilised in the 1990s, but officially the Government does not admit that driftnetting occurs.

Interaction with cetaceans
There are no official reports but it is thought that bottlenose, striped and common dolphins may be involved. No cetaceans were reportedly caught by the largest vessel during the 1990 fishing season. We have been unable to obtain more recent information.

(R) Turkish gillnet fishery

Ports/operation area
The fishery operates in the eastern Aegean Sea.

Target species
Benthic species are targetted.

Available information
An unknown number of wooden boats, manned by Turkish fishermen are involved. The nets used are made of polyamide polyfilament, 365–550m long and 1–3.65m deep. The stretched mesh size is 20–300mm. The fish are landed fresh.

Interactions with marine mammals
No official data exist but smaller species (bottlenose, striped and common dolphins) are suspected to be incidentally taken. The endangered monk seal is known to be accidentally killed by coastal trammel nets.

DISCUSSION AND RECOMMENDATIONS

Tuna traps
This fishery activity is now only a remnant of the past, and has a traditional rather than an economical relevance. Its significance, as far as cetacean mortality is concerned, is negligible.

Coastal bottom gillnets
This fishery is extremely widespread throughout the Mediterranean and may result in mortality of coastal species such as the bottlenose dolphin and the monk seal. Given the perilous state of the monk seal (Durant and Harwood, 1992), any mortality is serious but the fishery probably has only a small impact, if any, on the bottlenose dolphins. However, given its widespread use, closer monitoring of the situation is recommended. In addition, both bottlenose dolphins and monk seals in the Mediterranean are known to take fish from the bottom setnets and damage gear; this induces human hostility towards these species, which may lead to directed mortality (Anon., 1988b).

Pelagic driftnets
There are two principal categories of driftnets in the Mediterranean: driftnets used to catch large pelagic scombriform fishes (swordfish and albacore) and driftnets used to catch smaller pelagic schooling fishes. It appears that only the former has a significant impact on cetaceans, mostly because of the great lengths of the nets (Di Natale, 1990b; 1992; Di Natale *et al.*, 1993); pelagic driftnetting has been responsible for a large number of cetacean deaths throughout the Mediterranean (Notarbartolo-di-Sciara, 1990; IWC, 1992). Of all cetacean specimens stranded in Italy between 1986 and 1988, for which the cause of death could be established, 83% had died in driftnets (Cagnolaro and Notarbartolo-di-Sciara, 1992).

Until July 1990, the largest pelagic driftnet fleet in the Mediterranean was the Italian fleet, reaching about 90% of the total (by number of vessels, Fig. 16). Although the situation changed dramatically after pelagic driftnetting for swordfish and albacore was outlawed in Italy in 1990 (Fig. 17), since then it has been confused by several 'bans' and reallowances, established by both the Government and the Administrative Courts; the situation now seems to be even

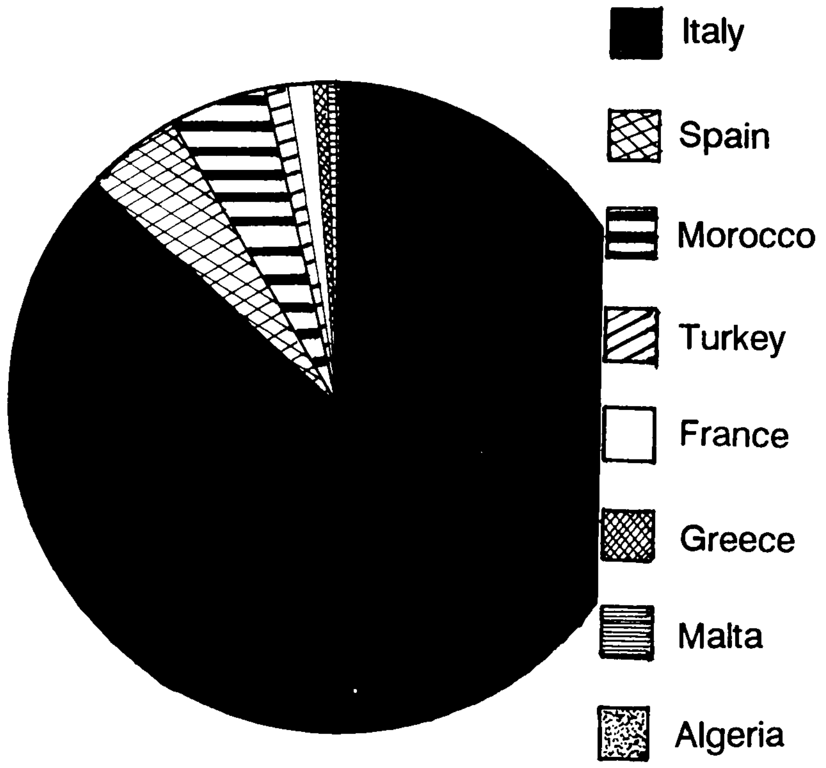

Fig. 16. Mediterranean pelagic large driftnet fleets (by number of vessels).

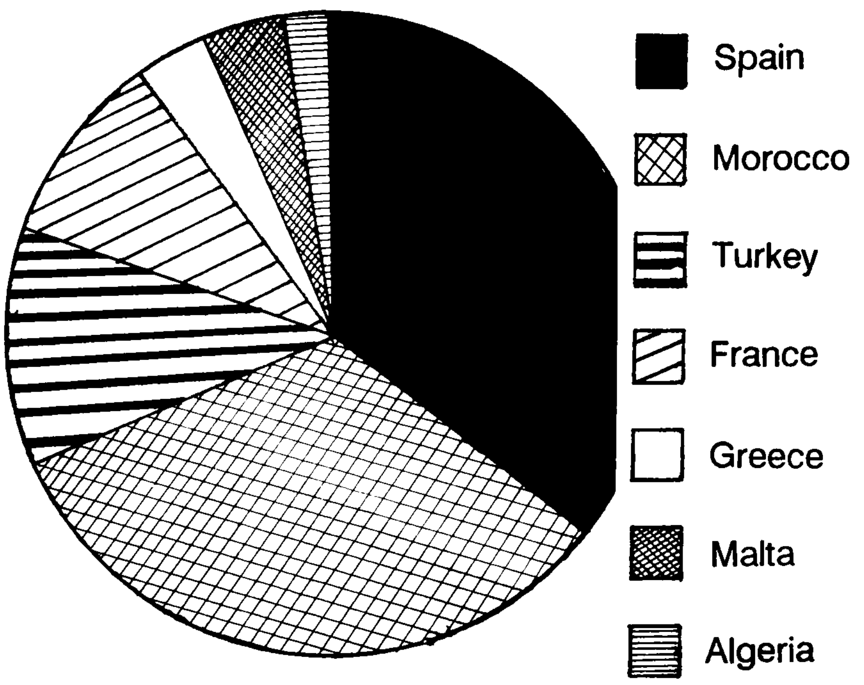

Fig. 17. Mediterranean pelagic driftnet fleets (by number of vessels, excluding the Italian fleet).

worse than before 1990 (Aguilar and Silvani, 1994). The collection of information on this subject is often very difficult for political reasons. In particular the IWC Scientific Committee has drawn attention to the situation of the striped dolphin. IWC (1994) expressed concern that incidental catches of this species were unsustainable. This was followed by a series of recommendations for research and management action (IWC, 1992, p. 207; IWC, 1995, Item 15.5). We reiterate those recommendations.

If the problem of bycatches is to be properly addressed, research is needed:

(1) to obtain reliable estimates of bycatches for all fisheries in the region;
(2) to obtain reliable estimates of cetacean population size;
(3) to better understand the stock structure of cetaceans in the Mediterranean.

It is clear that urgent action is required, in terms of enforcing existing regulations banning the use of driftnets >2.5km, carrying out the Action Plan for Cetaceans established by the 1991 meeting of the Barcelona Convention in Cairo and perhaps, most importantly, adopting a legally binding approach to the conservation of cetaceans in the Mediterranean under the auspices of the Convention on the Conservation of Migratory Species of Wild Animals. A draft agreement is under discussion at present (November 1994).

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Bycatch and Bycatch Reduction of the Harbour Porpoise (*Phocoena phocoena*) in Danish Waters

Nicholas Lowry

DIFTA, North Sea Centre, PO Box 59, 9850 Hirtshals, Denmark

and Jonas Teilmann

Danbiu ApS, Toragevej 2, 2920 Charlottenlund, Denmark

ABSTRACT

The harbour porpoise (*Phocoena phocoena*) is the only cetacean incidentally caught in significant numbers by the Danish fishing fleet and there is some concern that the populations in Danish waters may be in decline. The main catches are in the extensive fleet of vessels fishing dermersal gillnets. Recently, this bycatch has been quantified by a rough estimate of up to 7,000 bycaught harbour porpoises and public and political awareness of the issue is increasing. This paper reviews the Danish passive gear fishery and the level of the bycatch of harbour porpoises. Methods with potential for reducing this bycatch are briefly discussed.

KEYWORDS: NORTH ATLANTIC; BALTIC; INCIDENTAL; CAPTURE; FISHERIES; HARBOUR PORPOISE.

INTRODUCTION

The harbour porpoise (*Phocoena phocoena*) is the only cetacean that is known to be resident in Danish waters (e.g. Jensen, 1946; Clausen and Kinze, 1993). This primarily coastal species has a circumpolar distribution in the Northern Hemisphere from the Cape Verde Islands at 15°N to Thule at 78°N (Gaskin, 1984; personal observation).

Several studies have considered the status and distribution of the harbour porpoise in Danish and adjacent waters and concluded that its numbers may have declined and its distribution narrowed (e.g. Andersen, 1982; Smeenk, 1987; Clausen and Andersen, 1988). These assumptions are mostly based on information from historical catch statistics (e.g. the extensive Danish fishery up to the 2nd World War is reviewed by Kinze, In press), and scattered information from strandings and incidental sightings.

In recent years there has been increasing international interest and concern about the bycatch of small cetaceans in fishing gear (e.g. IWC, 1994a). In northern Europe, the harbour porpoise is the species most frequently caught in fishing gear and concern about the problems this may cause for the populations have been widely expressed (e.g. IWC, 1992; 1994a).

Few studies have tried to assess the magnitude of the bycatch in fishing gear, or to obtain estimates of species abundance – two factors critical to the management of the harbour porpoise. Some preliminary work has been done to attempt to find solutions to entanglements in fishing gear, but so far no commercially useful solutions have been developed.

This paper presents current information on the Danish gillnet fishery and the bycatch in fishing gear in inner Danish waters and the North Sea. The final section briefly reviews possible ways of reducing bycatches.

SUMMARY OF DANISH PASSIVE GEAR FISHERIES

This section summarises the situation of Danish fisheries in the 1990s. Information for previous years is given in Coviconsult (1988), Flintegård (1986) and Kinze (1990).

Gillnet fishery

Denmark has the largest gillnet fleet of any member state of the European Community (EC). In 1992, a total of 1,549 vessels were registered as prosecuting gillnet fisheries and 3,198 people were directly employed. The distribution of these vessels by area and as a proportion of the total number of vessels in the fleet is shown in Fig. 1. The most important species for gillnetters are (by value) cod, plaice, sole, turbot, hake, pollack and lumpsucker, with at least 30 other species of fish represented in the catches. The relative tonnage of the most important species by area is given in Table 1. The total value of the catch is at least 600 million Danish kroner (about $US100,000,000).

Gear and fishing strategies

In all gillnet fishing, the nets are constructed individually and tied together into 'strings' or 'fleets', each end of which is marked by an anchor and a buoy (IWC, 1994b). The number of nets carried by a boat and the number of nets in a string varies according to the size of the boat, the fishery, and how the net is hauled. There are approximately 50–80 nets for a vessel of 10 BRT (1 man), 100–200 nets for a vessel of 10–15 BRT (2 men) and 350–400 nets for a vessel of 20 BRT (4–5 men). The total length of the nets set by Danish gillnetters in the North Sea each day is about 5,000–10,000km. Strings vary in size depending on the fishery, but are typically 5–15 nets. In the Danish fishery, there are large numbers of both small boats operating in coastal waters that make day trips and of larger boats that work further offshore and make trips of 5 to 14 days. Operational strategies are variable depending on the particular fishery and the prevailing conditions during the day. Typically, it involves setting the net, leaving it overnight and returning the next day to haul and clean the net before resetting. This lets the net fish over two changes of tide (or two day/night changes in the Baltic where there is little tide) which is when the greatest catches occur. The exceptions to this are nets for turbot, which are left for 2–8 days before hauling, and the sole fishery, in which the soak time is often only 6 hours. Soak times are shorter during periods of high water temperature or where there are

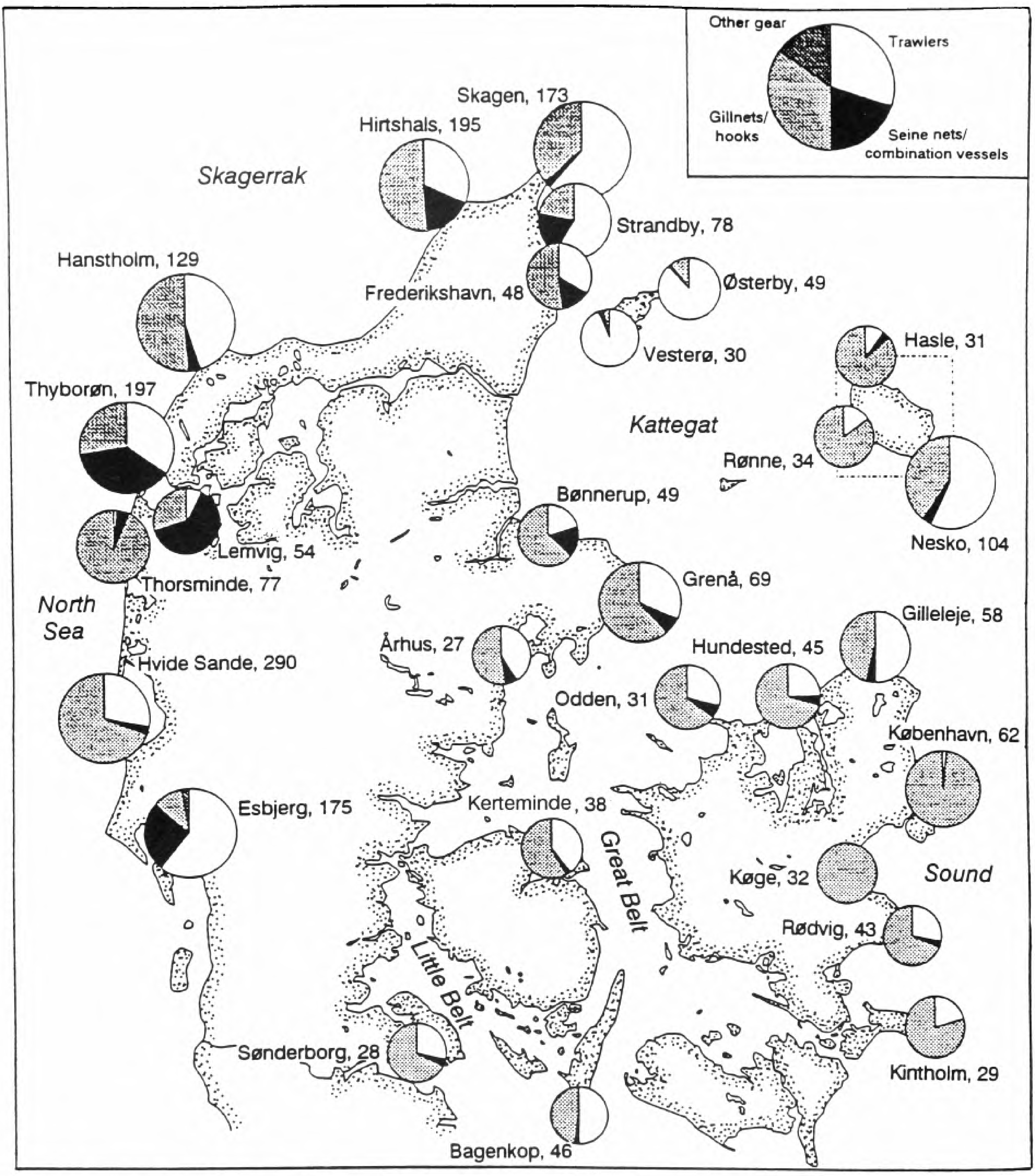

Fig. 1. Map of Denmark. Number of Danish fishing vessels by type and home port 1992 (*Yearbook of Danish Fishery Statistics, 1992*).

problems with, for example, lice or crabs attacking the fish, weed clogging the net or a high bycatch of unwanted species.

Cod fishery

The nets used in cod fisheries are generally made of nylon monofilament or multimono. They range from 110 to 180mm mesh size (all mesh sizes are given as inside mesh opening). Meshes are generally larger in the North Sea than the Baltic. Height ranges from 15½ to 35½ meshes, and length is generally 1,000 meshes. Hanging ratios (length of headline/length of netting) are of the order of 35–50%. Lead-cored ropes are used for the footrope, with plastic floats (65–125g lift) used on the headline. Fishing occurs in all Danish waters, notably the central North Sea (Fig. 2) and the Baltic, and is year round.

Table 1

Danish gillnet fishery (incl. traps and lines) catch (tonnes) by area and species in 1992 (only those with a total catch of over 600 tonnes). Source: *Yearbook of Danish Fishery Statistics 1992.*

	North Sea	Skagerrak	Kattegat and Isefjord	Belts and Western Baltic	Sound and Eastern Baltic
Cod	9,849	3,796	573	2,500	7,628
Plaice	6,358	1,290	583	95	35
Sole	1,100	75	314	35	32
Turbot	682	60	35	159	81
Herring	181	0	69	238	1,336
Hake	1,056	371	6	0	0
Lumpfish	6	7	512	262	95
Pollack	476	453	14	3	1
Other species	1,823	604	991	879	1,406
Total	21,531	6,656	3,097	4,171	10,614

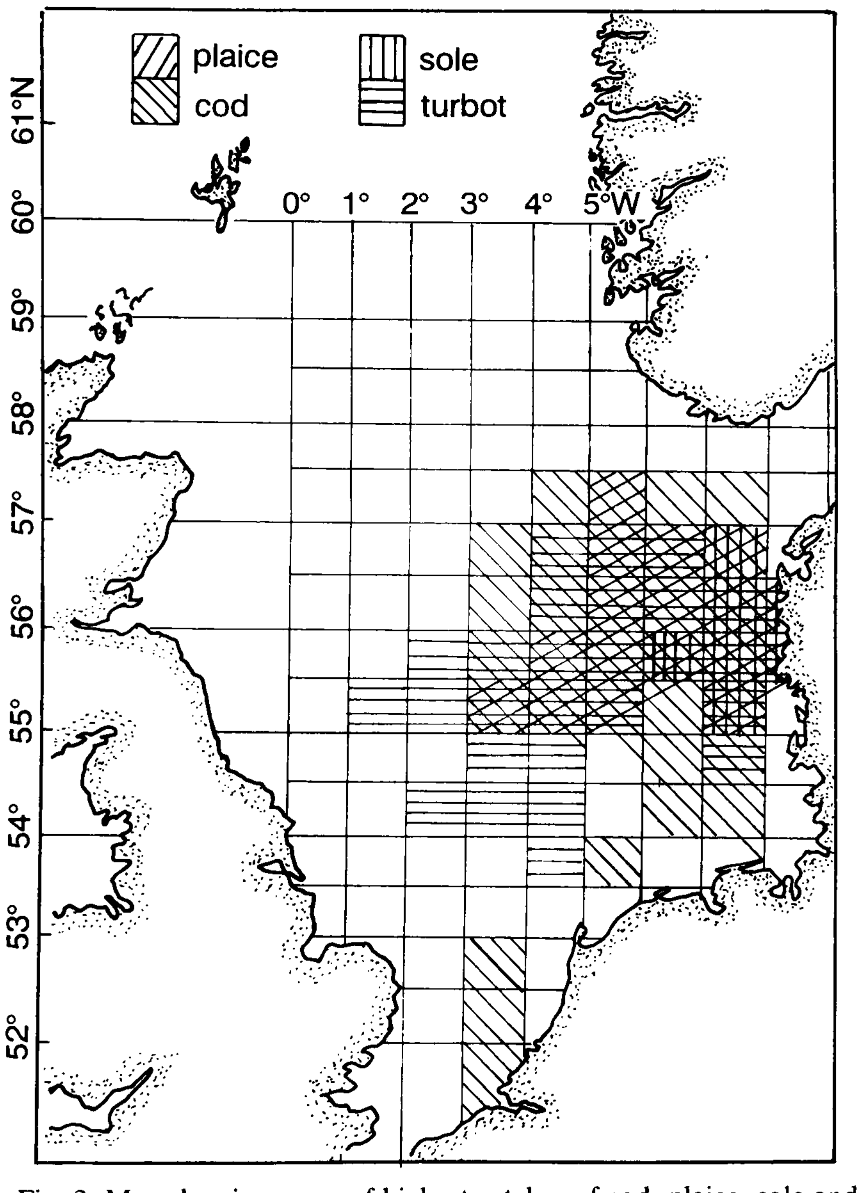

Fig. 2. Map showing areas of highest catches of cod, plaice, sole and turbot, taken by Danish gillnetters in the North Sea (based on information in Vinther, 1994). Smaller catches are taken outside these areas.

Flatfish fisheries

Turbot nets are mainly monofilament, with large mesh sizes (up to 270mm); nets are 6½ to 10½ meshes high. The footrope is lead cored. There is a great deal of variation in the flotation used, varying from floating polypropylene ropes to floats of the type used in the cod fishery. All Danish waters are fished, but most effort occurs in the North Sea (Fig. 2) and Western Baltic.

In the sole fishery, monofilament gillnets with mesh sizes of around 100mm are usually used. Nets are 1000 meshes long and 9½ to 16½ meshes high. Hanging ratios are around 30%. The footrope is lead cored and the headrope is usually polypropylene, which is sufficiently buoyant that little or no other flotation is needed. The main fishing area is off the North Sea coast of Jutland (Fig. 2). The fishery has low quotas and only takes place in the spring and early summer. About half of the fishery uses trammel nets. These nets use monofilament or multimono inner meshes of 120mm with outer meshes of 600mm and the nets are 1½-2 outer meshes deep. Hanging ratios are about 40% of the inner net and higher for the outer. Headlines with $20gm^{-1}$ braided in floats are used.

Trammel nets account for about 90% of the plaice fishery. The nets used are similar to those used in the sole fishery, except for a slightly larger inner mesh size, about 150–170mm. The plaice fishery occurs mainly in the North Sea (Fig. 2), Skagerrak and Kattegat. The fishery is year round but location moves with migration of plaice; the peak occurs during the northward migration from April to October.

Other species

The lumpsucker fishery uses similar nets to the turbot fishery, mainly in the Kattegat, the Belts and the Sound. The fish are caught mainly for the lump caviar industry, so the fishery only occurs during spring.

The gear used in the hake fishery is similar to that used in the cod fishery, although the nets have a smaller mesh size and greater height. The fishing area is mainly off the coast of Northern Jutland during the summer.

Driftnet fishery

There are few Danish driftnet fisheries. The major fishery is the fishery for salmon in the Baltic Sea. Kinze (1990) summarised the available information. In the late 1980s, 50–70 driftnetters operated using net panels mounted to a headrope equipped with floaters. The nets are made of polyester multifilament (terylene) which (twine diameter, 0.5mm) nets of 300–350 meshes long and 40–50 meshes deep (mesh size 160mm) with no footrope or an unweighted footrope are used. Usually, some 30 nets are set in a straight line at sunset and hauled just before sunrise (maximum soak time 15 hours). A maximum of 600 nets per vessel per operation is allowed. In 1992, driftnets accounted for about half of the total Danish salmon catch (308 tonnes out of 656 tonnes), worth over 15m Danish kroner (about $US2,500,000). Herring driftnets (small mesh, 45mm) are used only in the Sound, by small vessels.

Pound nets

Pound nets used to be commonly used in Danish waters but numbers have decreased recently (Kinze, 1990). Land fixed pound nets are used in the autumn for eels. This provides the most important part of the poundnetters' income. In spring, the nets are set further offshore for herring and mackerel.

LEVELS OF BYCATCH

Gillnet fisheries

The bycatch of porpoises in the Danish fisheries has, until recently, been poorly documented, although concern was expressed as early as 1983 about the status of the stocks of harbour porpoise in the North Sea and Baltic, due to the apparently large bycatch in the Danish gillnet fisheries

(Andersen and Clausen, 1983; IWC, 1984). Kinze (1994) reported an estimated 750 harbour porpoises from a single harbour (Hanstholm) on the northwest coast of Jutland. Clausen (1990) suggested a conservative estimate of 1–3,000 for the total Danish fishery and Clausen and Andersen (1988) stated that they believed that up to 3,000 animals were taken in the wreck net fishery alone, with a total figure of 'several thousand'. However, these estimates were largely based on information from strandings, animals handed in by fishermen or interviews, and then subject to necessarily simplistic extrapolations. Such results are vulnerable to a number of sources of error and cannot be considered reliable (e.g. see IWC, 1994a; Lien *et al.*, 1994b).

The only systematic study to estimate Danish bycatch numbers is being carried out by DIFMAR (Danish Institute for Fisheries and Marine Research). Bycatches are counted directly by observers on board Danish gillnet vessels fishing in the North Sea. Vinther (1994) presents preliminary results from this survey. In 1993, bycatch statistics were obtained for between 1 and 3% of the total annual fleet effort (51 trips, about 20 vessels from 20–60 GRT, 1,546km nets) for the fisheries and vessel classes involved (sole, turbot and cod fisheries). A total of 117 bycaught porpoises were recorded.

However, a number of problems have been recognised in this study. In particular, these centre around how representative the coverage was of the total fleet and the total fishing area. They can be summarised as follows.

(1) Only vessels greater than 10GRT were sampled. Thus only medium and large gillnet vessels operating in offshore waters were covered. In fact, vessels less than 10GRT account for over 40% of the total fleet tonnage and 25% of the catch.
(2) The directed plaice and hake fisheries (36% of effort of vessels over 10GRT) were not covered.
(3) As in all surveys of this kind, animals which are caught and die but fall out of the net during hauling are usually missed by observers (e.g. Frady *et al.*, 1994). Similarly animals which escape but are fatally injured will not be counted.

Despite these problems, Vinther (1994) extrapolated their data to obtain an estimated total Danish bycatch figure of 4,629 porpoises for 1993 in the sole, turbot and cod fisheries in the North Sea. However, given the clustered distribution of the sampled animals, an estimate stratified by area (which would have resulted in a lower estimate) may have been more appropriate. Vinther (1994) also estimated that approximately 7,000 porpoises were incidentally caught in 1993 for the total Danish North Sea gillnet fleet. While this is the best available estimate, it must be treated with caution until more extensive surveys with a scientifically based sampling strategy are carried out.

Although the data for the North Sea are uncertain, data for the inner Danish waters are almost nonexistent. A brief review by Kinze (1990) noted that bycatches are taken in gillnets in these waters but no estimates of the size of this bycatch are available.

Other fisheries
Although salmon driftnets caught relatively large numbers of harbour porpoises (e.g. 50 specimens collected in a single year) in the 1960s and earlier (Lindroth, 1962), only one was reported between 1986 and 1990 from the Danish fleet (Kinze, 1990).

Catches in pound nets, which are set to catch herring and salmon, are also occasionally recorded (Kinze, 1990), but probably only represent between 1–7% of the total (Clausen and Kinze, 1993), and many of these animals are released alive and apparently unharmed.

In addition to the bycatches in passive gear, it is known that there are some harbour porpoises caught in midwater trawls (van Utrecht, 1978; Andersen and Clausen, 1983; Northridge and Lankester, 1990). The total trawl bycatch appears to be much less than that in static gear, although some individual hauls produce large numbers. Reliable data are sparse but the few studies in Danish waters suggest that the catch in trawls may represent 2–19% of the total bycatch (Clausen and Kinze, 1993).

Effect on harbour porpoise population(s)
In order to properly assess the impact of the bycatches on harbour porpoises, the following information is required:

(1) reliable estimates of bycatches for all countries in the region;
(2) knowledge of harbour porpoise stock identity and migration patterns;
(3) reliable estimates of population size.

Bycatch estimates
As we have shown, estimates of bycatch numbers in Danish fisheries are poor for the North Sea and almost non-existent for inner Danish waters and the Baltic. Information on bycatches for other fleets fishing in these and adjacent waters is also poor.

In Norway, the main bycatch was thought to be in the salmon driftnet fishery (96 recorded in 1988) and this influenced the banning of driftnets. However, the data available are insufficient for assessing the total mortality in Norwegian fisheries (Bjørge *et al.*, 1991).

German data are also limited (see review by Benke, 1994). From 1987–94, annual reported catches in the western part of the German Baltic ranged from 6–26, mainly between May to November coinciding with the observed migration pattern through Danish waters. In the German North Sea, the level of bycatch is unknown. The situation in Swedish waters is summarised by Berggren (1994).

In Britain, there are few available figures on bycatches in the gillnet fishery, but catches occur regularly in set nets along the east coast (Northridge and Lankester, 1990). A scheme to record bycaught and stranded animals, co-ordinated by the Institute of Zoology in London, is now in place (Anon., 1992).

In Poland, approximately 1 harbour porpoise per year has been recorded (sighted, stranded or caught) since the second world war (Skora *et al.*, 1988; Skora, 1991).

Stock identity and migration patterns
Harbour porpoises migrate seasonally through the Danish Belt Seas into the western Baltic (e.g. Möhl-Hansen, 1954) and this regular migration allowed the long history of direct exploitation in Danish waters (Kinze, In press). As several authors have noted, the abundance of the harbour porpoises in these areas, particularly in the Baltic seems to have declined and/or the distribution narrowed (e.g. Clausen and Andersen, 1988).

Although there is evidence of several population units in the Baltic/North Sea region, stock identity is poorly understood at present (IWC, 1992, p.209). If the impact of bycatches is to be determined, improving our knowledge of stock structure in these waters should be accorded high priority.

Population size
Until recently, little was known about the numbers of harbour porpoises in these waters. The first quantitative work was carried out in Danish and German waters by Heide-Jorgensen *et al.* (1992; 1993). However, in July 1994, a major multi-national survey of the Baltic and North Sea area was undertaken (Anon., 1994). Although analyses of the results are not yet complete, this survey should provide a useful base for attempting to evaluate the effect of bycatches on harbour porpoise stocks.

Implications for the fishing industry
The cost to gillnet fishermen in terms of damage to gear and loss of catch caused by entanglement of marine mammals can be high; annual losses of $2,000,000 were estimated for Newfoundland, but this included damage by seals and large whales (Lien *et al.*, 1988). The losses experienced by Danish fishermen cannot be quantified from the available data but in general they do not consider the losses to be significant. The main impact on the Danish fishing industry is probably in the form of the negative publicity which is associated with the bycatch of marine mammals. Public pressure has had a major impact on fisheries around the world in terms of changed fishing practices (e.g. the tuna fishery in the eastern tropical Pacific – see IWC, 1992), closed seasons (e.g. New Zealand – Dawson, 1991a) and even complete bans (e.g. driftnetting in many areas including the North Pacific – see Nagao, 1994). All these measures may, of course lead to losses of income to the fishing industry and in some cases lead to fishermen losing their livelihood. However, it should be noted that changes in fishing gear and practices may have unforeseen ecological consequences that should be monitored, such as reducing the average length of the target fish species caught or increasing bycatches of non-marine mammal species (e.g. Joseph, 1994).

The increasing public awareness of the bycatch of harbour porpoises in gillnets in Denmark is likely to result in more pressure being put upon the fishermen to reduce this bycatch, and may result in legislation closing areas to fishing or in regulation of gear types. Current US legislation in the western North Atlantic states that the deaths of harbour porpoises must be significantly reduced towards zero in the near future (Read, 1994). One beneficial effect of this is that it has resulted in co-operation between fishermen and scientists to attempt to achieve this (Fullilove, 1994). It is important that the fishing industry, biologists and gear technologists work together to find solutions to bycatch problems which will minimise the difficulties to the industry, without losing the practical benefits of gillnets as a gear type (IWC, 1994a).

POSSIBILITIES FOR BYCATCH REDUCTION

A major difficulty in attempting to reduce cetacean bycatches is our lack of knowledge of why cetaceans become entangled (IWC, 1994a). In simple terms, it is not known if porpoises get entangled in the gear because they do not know it is there (detection) or if they do know it is there but do not perceive it as a threat (classification). Much of the early work on modifying gear relied on the trial-and-error approach, rather than an understanding of the physiology of the animals and the entanglement process.

Acoustic devices
A considerable body of work now exists that shows that cetaceans are at least theoretically able to detect gillnets acoustically (e.g. Au and Jones, 1991; Dawson, 1991b; Au, 1994; Goodson *et al.*, 1994a). At present there are two schools of thought concerning the utility of using acoustic devices (either 'passive' or 'active') to reduce cetacean bycatches (IWC, 1994a). Some authors (e.g. Dawson, 1991b; 1994) believe that this approach is unlikely to succeed, whilst others (e.g. Goodson *et al.*, 1994a; b; Hatakeyama *et al.*, 1994) believe that the approach has considerable potential. It is not appropriate to enter into this debate here but merely to note that there is some evidence from field trials that is encouraging for both acoustic enhancement of nets (Goodson *et al.*, 1994b) and the use of a commercially available buzzer (Lien *et al.*, 1994a). As yet, however, there remain problems of sample size in determining their effectiveness and in the practical deployment of modified gear in an actual fishery.

Other alterations to fishing gear

Net height
Vinther's (1994) data from the North Sea suggested that the catch rate per hour may be correlated with the net height (and hence area of mesh), but no such correlation was observed in the Gulf of Maine (Frady *et al.*, 1994). As yet the evidence is equivocal and from the fishermen's perspective, any change in the net height will only be acceptable if it is not associated with a significant reduction in the catch of the target species.

An approach which may have some potential to reduce bycatches in flatfish fisheries is to reduce the effective fishing height of the net by reducing the amount of flotation. It is known that the effective height of the net during fishing is less than the rigged height and varies due to tidal flow (Stewart, 1988). Fishermen do not consider that it is important to have great flotation on nets for flatfish (many sole nets have almost no flotation) and it is thought that these nets are effective when almost flat on the bottom due to the habits of the target species. However, it is likely that this approach would reduce catches of groundfish species.

Mesh size
All mesh sizes pose some risk to porpoises, but there is no clear evidence that different mesh sizes result in different bycatch rates (e.g. Frady *et al.*, 1994). Any change in mesh sizes will of course affect the size of fish caught and perhaps the species composition of the catch; this will probably be unacceptable to fishermen.

Hanging ratio
The hanging ratio for most demersal gillnets used in the North Sea, Baltic and in the Western Atlantic, is approximately 30–50%. The hanging ratio has an effect on whether fish are gilled or tangled in the net (more are gilled, fewer tangled with tighter hanging ratios). This is especially the case for the flatfish fisheries that use very slack nets and catch many fish by entanglement. This may be relevant to porpoises, with more tightly stretched meshes causing the porpoises to 'bounce off' the netting without getting entangled (Dawson, in Frady *et al.*, 1994). However, increasing the hanging ratio would be likely to cause a decrease in target species catch rates.

Bridle changes

It has been suggested that widening the gaps between nets in a string may reduce cetacean bycatches (Frady *et al.*, 1994) but this would probably only be viable if the cetaceans perceive the nets and require a gap to go through. It may be useful as a supplement to the use of passive acoustic reflectors in driftnets (Goodson and Mayo, 1994).

Changes in fishing strategy

Frady *et al.* (1994) found a lower than expected bycatch in over 90 fathoms depth. If the animals have shallower areas available in which they prefer to forage, then minimum depth restrictions may be useful in reducing bycatches.

Frady *et al.* (1994) also found evidence that harbour porpoises forage more in areas of high bottom relief and this might be useful in identifying areas with high porpoise activity in order that they may be closed to fishing. It may cause a conflict among fishermen however, by moving gillnetters onto grounds which are usually fished by trawlers. This may result in a loss of gear and a reduction in catch.

CONCLUSIONS

For centuries, thousands of harbour porpoises were hunted for domestic purposes in Denmark; this direct hunt ceased after the second world war (Kinze, 1994). Since then, increasing fishing effort has caused an increasing conflict with the harbour porpoise. The DIFMAR study (Vinther, 1994) in the North Sea has shown that this problem is far larger than was previously thought, but the estimates are still unreliable. Despite our present inability to adequately quantify the impact of bycatches on harbour porpoises, the available information makes it clear that bycatches in fishing gear now appear to represent the main threat to the harbour porpoise.

Methods to reduce bycatches of marine mammals can be grouped into those which involve stopping fishing (either by closed areas, seasons or restricting gear types) and those which involve modifying fishing gear and/or practice. Our knowledge of the areal and temporal variation in harbour porpoise stocks is insufficient to recommend specific closed areas or closed seasons which will reduce bycatches. The most promising gear modifications appear to be those involving passive or active acoustic approaches. Tests of these approaches are so far inconclusive but show potential. Further development work and thorough testing of their effectiveness and practicality is needed.

Governments in the region have accepted that fishing operations pose a potential threat to cetaceans, particularly the harbour porpoise. In September 1994, the first meeting of the parties to ASCOBANS (Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas) took place. The parties, including Denmark, passed a Resolution on the implementation of a conservation and management plan for the region. This included a number of priorities for action including: reduction of pollution; reduction of direct and indirect interactions with fisheries (including reliable estimation of bycatch numbers and research on gear and fishing method modification); reduction of 'disturbance'; and monitoring, status and population studies (ASCOBANS, 1994). It is to be hoped that Governments fulfil their own guidelines in these matters.

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Bycatches of the Harbour Porpoise (*Phocoena phocoena*) in the Swedish Skagerrak, Kattegat and Baltic Seas; 1973–1993

Per Berggren

Department of Zoology, Stockholm University, S-106 91 Stockholm, Sweden

ABSTRACT

The harbour porpoise is the only cetacean common to Swedish waters. This paper reviews data on harbour porpoise bycatches in the Swedish Skagerrak, Kattegat and Baltic Seas between 1973 and 1993. Bycatches in various fisheries are the major threat to harbour porpoises in Swedish waters. Gillnet fisheries are responsible for more than 80% of all incidental takes. Although bycatches occur year round in all areas, 51% were collected during three months; March, April and May. Bycatches occur in water depths between 0 and 100m, suggesting that depth restrictions for fisheries are not likely to reduce catches. In the Skagerrak Sea, 47.5% of the bycatches were taken in gillnets set for spiny dog fish in water depths between 40–80m; in the Kattegat Sea 72% were taken in gillnets set for cod in depths between 20–60m and in the Baltic Sea, 53.8% of the bycatches were taken in surface driftnets for salmon. It is not possible to quantify the threat bycatches represent to harbour porpoises in Swedish waters in the absence of reliable estimates of bycatches or abundance and uncertainty over stock identity. However, the existence of bycatches is a serious cause for concern and immediate action is needed.

KEYWORDS: INCIDENTAL CAPTURE; NORTH ATLANTIC; HARBOUR PORPOISE; FISHERIES.

INTRODUCTION

The harbour porpoise is the only cetacean common to Swedish and Baltic waters (e.g. see Aguayo L, 1978). There are reports of Polish (Skora *et al.*, 1988) and Danish (Kinze, 1995) fisheries for harbour porpoises as early as the 14th century. Anecdotal evidence suggests that all countries with a Baltic Sea coastline were engaged in harbour porpoise hunts to some extent during the 19th century. However, the only documented records of catches are from Danish waters in the 19th and early 20th centuries, when the annual hunt in the Danish Belt Seas in some periods averaged more than 1,000 animals (Andersen, 1982; Kinze, 1995). Catch numbers gradually decreased by the end of the 19th century, but whether this was due to a reduction in population size or a decreasing demand for porpoise meat and blubber is unclear. There have been no directed catches since the 2nd World War. There is no information to indicate a similar hunt in the Swedish Kattegat and Skagerrak Seas.

Every year, large numbers of harbour porpoises (*Phocoena phocoena*) are incidentally caught in fishing gear around the world (IWC, 1994). In most of these areas, population sizes have not been estimated and only minimum estimates of numbers of bycatches are available, based on the opportunistic collection of bycaught specimens. In a few cases, the development of independent observer schemes has made it possible to better estimate the total bycatch of animals (Smith *et al.*, 1993; Berrow *et al.*, 1994; Vinther, 1994) but unless the schemes are carefully designed and of adequate scale, the resultant estimates may still be unreliable (e.g. see Lowry and Teilmann, 1994). In perhaps the best studied area, the Gulf of Maine in the Northwest Atlantic, between 2 and 5% of the estimated population size has been estimated to be killed by incidental capture in the bottom set gillnet fishery (Smith *et al.*, 1993). Modelling exercises have shown that harbour porpoise stocks have limited potential to replace even moderate takes (Barlow, 1986; Woodley and Read, 1991).

Swedish fisheries are no exception to the general pattern and this paper reviews data on the harbour porpoise bycatch in Swedish coastal waters between 1973 and 1993. Data up to 1988 were discussed briefly in Lindstedt and Lindstedt (1989). The data presented here have been divided up into three geographical areas: the Skagerrak Sea, the Kattegat Sea and the Baltic Sea (Fig. 1), based on oceanographic and habitat differences between these areas and, as discussed later, the possible existence of a separate harbour porpoise stock in the Baltic Sea.

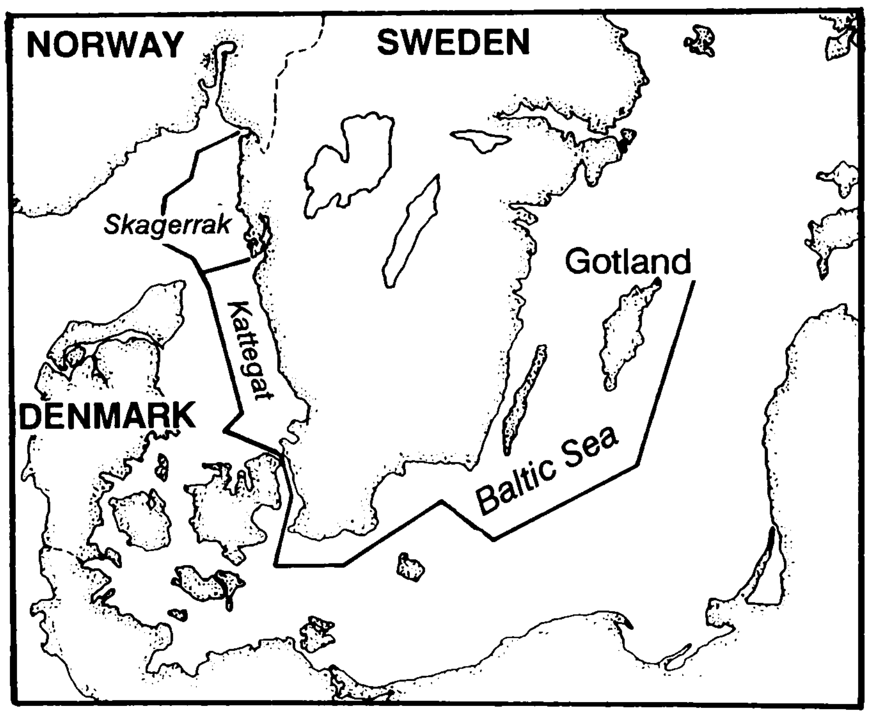

Fig. 1. Map showing the Skagerrak, Kattegat and Baltic Seas; areas where harbour porpoise bycatches occur in Swedish waters. The discontinuation of the line to the north of the island of Gotland in the Baltic Sea signifies no reports of bycatches beyond this point in the last two decades.

The areas were divided according to Fonselius (1994). The border between the Skagerrak and Kattegat Seas is between Skagen, Denmark and Pater Noster, Sweden, while that between Kattegat and the Baltic is the island of Saltholm in Öresund.

Legal status of the harbour porpoise in Swedish waters

The harbour porpoise has been protected in Sweden since 1 July 1973. Hunting Ordinance paragraph 33 states that any harbour porpoise found stranded, or that is incidentally killed, is state property and should (according to para. 36) be reported to the police as soon as possible. Para. 37 states that a report shall include information as to where and when the animal was killed or found dead. The police should, after receiving a report, ensure that the animal is properly handled according to regulations set by the Swedish Environmental Protection Agency (SEPA; para. 36). Para. 35, that allowed professional fishermen to kill trapped and entangled porpoises and keep them, was abolished in 1992.

MATERIALS AND METHODS

The Museums of Natural History in Sweden have collected and kept records of bycaught harbour porpoises for more than 100 years. However, only a few animals per year were collected prior to their protection in 1973. Following this, the collection of specimens became more systematic. The National Natural History Museum of Stockholm was the main collector of animals between 1973 and 1988. It also performed post-mortem analyses and collected samples for future analyses.

In June 1988, a scheme that attempted to collect all bycaught and stranded harbour porpoises was started. Requests for animals were sent to fishermen with a promise of a SEK 150 (approx. US$25) reward for every animal submitted. This scheme continued until January 1992. In total, 504 harbour porpoises were collected in the Kattegat, Skagerrak and Baltic Seas between June 1988 and December 1991. Most of these were collected by the National History Museum of Gothenburg.

In Sweden, protected fauna and flora are managed by SEPA and in 1992, SEPA stipulated that all reports of harbour porpoises bycaught or found stranded be sent to them. They also set new guidelines to the effect that only animals from the Baltic Sea should be collected whilst those found in the Kattegat and Skagerrak Seas should merely be reported. For this purpose, in the summer of 1993, SEPA distributed a new combined information folder and reporting form for the recording of sightings, strandings and bycatches of harbour porpoises. The folder was distributed to all fishermen, the coastguard, police, county and municipal officials and others. Following the decision not to collect animals from any areas but the Baltic Sea, and the lack of follow-up on the distributed folder, there was a drop in the number of reported bycatches and strandings in the Kattegat and Skagerrak Seas to levels similar to the Baltic Sea; approximately 5 animals per year.

When submitting bycaught porpoises, fishermen also provided information on the bycatch location, the type of gear used and the water depth in which the gear was set.

At the time of writing no effort data are available for the different fisheries. It is thus not possible to provide any detailed analyses of bycatches by gear type or relative effort.

RESULTS

A summary of the number of harbour porpoises collected by the Museums of Natural History between 1973 and 1988 and at the Natural History Museum in Gothenburg between 1988 and 1991, and the relative frequency of bycatches and strandings is shown in Table 1. Reported and collected animals are given for 1992 and 1993.

Table 1

Number of harbour porpoises collected from bycatches and strandings during the two periods of 1973-1988 and 1988-1991. The records for 1992 and 1993 are for reported and, in the case of the Baltic, collected animals.

	1973-1988	1988-1991	1992	1993
Bycatches	169 (65%)	297 (59%)	6	9
Strandings and floaters	70 (27%)	201 (40%)	6	6 *
Unknown	21 (8%)	6 (1%)	-	-
Total	260	504	12	15

* Including 3 collected from the Baltic.

The relative distribution of collected bycatches by month (Fig. 2) for the three years, January 1989 to December 1991 (n=270) shows that bycatches occur year round in all areas. During that period, most (70%) catches occurred in the Kattegat Sea followed by the Skagerrak (22%) and the Baltic (8%) Seas. There was a peak in bycatches in April and 51% of the bycatches were collected during the months of March, April and May.

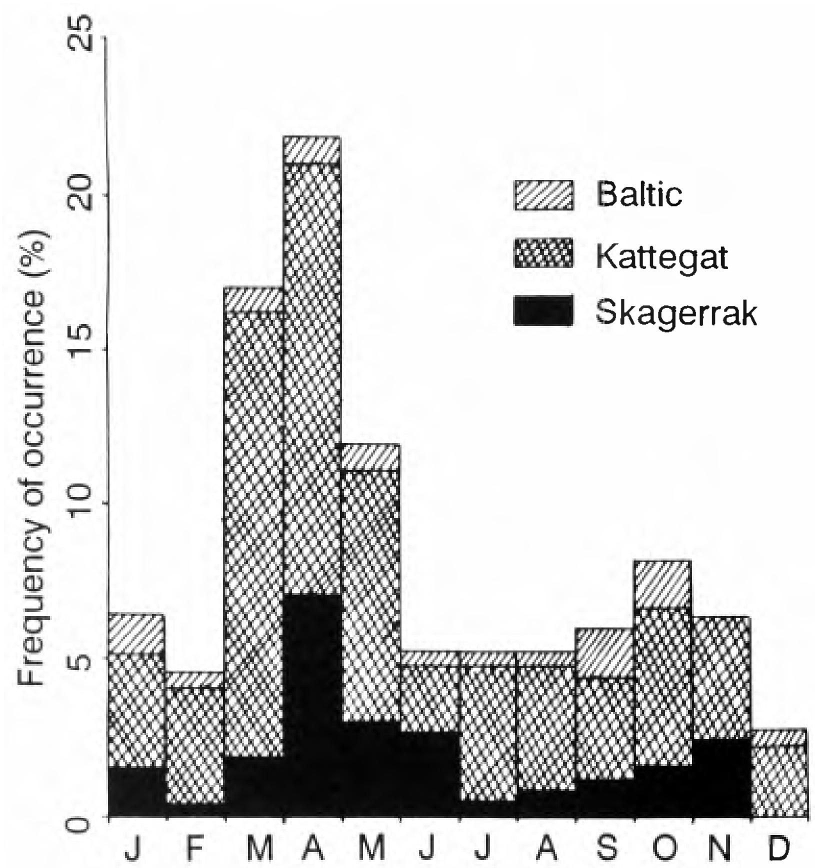

Fig. 2. The relative frequency of harbour porpoises caught by month for the Skagerrak, Kattegat and Baltic Seas between 1989 and 1991. A total of 270 specimens were collected.

The relative frequency of harbour porpoise bycatches in various gear used for the period 1989–1991 in the Skagerrak, Kattegat and the Baltic Seas is shown in Fig. 3. Gillnet fisheries are responsible for more than 80% of the bycatches in all three areas. In the Skagerrak Sea (n=59), 47.5% of the bycatches collected were in gillnets set for spiny dogfish while in the Kattegat Sea (n=175), 72% taken were in gillnets set for cod and in the Baltic Sea

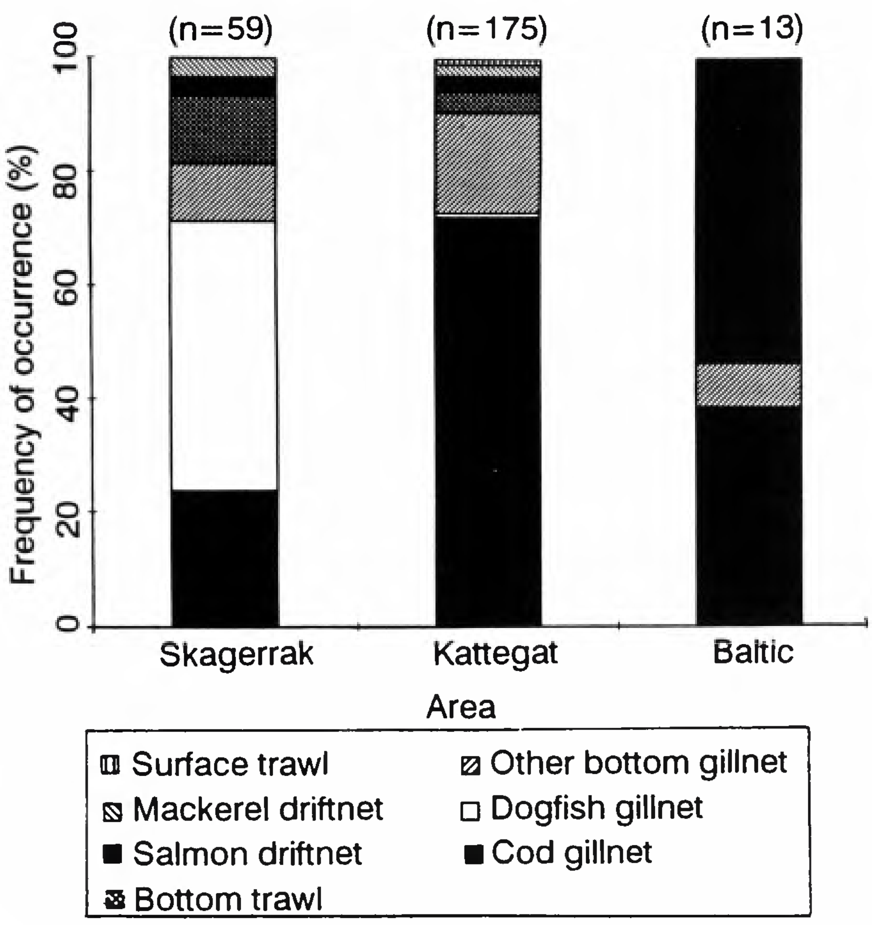

Fig. 3. The relative frequency of harbour porpoises bycaught in different types of fishing gear for the three areas studied; The Skagerrak, Kattegat and Baltic Seas between 1989 and 1991.

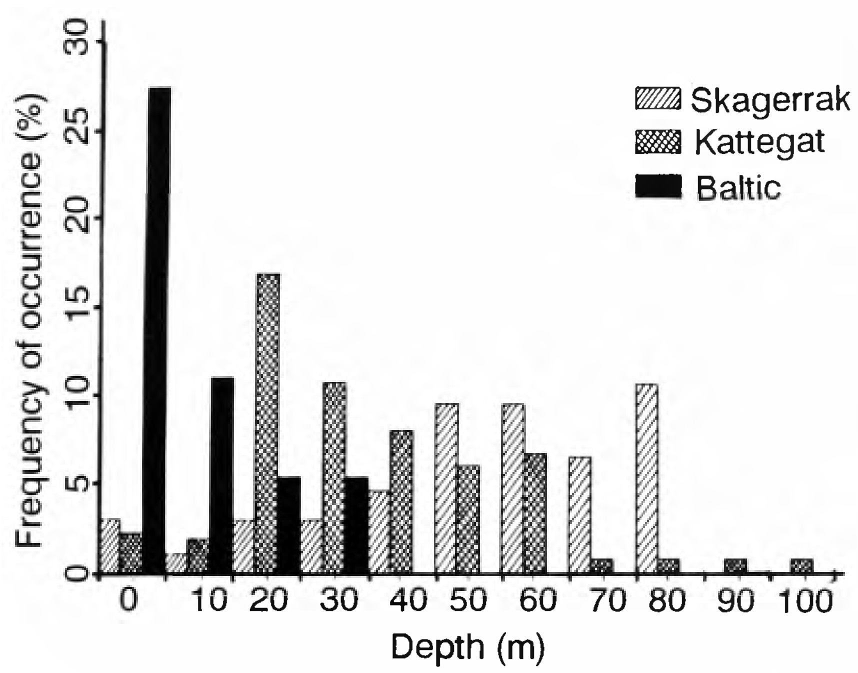

Fig. 4. The relative frequency of water depths in which 48 harbour porpoises were bycaught in the Skagerrak Sea between 1989 and 1991; 47 harbour porpoises were bycaught in the Kattegat Sea between 1989 and 1991 and 9 harbour porpoises were bycaught in the Baltic Sea between 1989 and 1991.

(n=13), 53.8% of the bycatches were in driftnets for salmon. Mesh size varied between 40–180mm for the different fisheries.

Water depth

Fig. 4 shows the depth distribution of bycatches between 1989–1991. In the Skagerrak Sea (mean depth 218m), 79% of the bycatches (n=48) occurred in water depths between 40–80m whilst in the Kattegat Sea (mean 25m), 86% (n=147) were between 20–60m. In the Baltic Sea (mean depth 67m) most (78% n=9) catches were in shallow waters between 0 and 10m.

Age distribution

Fig. 5 shows the age distributions of collected harbour porpoises from Swedish waters that have been aged at the time of preparation of this paper (November 1994). We are currently ageing the samples at the University of Stockholm. No preference was given as to which animals were aged first.

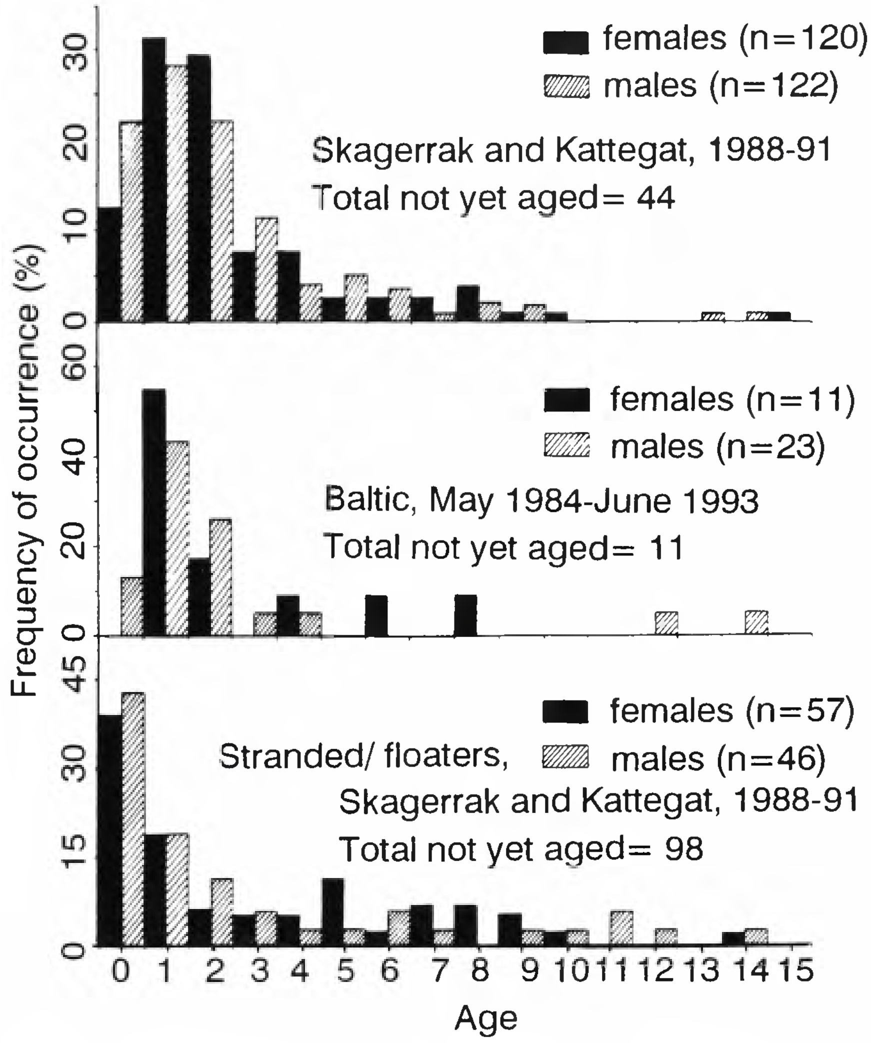

Fig. 5. The relative representation of age classes of harbour porpoises (a) bycaught in the Swedish Skagerrak and Kattegat Seas between 1988 and 1991; (b) bycaught in the Swedish Baltic Sea between 1984 and 1993; and (c) found dead, stranded or floating in the Skagerrak and Kattegat Seas during 1988–1991.

DISCUSSION

Impact of bycatches

In order to assess the impact of bycatches on a population or populations, the following information is needed:

(1) an estimate of the total bycatch (from more than one nation where appropriate);
(2) an understanding of stock identity and migration;
(3) an estimate of population size for the relevant population(s).

Of course it must be recognised that other threats than bycatches (e.g. pollution, habitat degradation) may have a negative impact on harbour porpoises in these waters.

Estimation of bycatches

Sweden does not have an independent observer scheme to monitor bycatches aboard fishing vessels. The information presented in this paper is insufficient to allow a reliable estimate of the bycatch of harbour porpoises in Swedish waters to be made. The changes to the legal and reporting situations described above have also made interpretation of the available data problematic.

On average, about 17 harbour porpoises were collected annually in Swedish waters between 1973 and 1988, compared to 150 animals per year between 1988 and 1991. This approximately tenfold increase in the number of animals collected can largely be attributed to the increased effort made to collect animals during the latter period, as a result of the scheme established in June 1988. It is clearly inappropriate to interpret the difference between the two collection periods as either an indication of an increase in the abundance of harbour porpoises or an increase in the actual bycatch. This view is supported by the fact that only 12 and 15 animals were reported bycaught or stranded in 1992 and 1993, with the advent of the SEPA guidelines.

These changes in numbers are consistent with the findings of the first attempt to study the Swedish bycatch problem by Lindstedt and Lindstedt (1987), who carried out a questionnaire survey of 68 fishermen. They found that the fishermen had officially reported only 13% of their actual bycatches to the authorities between 1973 and 1986.

Despite our inability to estimate total bycatch, however, the 1988–91 data do provide an absolute minimum estimate of the number of bycaught animals in Swedish waters.

Bycatches by other fleets that may have an impact on harbour porpoise population(s) affected by Swedish fisheries are discussed in Kinze (1990), Lowry and Teilmann (1994), Benke (1994), Skora *et al.* (1988) and Skora (1991).

Stock identity and migration

The stock identity of harbour porpoises in the Baltic/North Sea region is poorly understood, although there is some evidence suggesting that there may be several population units (IWC, 1992; p. 209).

Preliminary results from morphometric studies (Börjesson and Berggren, 1993) indicate that harbour porpoises collected in the Baltic and Skagerrak Seas belong to separate stocks. Andersen (1982) described a migration of harbour porpoises into the Baltic Sea in early spring and out of the area during late autumn, based on anecdotal notes and catch statistics. Incidental takes in Swedish fisheries however, show that at least some harbour porpoises spend winter months in the Baltic proper (Fig. 2). Anecdotal records also show that during severe ice winters, bottom trawl fisheries in the Baltic Sea catch a large number of animals that have apparently drowned under the ice (Hanström, 1960). This supports the view that some animals stay in the Baltic Sea year round. Fig. 2 also shows that some animals remain in the Skagerrak and Kattegat Seas year round.

In the absence of better information on stock structure, a conservative management approach would be to treat harbour porpoises in these areas as separate 'units'.

Population size

There is little information on either the historic or current population abundance of harbour porpoises in Swedish waters. Berggren and Pettersson (1995) compared results from a questionnaire survey that strongly indicated that the number of sightings of harbour porpoises in Swedish waters had significantly declined since the 1950s.

In July 1994, a major multinational survey of the North Sea/Baltic Sea region was undertaken (Anon., 1994). This survey, however only attempted to cover the western part of the Baltic Sea and poor weather led to poor coverage in that area. However, even a crude examination of the results reveals considerably lower densities in Baltic waters, supporting the generally held view that the numbers in the Baltic may have declined and its distribution narrowed (e.g. Kinze, 1995). There are plans to survey the whole of the Baltic Sea in summer 1995. The analyses of the 1994 data are not yet complete but the results should provide a useful base for attempting to assess the impact of bycatches in the surveyed area, including the Skagerrak and Kattegat Seas.

Possible measures to reduce bycatches

It is not appropriate here to discuss in detail the various approaches that have been suggested to try and reduce cetacean bycatches (e.g. see Dawson, 1994; Goodson *et al.*, 1994; IWC, 1994), but merely to note that no effective method of modifying gear has yet been developed. In this section I will simply examine the limited data available for the Swedish fishery and explore any potential for reducing bycatches (I have not commented on any effect on fishery yields).

Seasonal restrictions

Fig. 2 showed that the peak months for bycatches in the Skagerrak and Kattegat Seas were from March-May. Fig. 3 reveals that 81.4% of the Skagerrak and 90.3% of the Kattegat Sea bycatches occurred in the bottom set gillnets. Clearly in the absence of fishing effort data it is not possible to determine the strength of the seasonality factor i.e. whether it is merely a direct reflection of effort, but the possibility of reducing bycatches by restricting bottom set gillnet effort in the spring warrants further attention.

Depth restrictions

Fig. 4 shows that bycatches are taken in nets set at all depths down to 100m in the Kattegat and Skagerrak Seas. This suggests that depth restrictions are unlikely to reduce bycatches in these Seas. In the Baltic, over half the bycatches occur in the salmon driftnet fishery in depths of 0–10m.

Age distribution of the samples

Fig. 5 shows the age distributions of the animals aged thus far. In all areas, animals between 0–2 years predominated. This is not an unknown feature in several areas and may be a result of a number of factors including lack of experience or greater curiosity in juveniles (e.g. see IWC, 1994). The samples revealed no apparent difference in mortality between males and females.

Yearlings of both sexes were the most common age class found stranded in the Skagerrak and Kattegat Seas. This indicates that for whatever reason females are not always successful in raising their young. Of the older animals found stranded, some will probably have died of natural causes and others will be animals that have been caught and then fallen out of nets, or been dumped at sea by fishermen. That the latter occurs is supported by fresh net marks found on some stranded animals.

CONCLUSIONS AND RECOMMENDATIONS

The data presented in this paper do not allow for an evaluation of how serious a threat bycatches are to harbour porpoises in the Swedish Skagerrak, Kattegat and Baltic Seas, since no reliable estimates of either bycatches or abundance exist yet, and stock identity is uncertain.

However, the level of bycatches appears to be the most serious threat to harbour porpoises in Swedish waters, although other factors such as habitat degradation and pollution should also be regarded when assessing the status of this species in the Skagerrak, Kattegat and Baltic Seas. This is particularly true if the animals in the Baltic represent a separate population; even the low level of bycatches may be sufficient to prevent recovery.

I recommend that the following action should be taken:

(1) immediate efforts should be made to reduce bycatches;
(2) reliable estimates of bycatches (through a scientifically designed observer programme) should be obtained;
(3) estimates of the abundance of harbour porpoises in Swedish and adjacent waters should be obtained;
(4) the question of stock identity should be addressed.

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A Note on Cetacean Bycatches in German Waters

Harald Benke

Forschungs–und Technologiezentrum Westküste der Universität Kiel, Werftstr. 10, D-25761 Büsum, Germany

ABSTRACT

This note summarises available information on bycatches of harbour porpoises in German waters since 1987. Most information is for the cod set net fishery in Schleswig-Holstein. More recently, information on catches in the North Sea fishery has come to light. It is not yet possible to reliably estimate the actual bycatch numbers.

KEYWORDS: INCIDENTAL CAPTURE; FISHERIES; HARBOUR PORPOISE; NORTH ATLANTIC; BALTIC

INTRODUCTION

This short note summarises briefly, available German bycatch information. A more comprehensive review will be presented at a future date. Although a number of cetacean species are found in German waters (Benke and Siebert, 1994), the harbour porpoise (*Phocoena phocoena*) is by far the most common and the one for which a bycatch problem exists.

THE FISHERIES

The most important fishery in German waters with respect to harbour porpoises appears to be the set net fishery for cod. The fishery is concentrated in Schleswig-Holstein in an area between 54°32′N - 54°50′N and 9°52′E - 10°10′E and most effort is from August to March (Benke *et al.*, 1991). Nets are usually set overnight at depths of 5–40m (typically 7–13m). Monofilament triple nets with an outer mesh size of 300mm and an inner mesh size of 65–75mm are used. Typically, they are up to 600m long and 1.2m deep. Several hundred part-time and full-time vessels operate. Trammel net and trawl fishing also occur.

The main German fisheries in coastal North Sea waters are an otter trawl fishery for cod and flatfish, a beam trawl fishery for sole, plaice and brown shrimp and, seasonally, a small-scale set net fishery for sole (which is currently conducted by 12 vessels).

INTERACTIONS WITH HARBOUR PORPOISES

Investigations on harbour porpoise bycatches began in the late 1980s, centred at the University of Kiel. Contacts were made with local fishermen and authorities and a reporting and collection scheme was initiated. Between 1987 and 1990 a total of 41 bycaught harbour porpoises were recorded in coastal Baltic Sea waters off Schleswig-Holstein, 37 in set nets, with a peak between August and November (Benke *et al.*, 1991).

In 1990, a more comprehensive project to investigate harbour porpoises in German waters began, which included surveys to examine abundance and distribution (Heide-Jørgensen *et al.*, 1992; 1993). That programme was completed at the end of 1993 and a preliminary report is given in Bohlken and Benke (1993). Reported harbour porpoise bycatches between 1990 and 1993 are given in Table 1. The reported bycatch of harbour porpoises in the German North Sea fishery is low and there is circumstantial evidence (anecdotal records from fishermen) that it is underreported. The bycatch figure in the western Baltic is probably much closer to the true figure but has to be considered as a minimum estimate.

Table 1

Reported bycatches of harbour porpoises by German fisheries in the North and Baltic Seas.

Year	North Sea	Baltic Sea
1990	0	21
1991	4	26
1992	2	6
1993	6	5

It is not possible to estimate the total bycatch by German vessels from the available data but a number of projects to improve estimates of bycatches and to assess their impact are underway (Anonymous, 1994a, Appendices B and C). Germany participated in the multi-national survey to estimate harbour porpoise abundance in the North Sea in summer 1994 (Anonymous, 1994b) and is a signatory to the Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS, 1994; Donovan, 1994). Information on bycatches from other nations that might involve the same harbour porpoise population(s) is given in Kinze (1990), Berggren (1994) and Lowry and Teilmann (1994).

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Central America and Caribbean

Cetaceans and Gillnet Fisheries in Mexico, Central America and the Wider Caribbean: A Preliminary Review

Omar Vidal

Departamento de Ciencias Marinas and Centro do Conservación y Aprovechamiento de los Recursos Naturales, Instituto Tecnológico y de Estudios Superiores de Monterrey-Campus Guaymas, Ap. Postal 484, Guaymas, Sonora 85400, Mexico

Koen Van Waerebeek

Centro Peruano de Estudios Cetológicos, c/o Asociación de Ecología y Conservación, Vanderghen 560, Lima 27, Peru

and

Lloyd T. Findley

Centro de Investigación y Desarrollo de los Recursos Naturales de Sonora-Unidad Guaymas, Miramas 63 Plata Alta, Col. Miramas, Guaymas, Sonora 84150, Mexico

ABSTRACT

This paper reviews published and unpublished information on the mortality of cetaceans in gillnets in Mexico, Central America and the wider Caribbean. Data on this incidental mortality are provided from only nine of the 36 nations in the area (Colombia, the Dominican Republic, French Guiana, Honduras, Mexico, Panama, Surinam, Trinidad and Tobago, and Venezuela); the lack of mortality records from the other countries reflects poor or non-existent documentation. We surveyed those types of passive fishing gear which potentially or actually entrap cetaceans in this large area; these included gillnets with mesh sizes of 18 to 400mm. At least 14 species of cetaceans have been caught in fishing nets in this area: vaquitas, common dolphins, bottlenose dolphins, tucuxis, Atlantic spotted dolphins, spinner dolphins, clymene dolphins, Risso's dolphins, killer whales, pygmy sperm whales, botos, gray whales, humpback whales and balaenopterids. At least another five species are potentially at risk: pantropical spotted dolphins, striped dolphins, Pacific white-sided dolphins, false killer whales and short-finned pilot whales. Of special concern is the endangered vaquita in the northern Gulf of California, Mexico.

KEYWORDS: INCIDENTAL CAPTURE; NORTH PACIFIC; NORTH ATLANTIC; VAQUITA; COMMON DOLPHIN; BOTTLENOSE DOLPHIN; TUCUXI; SPOTTED DOLPHIN; CLYMENE DOLPHIN; RISSO'S DOLPHIN; KILLER WHALE; BOTO; PYGMY SPERM WHALE; GRAY WHALE; HUMPBACK WHALE; PANTROPICAL SPOTTED DOLPHIN; STRIPED DOLPHIN; WHITE-SIDED DOLPHIN; FALSE KILLER WHALE; PILOT WHALE–SHORT-FINNED.

INTRODUCTION

The problems of the incidental capture of cetaceans during fishing operations have been highlighted in recent years, e.g. Brownell *et al.* (1989). Data on the magnitude of such kills as a result of large-scale pelagic fisheries have been collected for certain regions, such as the eastern tropical Pacific tuna purse-seine fishery (e.g. Hall and Boyer, 1987; 1988; 1989; 1990) and the Japanese high-seas mothership salmon driftnet fishery (Jones, 1990). However, mortality due to small-scale artisanal fisheries, particularly coastal gillnet fisheries, remains largely unmonitored. The coastal distribution of many cetacean species, particularly dolphins and porpoises, renders them at risk from gillnet fisheries and the potential effect on their populations is a cause for concern among scientists, conservationists and fishery managers (IWC, 1994).

In this paper we review the limited available information on the incidental mortality of cetaceans in gillnets in Mexico, Central America and the wider Caribbean (Fig. 1). We document those types of passive fishing gear (gillnets and traps) which potentially or actually capture cetaceans in this area. The review is preliminary and covers only 26 of the 36 nations in the region. Much more effort will be required to fully assess the magnitude and impact of incidental captures on the populations of cetaceans in the region. Here we can only outline the problem and indicate the many gaps existing in the information from various countries and their fisheries.

Published records

Worldwide reviews of fisheries interactions with cetaceans have been prepared by Mitchell (1975) and Northridge (1984). Based on available literature, Northridge (1984) concluded that most gillnet and trap fisheries in the Caribbean region (FAO Marine Fishing Area 31) and in the Mexican and Central American Pacific region (FAO Area 77) are unlikely to involve interactions with marine mammals. We found only a few published reports dealing with cetaceans incidentally caught in gillnets in these two regions (Caldwell and Caldwell, 1971; Mitchell, 1975; O'Shea *et al.*, 1986; Engeman and Bromaghin, 1990; Ottley *et al.*, 1988; Vidal, 1989; 1990; In press; Agudo, 1990; Van Waerebeek, 1990).

As a result, much of the information we present on the fisheries in the countries involved comes from internal unpublished fishery reports provided by some of the individuals or organisations we contacted.

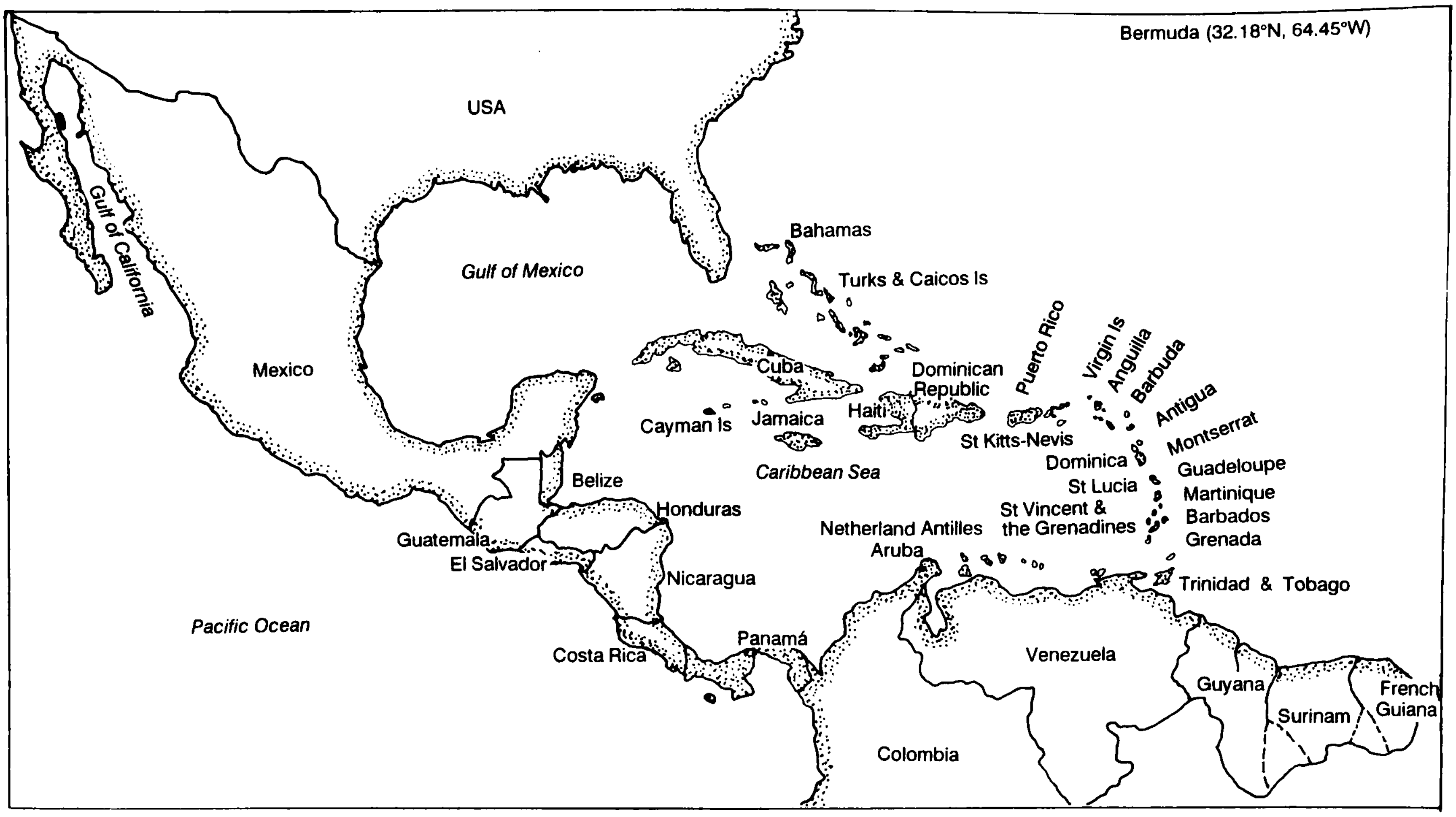

Fig. 1. Study area: Mexico, Central America and the wider Caribbean.

Table 1

Nations and overseas territories/departments within the study area (English spellings are used).

Mexico	Surinam	Guadeloupe, with St. Martin North	Haiti
Guatemala	French Guiana	and St. Barthelemy (France)	Turks and Caicos Islands (UK)
Belize	Trinidad and Tobago	Monserrat (UK)	Jamaica
El Salvador	Netherland Antilles*	Antigua and Barbuda (UK)	Cuba
Honduras	Grenada	St. Kitts and Nevis	Cayman Islands
Nicaragua	St. Vincent and the Grenadines	Virgin Islands (British)	Bahamas
Panama	St. Lucia	Virgin Island (USA)	Bermudas
Colombia	Barbados	Anguilla (UK)	
Venezuela	Martinique (France)	Puerto Rico (USA)	
Guyana	Dominica	Dominican Republic	

* Aruba, Curaçao, Bonaire, St. Maarten South, St. Eustatius and Saba.

METHODS

Published accounts of cetacean mortality in gillnets in the region are scarce or non-existent for most countries. Information was gathered in two ways. Firstly, over 150 letters soliciting information were sent to government agencies, universities and individuals (not necessarily involved in cetacean research). The replies received provided limited information (primarily related to the fisheries and not to cetacean interactions). Secondly, personal observations by the authors, cetacean research biologists and/or reliable local fishermen were used for Mexico, Colombia, Surinam, French Guiana and Venezuela. Difficulties in obtaining data may have been due either to its unavailability or the reluctance of the authorities to provide it for international scrutiny. Sources are identified for each country.

In our report, 'potentially at risk' means that incidental entanglement is strongly suspected but not actually recorded; 'risk' is inferred for coastal species previously reported killed in the same or similar kinds of fisheries.

The 36 nations and overseas departments within the study area and the 19 species of cetaceans involved in the survey are given in Tables 1 and 2, respectively, and shown in Fig. 1.

Table 2

Cetaceans mentioned in this survey.

Vaquita, *Phocoena sinus*
Tucuxi, *Sotalia fluviatilis*
Common dolphin, *Delphinus delphis*
Bottlenose dolphin, *Tursiops truncatus*
Atlantic spotted dolphin, *Stenella frontalis*
Pantropical spotted dolphins, *Stenella attenuata attenuata* and *S.a. graffmani*
Spinner dolphins, *Stenella longirostris longirostris*, *S.l. orientalis* and *S.l. centroamericana*
Striped dolphin, *Stenella coeruleoalba*
Clymene dolphin, *Stenella clymene*
Pacific white-sided dolphin, *Lagenorhynchus obliquidens*
Risso's dolphin, *Grampus griseus*
Killer whale, *Orcinus orca*
Short-finned pilot whale, *Globicephala macrorhynchus*
False killer whale, *Pseudorca crassidens*
Pygmy sperm whale, *Kogia breviceps*
Boto, *Inia geoffrensis* (also known as the Amazon river dolphin)
Gray whale, *Eschrichtius robustus*
Humpback whale, *Megaptera novaeangliae*
Unidentified balaenopterid whale, *Balaenoptera* spp.

ACCOUNTS OF CETACEAN-GILLNET INTERACTIONS BY COUNTRY

No data were available for Belize, Guatemala, El Salvador, Guyana, the Netherland Antilles, Haiti and Anguilla. [For data on Grenada, Montserrat, and St. Kitts and Nevis, see Antigua and Barbuda.]

Mexico[1]

Almost all available information on incidental mortality of cetaceans in gillnets in Mexico is limited to the northern Gulf of California, and, therein, to only one species, the vaquita, *Phocoena sinus* (Vidal, In press). However, since 1979, two of us (OV and LTF) have frequently found fresh carcasses of common and bottlenose dolphins (*Delphinus delphis* and *Tursiops truncatus*) on beaches of the central Gulf (coast of Sonora and Sinaloa) which showed signs of entrapment in gillnets (e.g. net marks on head and trunk, tip of dorsal fin and lobes of caudal fin cut away to allow for easier removal from the net, etc.). Interviews with local fishermen also substantiate incidental captures. Information is lacking on total numbers of dolphins killed, but recent findings suggest that incidental mortality could be relatively high locally. For example, 19 common dolphin carcasses were found between late February and late March 1990 along five kilometres of beach at a single location north of Estero de Tastiota, *ca* 60km NE of Guaymas, Sonora. Gillnets are one of the most common types of fishing gear used throughout the Gulf of California and we suspect that dolphins (of at least these two species) are often caught in other areas where gillnets are common (e.g. Los Cabos, La Ribera, La Paz, Loreto and Mulegé in Baja California Sur; Puertecitos, Bahía San Luis Gonzaga and San Felipe in Baja California (Norte) (BCN); El Golfo de Santa Clara, Puerto Peñasco, Desemboque, Puerto Lobos, Puerto Libertad, Bahía Kino, Guaymas, Bahía Lobos, Tobarí, Bahía Santa Bárbara, Yavaros, and Las Bocas in Sonora; and Estero de Agiabampo, Topolobampo, Bahía de Navachiste, Bahía Santa María, Altata, Mazatlán and Teacapán in Sinaloa). Common and bottlenose dolphins, as well as other small cetaceans, are probably caught in other areas of Mexico where gillnets are commonly used.

In addition, at least four entanglements of gray whales, *Eschrichtius robustus*, all in the Gulf of California, have been documented. Riley (1979) reported a gray whale near Punta Colorado, La Ribera, Baja California Sur (BCS), dragging a large gillnet wrapped mainly around its tail. This animal was released when the net was removed by fishermen. K. Balcomb (Center for Whale Research, Friday Harbor, WA, USA) presented a film (XIV International Meeting of the Mexican Society for the Study of Marine Mammals, La Paz, March 1989) on the lengthy efforts culminating in the release of a gray whale entrapped by a gillnet near Playa Palmilla, BCS. Finally, Vidal (1989) reported separate incidents (1978 and 1984) wherein two gray whales (a calf, and a small juvenile) were temporarily trapped in gillnets near Yavaros, Sonora; one of the two calving grounds for this species in the Gulf of California (Gilmore *et al.*, 1967; Findley and Vidal, In press). Both whales were eventually released by local fishermen. Vidal (1989) concluded that entanglements in gillnets are probably an important cause of mortality for gray whale calves in and near the calving grounds in the Gulf, as has been reported for other areas along the migratory route of the species (e.g. Brownell, 1971).

There are two major artisanal fisheries using gillnets in Mexico. We have no data on the fishery along the Gulf of Mexico coastline, other than that gillnets are extensively used. A summary of the available information on the Gulf of California fishery is given below.

[1] Since this review was completed, results of further work have been presented by Zavala-Gonzalez *et al.* and these are published in this volume, pp. 235–8.

Artisanal gillnet fishery of the upper Gulf of California

PORTS

The main ports are San Felipe and Puertecitos in Baja California (Norte) and El Golfo de Santa Clara and Puerto Peñasco in Sonora.

TARGET SPECIES

The main target species are: sierra, *Scomberomorus sierra*, and Monterey Spanish mackerel, *S. concolor* (Scombridae); totoaba and corvinas, *Totoaba macdonaldi* and *Cynoscion* spp. (Sciaenidae); striped mullet, *Mugil cephalus* (Mugilidae); several species of sharks including lamnids (white shark, *Carcharodon carcharias,* and shortfin mako, *Isurus oxyrinchus*), carcharhinids (lemon shark, *Negaprion brevirostris,* Pacific sharpnose shark, *Rhizoprionodon longurio*, and *Carcharhinus* spp., especially blacktip shark, *C. limbatus*, and dusky shark, *C. obscurus*), alopiids (bigeye thresher, *Alopias superciliosus*), sphyrnids (scalloped hammerhead, *Sphyrna lewini*) and triakids (brown smoothhound, *Mustelus henlei*, and sicklefin smoothhound, *M. lunulatus*); and rays including myliobatids (e.g. bat ray, *Myliobatis californica*, and cownose ray, *Rhinoptera steindachneri*), the stingray, *Dasyatis brevis*, and mobulas, *Mobula* spp.

AREA OF OPERATION

Operations occur throughout the entire area, generally close to shore, but often as far as Rocas Consag, a small rocky island in the central part of the (generally shallow) upper Gulf.

VESSELS AND CREW

Boats comprise *pangas* of (mainly) fibreglass, 6–8m long, with 2–3 local men. Boat numbers by port are: San Felipe, 260; El Golfo de Santa Clara, 226; and Puertecitos, 30; there is no information available for Puerto Peñasco. The fish are handled fresh and iced.

GEAR (GILLNETS)

Monofilament nylon nets of the following mesh sizes are used: 85mm (mackerels and corvinas); 100–150mm (sharks and rays) and 200–305mm (totoaba). Totoabas also have been frequently fished with the same nets from shrimp boats. Each *panga* carries 1–2 panels of the following lengths: mackerels and corvinas (459m), sharks and rays (680m) and totoaba (180m).

OPERATIONS

Trips usually last about five hours. Nets are set for either bottom, midwater or near surface fishing at depths between 7 and 40m. They are set (and usually retrieved) in the early morning. The soak time ranges from *ca* 12–24 hours.

ECONOMICS AND HISTORY

In general the fish is supplied to the domestic market, although some of the corvina, totoaba, shark and ray products are exported. The fish are processed fresh, iced, frozen or salt-dried (shark and ray fins, and shark skins and some meat). The important totoaba fishery began on a very small scale in the mid-1920s. From 1929, it responded to a growing USA market and improved its fishing methods, progressing from dynamiting and hook-and-line and primitive gillnetting to (especially after 1942) the use of efficient nylon gillnets (Flanagan and Hendrickson, 1976). Most totoaba fishing boats operated out of San Felipe, El Golfo de Santa Clara and Puerto Peñasco, which had been established near the main fishing areas which include the large Colorado River estuary (Arvizu and Chávez, 1972; Flanagan and Hendrickson, 1976). After a peak catch of 2,261 tons of totoaba meat in 1942, and despite intensified fishing effort, annual catches declined to a minimum of approximately 59 tons in 1975. Consequently, the Mexican government declared a complete ban on fishing the species (Flanagan and Hendrickson, 1976). However, illegal and 'experimental' fishing has continued at El Golfo de Santa Clara and around San Felipe (Vidal, In press; Lagomarsino, 1991). Comparable available information is lacking for the shark and ray gillnet fishery, but it has been growing rapidly in the upper Gulf of California since the early 1940s and continues to operate without controls.

EFFORT DATA

Little information exists for determining total fishing effort in the area. Vidal (In press) summarised available information for 1990 as follows: El Golfo de Santa Clara – 126 gillnets in use for sharks and rays (Feb.-Jul.), 125 for mackerels (Apr.-Sept.) and at least 30 for totoaba (Jan.-May); San Felipe – 300 for sharks and rays (Feb.-Jul.), 300 for mackerels (Apr.-Sept.) and at least 30 for totoaba (Jan.-May); Puerto Peñasco – 136 for sharks and 52 for smaller fishes (Sept. 1989-Jan. 1990); and Puertecitos – 30 for sharks (year-round).

INTERACTIONS WITH CETACEANS

Vaquitas, common dolphins and bottlenose dolphins are regularly caught. Fishermen report that vaquitas become entangled in the early morning, when the net is hauled and they are usually brought aboard. However, for the larger entangled dolphins, the fins are often cut-off to allow removal from the net when the carcass is shaken out and they are rarely brought aboard. Except for two reports by fishermen, all vaquitas were found dead in the net. Some fishermen from San Felipe reported eating vaquita meat. Sometimes, bottlenose or common dolphin meat is used as bait in hook-and-line fisheries, but dolphins are not actively pursued for this purpose in the area. Catch data since 1985 (minimum known catches) are shown in Table 3. The best monitored years were 1985, 1990 and 1991, the years with the highest catches as one might expect (data from Vidal, In press). At least 35 vaquitas are estimated to be killed each year in fishing activities (Vidal, In press). Detailed catch information is lacking for the other two cetaceans involved, although from second-hand information, Mitchell (1975) estimated that perhaps 50 bottlenose dolphins are taken yearly by the shark and totoaba fisheries, mainly north of San Felipe. We know of many unpublished records of both common and bottlenose dolphins entangled in gillnets in the upper Gulf (e.g. at least eight common dolphins between February to June 1984 near Puerto Peñasco, R. Boyer, Centro Intercultural de Estudios de Desiertos y Océanos, *in litt.*, 11 February 1988, Puerto Peñasco, Sonora).

All marine mammals are legally protected in Mexico.

Table 3

Summary of the incidental mortality of *Phocoena sinus* in fishing activities in the Gulf of California, 1985-1992 (Vidal, In press)*.

Year	No. individuals	Year	No. individuals
1985	35	1989	13
1986	>2	1990	36
1987	6	1991	22
1988	9	1992	5

* Mortality numbers are minima; the best monitored years were 1985, 1990 and 1991.

Considering the probable low population size and very limited range of the vaquita, the current (and potential) levels of incidental mortality due to fishing activities, the difficulties in implementing and enforcing long-term conservation measures quickly and other detrimental factors affecting the upper Gulf of California ecosystem, the vaquita is in immediate danger of extinction (Robles *et al.*, 1987; Vidal, In press). On 10 June 1993, the Mexican Government declared the Biosphere Reserve of the Upper Gulf of California and the Colorado River delta to protect the vaquita, the totoaba and their natural habitat (Vidal, 1993). At present, we have no systematically gathered information on the incidental mortality of the region's common and bottlenose dolphins but mortality is suspected to be high, and other fisheries (e.g. the purse-seine fishery for sardines, etc.) are possibly detrimental (Mitchell, 1975; Vidal *et al.*, 1993).

CONCLUSION

Cetaceans potentially at risk in Mexican waters are: humpback whales, *Megaptera novaeangliae* (Gulf of California and rest of Mexican Pacific); spotted dolphins, *Stenella attenuata graffmani* (Pacific); common dolphins (Gulf of California, Pacific and Gulf of Mexico); bottlenose dolphins (Gulf of California, Pacific and Gulf of Mexico); Pacific white-sided dolphins, *Lagenorhynchus obliquidens* (southwestern Gulf of California); the three subspecies of spinner dolphins (Perrin, 1990), *S. longirostris longirostris* (tropical and subtropical Pacific), *S.l. orientalis* (endemic to the eastern Pacific) and *S.l. centroamericana* (coastal waters of Mexico and Central America); and Atlantic spotted dolphins, *S. frontalis*, and *S. longirostris* (Gulf of Mexico).

There is an urgent need to monitor and to reduce the incidental mortality of the vaquita in fishing activities. Vidal (In press) identified the following research needs and management requirements for the conservation of this species: (1) reduce incidental mortality by enforcement of existing law prohibiting totoaba fishing activities; (2) determine the magnitude of incidental mortality in other gillnet fisheries (i.e. sharks and rays, mackerels, corvinas, etc.) to provide accurate estimates of the total annual rate of incidental mortality; (3) investigate possible modified or alternative fishing methods (e.g. net modifications and/or deployment) that could reduce incidental mortality; and (4) obtain accurate estimates of population size and possible seasonal movements. In addition, effort should be made to obtain more information on incidental mortality of common and bottlenose dolphins and gray whales and the possible effects of this mortality on their regional populations.

Honduras[1]

PORTS

The major ports are Puerto Cortés, Tela, La Ceiba, Roatan, Guanaja, Trujillo and Puerto Lempira on the Atlantic coast and San Lorenzo and Amapala on the Pacific coast.

AREA OF OPERATION

Operations on the Atlantic coast are within 4.5km of the shore.

GEAR (GILLNETS)

Information on the number of boats using gillnets was not provided. The monofilament nylon nets have a mesh size of 75mm. Panel lengths range from 50–400m and there are 1–4 panels/fisherman.

OPERATIONS

A typical trip lasts from 1–3 days and each fisherman makes 150–180 trips/yr. Bottom and surface fishing occurs in waters ranging from 2–25m in depth. The fish are processed fresh.

INTERACTIONS WITH CETACEANS

Small cetaceans have been incidentally killed. Suspected species are *Stenella attenuata graffmani* (Pacific), the Costa Rican spinner dolphin (*S. longirostris*, Pacific), bottlenose dolphins (Pacific, Atlantic), tucuxi (*Sotalia fluviatilis*, Atlantic – see Carr and Bonde, 1993) and common dolphins (Pacific, Atlantic). Dolphins generally become entangled at night, at entrances to rivers or coastal lagoons (and are thus most likely bottlenose dolphins). There are no cetacean catch data, with incidental mortality being reported as occurring 'rarely'. No information was provided on any utilisation of the by-catch and no efforts to reduce the by-catch were reported.

In addition, 166 boats were reported to participate in a lobster fishery deploying traps, but interactions with cetaceans are probably minimal.

Nicaragua[2]

Artisanal fisheries use gillnets set from small boats (4m long) and catch snappers, sciaenids and other small fishes along the coasts (within 10km offshore). There are no data on incidental mortality, but bottlenose, tucuxi (Atlantic), pantropical spotted (Pacific only) and common dolphins are potentially at risk. Apparently, a lobster fishery also exists, possibly using traps.

Costa Rica[3]

Approximately 66 fishing communities exist along the Pacific coast, the most important (by number of boats) are Punta Arenas, Isla Chira, Playa del Coco, Quepos, Costa del Pájaro, Portete, Cuajiniquil, Isla Venado, Samara, Golfito, Chomes, Puerto Thiel and Manzanillo. Along the Atlantic coast the principal ports are Puerto Limón, Barra del Colorado and Puerto Viejo.

TARGET SPECIES

The following species are caught: corvinas (Sciaenidae, *Cynoscion*); seabasses (Serranidae, *Epinephelus*); snappers (Lutjanidae, *Lutjanus*); sierra mackerels (Scombridae, *Scomberomorus*); jacks (Carangidae, *Caranx*); snooks (Centropomidae, *Centropomus*); dolphinfish or dorado (Coryphaenidae, *Coryphaena hippurus*); and sharks of the families Sphyrnidae (hammerheads, *Sphyrna*) and Carcharhinidae (requiem sharks, *Rhizoprionodon longurio, Carcharhinus porosus, C. leucas* and *Galeocerdo cuvier*).

AREA OF OPERATION

Fishing takes place along the entire Pacific coast within *ca* 54km offshore (80% within 22km), in the Gulf of Nicoya and near the far-offshore Isla del Coco and the Costa Rican Dome. Fishing is also mainly coastal in the Atlantic.

VESSELS AND CREW

Boats are made of wood and fibreglass. Two types of vessels operate in the Pacific: *pangas* (4–8m long, 60% of all boats) and *lanchas* (7–12m). In the Atlantic *pangas* (4–8m) comprised 95% of all boats. Over 5,300 boats operated in 1990: Punta Arenas (1,100); Isla Chira (602); Playa del Coco (200); Quepos (260); Costa del Pájaro (230); Portete (160); Cuajiniquil (175); Isla Venado (140); Samara (62); Golfito (59); Chomes (80); Puerto Thiel (60); Manzanillo (25); plus 853 distributed in smaller communities. Country totals were also provided for the following years: 1981 (502 boats); 1982 (615); 1983 (761); 1984 (800); 1985 (1,038); 1986 (1,163); 1987 (2,707) and 1989 (3,000). The fish are handled fresh and iced. Crews range in size from 1–3.

GEAR (GILLNETS)

The gillnets used have a mesh size of 85–150mm (the minimum allowed by law is 85mm). Panels are 500-600m long and 7–10m deep. Both set and drift nets are used.

OPERATIONS

Trips usually last about 1 day (60% of all boats) or 4–5 days. Bottom, midwater and surface fishing takes place in waters ranging from 5–100m.

ECONOMICS

The catch is mostly for domestic use. However, some snappers, sea basses, dolphinfish and shark fins are exported (both fresh and frozen).

DEVELOPMENT OF FISHERY AND CURRENT TRENDS

Both fishing effort and catches have been increasing since 1979, especially since 1981. Between 1981 and 1987, the number of artisanal fishing boats increased four times, with nearly 80% of fishing concentrated within 22km of the coast.

INTERACTIONS WITH CETACEANS

Although no information on incidental catches was provided, bottlenose, pantropical spotted, Costa Rican spinner and common dolphins are potentially at risk along the Pacific coast, while bottlenose, tucuxi and common dolphins may be at risk along the Atlantic coast.

[1] Information from M. Castellón (*in litt.*, 27 August 1990), Departamento de Pesca, Secretariat of Natural Resources of Honduras, Tegucigalpa.

[2] The only relevant information was provided by R. Sánchez (*in litt.*, 8 February 1990), Centro de Investigaciones Pesqueras, Nicaraguan Ministry of Fisheries, Managua.

[3] Information provided by E. Madrigal (*in litt.*, 10 July 1990), Departamento de Pesca y Caza, Costa Rican Ministry of Agriculture, San José.

Considering the relatively high fishing effort, these fisheries should be monitored to determine any interactions with cetaceans.

Panama[4]

There are two main gillnet fisheries in Panama, both off the Pacific coast. The available information is summarised below.

Shark fishery of the Pacific Coast

PORTS

The main ports are Pedregal, Provincia de Chiriquí; Vacamonte, Provincia de Panama and Ciudad de Panama.

TARGET SPECIES

The target species include requiem sharks (Carcharhinidae), smoothhounds (Triakidae) and hammerheads (Sphyrnidae).

AREA OF OPERATION

Fishing operations are coastal and around islands.

VESSELS

Boats are made of wood, steel or fibreglass and are from 15–23m long. The number of boats operating out of each port varies, but no more than ten operate at a given time. The fish are iced.

GEAR (GILLNETS)

Mesh sizes range from 150–200mm. Panels are 126–180m long and 7.5–11.0m deep. Each boat carries 2–4 panels.

OPERATONS

Trips last from 5–15 days and each boat usually makes 15–25 trips annually. About 2,000 panels are fished each year in total. Both set and drift nets are used, with most fishing at the bottom in depths of 18–54m. The soak time is from 6–10 hours.

ECONOMICS AND HISTORY

The product is sold fresh (meat) or salt-dried (fins, skin). Total landings are estimated to be 68,000–90,000 kg/yr. Although the fishery was very important some years ago, it has been decreasing due to the lack of good markets.

INTERACTIONS WITH CETACEANS

At least bottlenose and common dolphins and *Stenella* spp. have been occasionally killed to use their meat for bait for the shark fishery (Vidal, 1992).

Artisanal fishery for fin-fishes ('peces de escama') off the Pacific Coast

PORTS

Fishing occurs from many localities along the coast in coastal waters.

TARGET SPECIES

The main target species are sciaenids, mackerels (Scombridae) and snooks (Centropomidae, *Centropomus*).

VESSELS

The fishery involves some 3,000–4,000 wooden boats, 8–10.5m long. The fish are handled fresh or iced.

GEAR (GILLNETS)

The nets used have mesh sizes of 90–140mm. Panels are 180m long and 9–14m deep. Each vessel carries from 1–4 panels.

OPERATIONS

Trips last from 1–5 days and boats usually make 50–100 trips/yr totalling about 225,000 panels. Surface and bottom fishing takes place in waters of 1.8–36m depth using set nets. The soak time is 4–6 hours.

ECONOMICS AND HISTORY

This was a very important fishery in past years, but presently is decreasing.

INTERACTIONS WITH CETACEANS

Only one definite record has been reported; that of an 'adult male' bottlenose dolphin caught *ca* 60km east of Panama City. Pantropical spotted dolphins (Pacific), common dolphins (Pacific and Caribbean) and tucuxi, (Caribbean) are potentially at risk. There are no laws or regulations applying to cetaceans, but there are a number of coastal conservation areas that may provide protection for some of their habitats.

Colombia

The few documented incidental kills of cetaceans in gillnets are from Vidal (1990). Information on the gillnet fisheries is based on Hernández (1986) and Arias and Anzola (1989).

Artisanal fishery of the Atlantic coast of Colombia

PORTS

The main ports are Dibulla, Riohacha, Manaure, Cabo de la Vela, Bahía Portete, Pueblo Viejo, Tasajera, Gaira, Santa Marta, Taganga, Parque Tayrona, Cartagena, Galerazamba, Barú, Tolú, Islas del Rosario, Archipelago of San Bernardo, El Rincón, Caimanera, Puerto Viejo, Coveñas, Berrugas, Aspescordel, Coopetolú, Turbo, El Roto, Punta Urabá, Ciénega, Unguia, Bajo Atrato, and San Andrés and Providencia Islands.

TARGET SPECIES

The major target species are mackerel (Scombridae, *Scomberomorus*), snooks (Centropomidae, *Centropomus*), snappers (Lutjanidae, *Lutjanus*), jacks (Carangidae, *Caranx*) and various species of sharks.

AREA OF OPERATIONS

Fishing occurs between the Gulf of Urabá and Guajira peninsula (the border with Venezuela).

VESSELS AND CREW

Boats are made of wood, fibreglass and aluminum and are of two types: *cayucos* (4–6m long) and *canoas* (8-10m). The number of boats is only available for the Santa Marta region where 440 operate. The fish are handled fresh and iced. Crew size ranges from 2–4.

GEAR (GILLNETS)

Data are available only for the Santa Marta region where the stretched mesh size ranges from 85–400mm. Most nets are made of monofilament nylon but there are some multifilament nets. Panels are 18–600m long and 3.2–21.5m deep. There is usually only one panel per boat.

[4] Information was provided by D.H. Arosemena (*in litt.*, 24 August 1990), Dirección General de Recursos Marinos, Ministry of Commerce and Industries of Panama.

OPERATIONS

Again, data are only available for the Santa Marta region where set nets are usually used. Vessels operate for about 247 days per year. The soak time ranges from 2–16 hrs.

ECONOMICS

The fish, either processed fresh, frozen or canned are for the domestic market.

INTERACTIONS WITH CETACEANS

Reported catches (Vidal, 1990) are of one individual each of the pygmy sperm whale, *Kogia breviceps* (November 1988, Gulf of Morrosquillo), tucuxi (September 1986, Bahía de Cispatá, mouth of Sinú River), Risso's dolphin, *Grampus griseus* (Islas del Rosario), bottlenose dolphin (1989, Tierra Bomba, *ca* Cartagena), Atlantic spotted dolphin, *Stenella frontalis* (April 1989, Bahía de Barbacoas, *ca* Barú). Pantropical spotted, striped, *S. coeruleoalba*, and common dolphins and short-finned pilot whales, *Globicephala macrorhynchus*, are potentially at risk (Vidal, 1990).

DISCUSSION

In view of the large mesh-sizes of the nets, sizes which regularly catch cetaceans in other regions (e.g. Read *et al.*, 1988; Vidal, In press; this paper), this fishery should be monitored to document the number and species of dolphins incidentally killed.

Artisanal fishery of the Pacific coast of Colombia

PORTS

The main ports are Bahía Solano, Ensenada de Utría, Golfo de Upica, Boca Charambirá, Punta Soldado, Puerto Buenaventura, Pueblo Nuevo, Punta Merizalde, Saija, Chacón, Corozal, Playa de Coco, Trapiche, Noanamito, Chontal, Milagros, Chajal and Salahonda.

TARGET SPECIES

The major species caught are mullets (Mugilidae, *Mugil*), croakers and corvinas (Sciaenidae), snappers (Lutjanidae, *Lutjanus*) and various species of sharks.

AREA OF OPERATION

Fishing occurs between the borders with Ecuador and Panama.

VESSELS AND CREW

Wooden and fibreglass boats, 6–8m and 10–12m long, are used. The fish are handled fresh and iced.

INTERACTIONS WITH CETACEANS

Humpback whales, bottlenose, common and two types of spotted dolphins (*S.a. attenuata* and *S.a. graffmani*) are potentially at risk (Vidal, 1990). One of us (KVW) interviewed members of the fishing community at Buenaventura in March 1990. Although nearly all were circumspect on the matter, one person stated that harpooning of dolphins for bait is a common practice in the area.

Artisanal fishery of the Orinoco River Basin

PORTS

The main ports are Puerto López, Puerto Gaitán and Puerto Carreño (Meta River), San José del Guaviare, Puerto Inírida and Barrancominas (Guaviare and Inírida rivers) and Arauca River.

TARGET SPECIES

Fishing is mainly for pimelodid catfishes (*Sorubim*) and characids (*Colossoma*).

AREA OF OPERATION

Fishing takes place in the Arauca, Meta, Guaviare, Vichada and Tomo rivers.

VESSELS

Wooden vessels, 4–10m long, are used. The fish are handled fresh and iced.

INTERACTIONS WITH CETACEANS

Boto, *Inia geoffrensis*, and tucuxi are at risk (Vidal, 1990; Borobia *et al.*, 1991).

Artisanal fishery of the Colombian Amazon

PORTS

The main ports are Leticia, Puerto Nariño, La Pedrera, Araracuara and Alto Caquetá, Orteguaza and Putumayo rivers.

TARGET SPECIES

The target species are pimelodid catfishes and characids.

AREA OF OPERATION

Fishing occurs in the Amazon, Putumayo, Caquetá, Orteguaza and Vaupés rivers.

VESSELS

Wooden boats, 3–8m long, are used. The fish are handled fresh and then dried or iced.

INTERACTIONS WITH CETACEANS

At least two boto were caught near Puerto Nariño in *ca* 1986 (Vidal, 1990). Beltrán and Trujillo (1992) reported that during 1991–2, 17 dolphins (botos and tucuxis) were found dead in an area of *ca* 80km^2 in the Colombian Amazon: 55.6% in gillnets, 22.2% hunted and 11.1% struck by boats.

Venezuela

According to Northridge (1984), most of the reported 167,000 tonnes of landed catches of fishes by Venezuela in 1981 came from artisanal fisheries along the coast, and included mullets (Mugilidae), croakers and corvinas (Sciaenidae), groupers (Serranidae), grunts (Haemulidae) and sharks. Caldwell and Caldwell (1971) reported that beach-seine nets used along the Venezuelan coast and on offshore islands incidentally kill some cetaceans, mainly bottlenose dolphins and tucuxi around some river mouths. Botos are occasionally incidentally killed in fishing gear, and those dolphins taken are sometimes eaten (O'Shea *et al.*, 1986).

Agudo (1990) reported that in the area between 9°55'-11°25'N and 61°50'-64°30'W, local fishermen use 80-130mm mesh gillnets 50–200m long and 5–12m deep. In February 1987, 1,537 nets were reported fishing in this area. Although no systematic efforts have been made to determine the species of cetaceans involved, or the rate of incidental mortality and its impact on the cetacean populations, preliminary reports indicate that since early 1988, cetacean deaths in gillnets have been 'frequent'. Animals caught have been used for bait and for human consumption. Agudo (1990) reported the sale of six dolphins (*Stenella frontalis*, *S. longirostris* and *S. clymene*) to be used as bait in the bottom-longline shark fishery. He also reported that other cetaceans incidentally killed were common and bottlenose dolphins, tucuxi and *Balaenoptera* sp. Venezuelan longliners operating out of French Guiana occasionally harpoon dolphins for bait (Van Waerebeek, 1990). Pantropical spotted dolphins, false killer, short-finned pilot and humpback whales are potentially at risk.

Surinam

Information is based on two publications describing Surinam's fisheries (Charlier, 1988; 1989). The only data on cetacean-fisheries interactions come from osteological materials from incidentally killed tucuxi housed in two museums in the Netherlands, the Rijksmuseum van Natuurlijke Historie, Leiden (C. Smeenk, *in litt.*, 20 July 1990) and the Zoologisch Museum, Amsterdam (P.J.H. van Bree, pers. comm., 13 June 1990). Offshore fishing activity in Surinam is dominated by a Venezuelan red snapper (*Lutjanus purpureus*) line fishery and an international trawl fishery for shrimp and fin-fish. Between 18,000 and 20,000 tonnes of penaeid shrimps are caught annually by a flotilla of 120 to 140 trawlers mainly from South Korea and Japan. The coastal artisanal fishery is described below.

Artisanal coastal and estuarine fin-fish fishery

PORTS

The main ports are Paramaribo, Braamspunt and Pomona. Boats are also based in or near villages (85% along the lower part of the Surinam River).

TARGET SPECIES

Fishing is mainly for inshore demersal species. Large demersal species include only a few corvinas (Sciaenidae: *Cynoscion acoupa*; *C. steindachneri*) and sea catfishes (Ariidae: *Arius parkeri*; *A. proops*). Small demersal species include other corvinas and croakers (Sciaenidae: *Macrodon ancylodon*; *Cynoscion virescens; Nebris microps*), other sea catfishes (Ariidae: *Arius grandicassis; A. quadriscutis; A. passany; Bagre* spp., etc.), snappers (Lutjanidae: *Lutjanus synagris*), grunts (Haemulidae), snooks (Centropomidae) and a few other fish families.

AREA OF OPERATION

Fishing occurs in shallow coastal waters (<15m deep) including estuaries of the Corantijn, Nickerie, Coppename, Surinam and Marowijne rivers.

VESSELS AND CREW

The smallest boat used is the *korjaal* (flat-bottom canoe) used in lagoons. Larger boats of similar type are used in rivers and estuaries. In coastal marine waters two types of 'Guyana' boats predominate: decked and open gillnetters. Decked 'Guyana' boats seen in Cayenne, Guyana, were typically *ca* 15m long (KVW, pers. obs.). The available information on numbers of boats for Surinam are: decked gillnetters (30 in 1989), open gillnetters (81 in 1987), estuary gillnet fishery (87 in 1987), riverine drift and set gillnets (74 in 1987). Fish are handled fresh and iced. Crew size varies with the type of vessel: decked gillnetter, 4–5 men; open gillnetter, 3–4; estuarine, 1–4; and riverine, 3–4. Total numbers of fishermen were: 284 on open gillnetters; unknown on decked gillnetters (in 1987, reported to have increased now); 218 in the estuarine gillnet fishery; and 205 in the riverine set and drift gillnet fishery. In the coastal fisheries, 5–50% of the crew are local (foreigners are not specified but are supposedly mainly from Venezuela and Guyana) while in the estuarine and riverine fisheries 50% of the crew are locals.

GEAR (GILLNETS)

Both set and drift nets are used with a range of mesh sizes. Panels are up to 4km long and 10m deep.

OPERATIONS

Gillnets take *ca* 50% of total landings (40% for driftnets only). All present fishing methods are directed towards demersal species and the pelagic element is almost completely unexploited.

ECONOMICS AND TRENDS

Present overall production (all fisheries except shrimp) is estimated at 11,000 tonnes (about three times that recorded in the official statistics). Domestic consumption is estimated at 6,800 tonnes with the remainder of the fish being exported. Fishery resources of the Surinam Exclusive Economic Zone apparently include several underexploited fin-fish stocks and Charlier (1989) suggested that improved versions of the present coastal gillnetters should be developed.

INTERACTIONS WITH CETACEANS

Tucuxi are known to be incidentally killed: three animals were presumably caught in gillnets at the mouth of the Surinam River and two animals at the mouth of the Coppename River (May 1964-November 1972), the skeletal materials are kept in Amsterdam. Three tucuxi at Pomona and one at Braamspunt were caught in 'shrimp traps' at the mouth of the Surinam River (April-June 1963) and the skeletal materials are in Leiden. Seven other animals were also received in Leiden (February-May 1971) from the Fishery Department of Surinam that were probably caught in fishing activities at the mouth of the Surinam River (at Braamspunt or Pomona). Bottlenose dolphins and humpback whales are potentially at risk. Fishermen who seemed reluctant to provide details admitted that dolphins were caught 'occasionally' but dolphin meat is not consumed and carcasses are discarded at sea (C. Lietaer, ABOS, Paramaribo, *in litt.*, 9 October 1990).

French Guiana

Data are based on observations of fishing gear and vessels and on personal interviews with both local and foreign fishermen conducted by one of us during a visit from 25 April-1 May 1989 (Van Waerebeek, 1990).

PORTS

Only Cayenne (04°56′N, 52°20′W) and Saint-Laurent-du-Maroni, Marowijne River (05°30′N, 54°02′W) were surveyed.

TARGET SPECIES

The target species of the fishery are grey mullet (Mugilidae), several sciaenids and carangids, tarpon (*Megalops*) and sharks.

AREA OF OPERATION

Fishing occurs near Cayenne and on the Marowijne River. Reportedly, foreign fishermen based at Cayenne also operate in Surinam and Brazilian waters. Local artisanal fishermen mainly fish close to shore.

VESSELS AND CREW

Wooden boats, typically 15–20m long, are used. About 20–25 Brazilian vessels and approximately a dozen Venezuelan boats operate out of Cayenne. Crewmen are all locals at Saint-Laurent-du-Maroni. The fish are handled fresh and iced.

GEAR (GILLNETS)

Most nets are made of multifilament nylon with a mesh size of 200mm, but at least some small-mesh monofilament nets are used, presumably in the inshore fishery. One net observed being repaired had a panel size of 2,000m long and 7m deep.

OPERATIONS

Trips may last up to a week. The Brazilian vessels operate throughout most of the year.

ECONOMICS

The fish (fresh and iced) is for the domestic market.

INTERACTIONS WITH CETACEANS

At least two species of small cetaceans are commonly mentioned by fishermen as incidentally killed. The smaller one is almost certainly the tucuxi and the 'much' larger one may be either the bottlenose or common dolphin. Dolphins are generally considered of no value and are usually discarded at sea. Some Brazilian fishermen said they had tried dolphin meat but did not particularly like it. However, dolphins are occasionally harpooned for fish bait. One fisherman estimated that for every trip lasting a week, about 4–5 dolphins become entangled, but actual effort data (i.e. number of trips) are not available. Van Waerebeek (1990) deduced from fishermen's assertions that the Brazilian gillnet fishery off French Guiana may account for considerable dolphin mortality, possibly as many as a few thousand animals per year. As an overseas department, French Guiana is governed by the same laws as France, and an order (20 June 1970) by the Director of French Maritime Fisheries prohibits the destruction, pursuit, or capture by any means, whether intentional or unintentional, of all species of dolphins (Marashi, 1986).

DICUSSION

Although information is preliminary, it appears that relatively high numbers of dolphins may have been killed. This suspected mortality may be significant for relatively small and possibly localised populations of such species as the tucuxi and the bottlenose dolphin. It is important that the fisheries are monitored to accurately estimate the extent of this incidental mortality. Also, as recommended by Van Waerebeek (1990), special attention should be given to existing and proposed marine and estuarine conservation areas, such as the Sinnamary and Iracoubo estuary, Kaw Marshes, Pointe Béhague and lower Oyapock River. Observers should be placed on the Brazilian vessels to document and evaluate the extent of incidental kills and the species of dolphins involved.

Trinidad and Tobago[5]

PORTS

Trinidad is the main fishing port, but the area of operation was not reported.

[5] Fishery information was provided by M.G. Sturm (*in litt.*, 8 August 1990), Trinidad and Tobago Institute of Marine Affairs.

TARGET SPECIES

The main species taken are the serra Spanish mackerel (*Scomberomorus brasiliensis*) and the king mackerel (*S. cavalla*).

VESSELS

At least 107, 10m-long boats operate out of Trinidad.

GEAR (GILLNETS)

Most nets are of multifilament nylon (set at night) although there are a few monofilament nylon nets (set during the day). Mesh size is 100–110mm and panels are 100–150m long and 10m deep. Each boat carries 1–2 panels.

OPERATIONS

Trips usually last overnight. The nets are mostly of the drift type and are deployed at dusk and retrieved around midnight after a 6 hour soak time. Fishing usually occurs in shallow (<50m) waters and takes place at the surface. Sometimes monofilament large-mesh nets (for sharks) are bottom set. A total of 5,325 trips was made in 1989.

TOTAL LANDINGS

In 1989, 1,662 tonnes of serra Spanish mackerel and 174 tonnes of king mackerel were landed (figures include some hook-and-line catches).

INTERACTIONS WITH CETACEANS

The only recorded entanglement was of a killer whale (Ottley *et al.*, 1988). The fisherman reported that the animal became entangled in his drift gillnet as it was being hauled, in the Gulf of Paria between Kronstadt and Gaspar Grande islands, in 6–7m of water.The trapped animal died after struggling for over an hour. The whale was one of about 15 individuals. Bottlenose dolphins and humpback whales are potentially at risk.

DISCUSSION

Although only one documented incidental take exists, the relatively high fishing effort makes it important that more information is gathered. B. Chakalall (FAO) reported some use of driftnets around both islands by day fishermen who leave the nets to drift for 3–5 and sometimes up to 8–10 hours (H. Gieben, 16 November 1986, *in litt.*, to S. Leatherwood).

However, of more concern is the fact that Taiwanese drift-netting activities have been observed for the first time in the western Atlantic-Caribbean region. S. Johnson (Secretary of the Trinidad and Tobago Game Fishing Association) reported[6] the presence of 15 Taiwanese vessels at dock in Port of Spain. According to the report, American experts who inspected photographs of the vessels provided by Johnson identified drift nets aboard. Moreover, M.G. Sturm (*in litt.*, 17 July 1990) of the Trinidad and Tobago Institute of Marine Affairs, reported that several Taiwanese fishermen have been landing catches at Trinidad's main markets. If allegations of high-seas gillnetting operations in the area are confirmed, the impact on cetacean populations should be evaluated as soon as possible.

[6] *The Arizona Daily Star*, Tucson, AZ, USA, 16 August 1990.

Barbados[7]

The limited information available concerns gillnets and fish traps used by Barbadian fishermen. Gillnets are used to catch flying fishes. The surface set nets have a mesh size of 41–45mm. Panels are 10–30m long and 3m deep. Fish traps ('Antillean traps') are used to catch 'reef fishes'. Mesh size varies from 25–38mm and traps are 2–3m long and 1–2m deep and set at depths of 5–100m. At least three species of cetaceans are potentially at risk: bottlenose dolphin, short-finned pilot whale and unidentified species of spotted dolphins.

Martinique

No reply to our request for data was received. The only information is that multifilament gillnets, apparently of small-mesh, have been seen (September 1990) in small, open wooden boats used for near-shore fishing in the vicinity of Fort de France. The vessels were equipped with high-powered outboard motors and were mostly launched from the beach (B. Van Waerebeek, pers. comm.). Also see Guadeloupe.

Organisation of Eastern Caribbean States (OECS)[8]

Information on three types of fishery (pot, gillnet and beach seine)[9] was provided by the OECS, although the areas of operation were not provided by country. Information for some individual countries was also provided and is included at the end of this section.

Pot fishery (ports not given)

TARGET SPECIES

The main target species are snappers (Lutjanidae), sea basses and groupers (Serranidae), surgeonfishes (Acanthuridae), jacks (Carangidae), squirrel- and soldier-fishes (Holocentridae), goatfishes (Mullidae), parrotfishes (Scaridae), grunts (Haemulidae=Pomadasyidae) and lobsters.

AREA OF OPERATIONS

The fishery occurs inshore on shallow shelf waters, banks and reef ecosystems.

VESSELS AND CREW

Vessels (2.5–8.8m long) made of wood and fibreglass are used. The catch capacity ranges from 364–682kg. Fish are handled fresh. Crew size is usually 2–3 men.

GEAR (POTS)

Pots are made of wire or bamboo and have mesh size of 32–51mm. The gear is hauled manually.

OPERATIONS

Mainly bottom fishing is carried out with a soak time of 2–3 days and a retrieval time of 4–6 hours. Catches usually range from 0–236kg per pot.

ECONOMICS

Fishermen can earn US$1.80–2.85/kg for reef fishes and US$4.00–8.50/kg for lobsters. The catch is processed frozen.

INTERACTIONS WITH CETACEANS

No cetacean entanglements were reported.

Gillnet fishery for flying fishes and demersal fishes, and turtles (ports not given)

TARGET SPECIES

The main target species are flying fishes (Exocoetidae), demersal fishes e.g. snappers (Lutjanidae), sea basses and groupers (Serranidae), and sea turtles.

AREA OF OPERATIONS

Fishing occurs in both territorial and contiguous zones.

VESSELS AND CREW

Open wooden and fibreglass vessels (2.5–9.2m) are used. Sloops (4.3–19.8m) are also used in Grenada and Dominica. Crew size ranges from 2–4.

GEAR (GILLNETS)

Mesh sizes (stretched) vary by species: flying fishes, 18mm; demersal fishes, 72mm; sea turtles, 128–144mm. Nets are made of nylon and panels are 100–165m long and *ca* 5m deep. The gear is hauled manually.

OPERATIONS

Fishermen operate daily in waters of 36–54m deep. Nets are set in the evening and the soak time is about 12 hours. Catches are usually 0–36kg per panel.

ECONOMICS AND HISTORY

Fishermen can earn US$2.00–2.85/kg. Gillnets have been traditionally used for pelagic fishes (e.g. flying fishes). In Grenada and Dominica some fishermen are now using bottom-set gillnets for demersal fishes.

INTERACTIONS WITH CETACEANS

No incidental catches were reported. Bottlenose and common dolphins and humpback whales are potentially at risk.

Beach seine fishery (ports not given)

TARGET SPECIES

The main species caught are clupeids, carangids and belonids.

AREA OF OPERATIONS

The fishery occurs in coastal waters.

VESSELS AND CREW

Open wooden and fibreglass vessels (2.5–9.2m long), known in Grenada as 'double enders', are used. Crew size can reach 8–10.

GEAR (BEACH-SEINES)

Nets of mesh size 25–38mm made of twine (thicker) or nylon are used. Panel length and depth were reported as 500–600 x 200–300 meshes, respectively. Nets are hauled manually.

[7] Information provided by the Fisheries Officer, Fisheries Division, Ministry of Agriculture, Food and Fisheries, St. Michael, *in litt.*, 24 July 1990.

[8] Most of the information for the members and associated states of the OECS, which includes Antigua and Barbuda, British Virgin Islands, Dominica, Grenada, Montserrat, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, was provided by D.C. Joseph (*in litt.*, 17 September 1990), Fisheries Unit, OECS, Kingstown, St. Vincent and the Grenadines.

[9] Scoop/dip nets are also used to catch flying fishes and other fishes which are attracted to a temporary fish aggregating device made of floating dried banana leaves.

OPERATIONS

About 144–192 trips per year are made. Up to 1,360kg of fish are caught per panel.

ECONOMICS

Fishermen are paid US$1.00–2.50/kg.

INTERACTIONS WITH CETACEANS

No cetacean entanglements were reported. Unless they are very large beach seines, they should have little effect on dolphins, but ambiguous data makes it difficult to judge.

St. Vincent and the Grenadines

No gillnet or trap interactions with cetaceans have been recorded. Traditional cetacean fisheries for 'blackfish' (*Globicephala*) and humpback whales are described by several authors (e.g. Caldwell and Caldwell, 1975; Price, 1985).

St. Lucia

No incidental catches of cetaceans are reported. Reeves (1988) summarised information on direct catches of cetaceans, mainly the short-finned pilot whale.

Dominica

Northridge (1990) reports that the Barbados driftnet type has been introduced to Dominica. The current status of the hand-harpoon fishery for the short-finned pilot whale (IWC, 1982) is unknown. This species is potentially at risk from gillnets.

Antigua and Barbuda

Some information was provided for Antigua alone: a total of less than 50 gillnets (both set and drift) are used to catch sea turtles. Mesh size is limited to 38mm, and nets measure under *ca* 900m in length and 100m or less in depth (E. Boyer, Fisheries Division, Ministry of Agriculture, Fisheries, Lands and Housing, St. Johns, Antigua, *in litt.*, 13 July 1990, to J. Lien, Whale Research Group, Memorial University of Newfoundland, Canada; received by the authors 24 October 1990).

Virgin Islands (British)

Fisheries officers maintain that there are no fishery incidents involving cetaceans. However, it has been rumoured that 'ghost' gillnets have washed up on the shores of Anegada, British Virgin Islands' northernmost island, probably from illegal fishing by foreign vessels (H. Gieben, West Indies Laboratory, St. Croix, US Virgin Islands, *in litt.*, 16 November 1986, to S. Leatherwood, San Diego, California, USA; received by the authors August 1990). Bottlenose dolphins, *Stenella* spp., short-finned pilot whales and humpback whales are potentially at risk.

Virgin Islands (USA)[10]

Only scant information is available. Fishing gear employed by commercial fishermen includes monofilament gillnets and surround nets for the harvest of reef fishes, such as jacks (Carangidae) and parrotfishes (Scaridae). There are no records of cetacean by-catches in the fishery. US laws protecting marine mammals are applicable in the US Virgin Islands.

[10] Information was provided by Wm. Tobias (*in litt.*, 4 October 1990), Department of Planning and Natural Resources, Division of Fish and Wildlife, Government of the Virgin Islands of the United States, St. Croix.

Guadeloupe

The only information available is that members of the French delegation at a 1986 Workshop on Coastal Protected Areas, hosted by the Eastern Caribbean Natural Areas Management Programme, mentioned the use of gillnets in Guadeloupe to H. Gieben (*in litt.*, 16 November 1986, to S. Leatherwood; received by the authors August 1990). Japanese and Koreans reportedly deploy 'tri-nets', which are three nets with different size meshes hung together. Because the foreign fishermen are secretive about their activities, little other information is available. The short-finned pilot whale is potentially at risk.

Puerto Rico (USA)

We received no reply to our request for data. The only information available is that gillnets (both set and drift types) are used and that a minimum 38mm mesh-size is allowed (J.E. Rivera, *in litt.*, to J. Lien; received by the authors 24 August 1990). H. Gieben (*in litt.*, 16 November 1986, to S. Leatherwood) cites Dr. Joe Kimmel of the Fisheries Research Laboratory of the University of Puerto Rico as stating 'that he was not aware of any gillnet fishing going on nor had heard of porpoises or whales being taken.' USA laws protecting marine mammals are applicable in Puerto Rico. Bottlenose, common and spinner dolphins, *Stenella* spp., short-finned pilot whales and humpback whales are potentially at risk.

Dominican Republic[11]

Artisanal fishery of Samaná Bay

PORTS

The main ports are Sánchez and Puerto Viejo. Fishing takes place in Samaná Bay.

TARGET SPECIES

The main target species are snooks (Centropomidae) and mullets (Mugilidae).

VESSELS AND CREW

Wooden *cayucos* and *botes* crewed by 1 or 2 men are used in the fishery.

GEAR (GILLNETS)

Multifilament nylon gillnets with mesh sizes from 40–100mm are used. Panels are 30–255m long and 4–5.7m deep. Each vessel usually carries 4–5 panels.

OPERATIONS

Nets are set at the surface at night, then retrieved in the morning after a soak time of about 12 hours.

INTERACTIONS WITH CETACEANS

A 3m humpback whale calf was caught (date not given) in a gillnet in Samaná Bay, 1.5km from Pueblo Viejo, on the east side of Sánchez and San Lorenzo Bay (at 19°14'N, 60°36'W). The calf was cut into pieces and eaten by the fishermen, who also sold some of the meat. The use of nets is illegal from November to May in the humpback Silver Bank Sanctuary and nearby areas, but this has been difficult to enforce. CRSBJBP is preparing regulations aimed at better protecting the whales entering Samaná Bay. This bay, which is another important humpback whale area, has been proposed for inclusion in the Silver Bank Sanctuary.

[11] Information was provided by I. Bonnelly de Calventi (*in litt.*, 7 September 1990), Comisión Rectora del Santuario de Ballenas Jorobadas del Banco de la Plata (CRSBJBP), Santo Domingo.

Turks and Caicos Islands[12]

There are no gillnet fisheries reported for the country. Two lobster trap boats work the deeper edges of the Caicos Bank, but interactions with cetaceans are not known or suspected. Humpback whales are seen regularly about 45km south of these islands.

Jamaica

According to H. Gieben (*in litt.* 16 November 1986, to S. Leatherwood; received by the authors August 1990) gillnets primarily are used close to shore, and no conflicts with cetaceans have been reported. Common and striped dolphins are potentially at risk.

Cuba

We received no reply to our request for data. The only information comes from H. Gieben (*in litt.*, 16 November 1989, to S. Leatherwood; received by the authors August 1990) who believes that gillnetting is becoming quite popular in Cuba.

Cayman Islands[13]

The Cayman Islands possess a narrow insular shelf which supports limited fisheries operated by local fishermen. There are no pelagic gillnet or trap fisheries around the islands. Inshore net fishing is restricted to a few (7–10) licensed seine-net fishermen who set their nets mainly for sea turtles. Trap fishing by locals is also confined to inshore waters. The traps used are the small, traditional, wire-mesh and frame 'fishpots' widely used in the Caribbean. There have been no reports of any cetaceans entrapped.

Bahamas

The most recent report on the commercial fisheries (Bahamas Department of Fisheries, 1990) states that gillnets are not used (in fact, they are prohibited) and fish pots are not used extensively. The most common method for capturing sea basses (*Epinephelus*), groupers (*Mycteroperca*) and other commercially important 'big fish' (principally snappers, *Lutjanus*) is by trapping them in 'arrowhead-shaped' or 'rectangular' wire traps. Such devices are unlikely to trap cetaceans. The capture or molesting of marine mammals is illegal in the Bahamas. At least three species of cetaceans are known to be found close to shore: bottlenose and Atlantic spotted dolphins and humpback whales.

DISCUSSION AND RECOMMENDATIONS IN ORDER OF PRIORITY

From the limited information available, seldomly reaching beyond the anecdote, it is evident that considerably more data are needed to assess the effects of gillnet fisheries on cetaceans in this large area. Every effort should be made to: (1) further document existing gillnet fisheries and those that may develop, by soliciting co-operation from local fishery officers and biologists, and through dedicated surveys by independent observers in those areas thought to be most seriously affected; (2) identify and stimulate interested local residents (e.g. biology students) and organisations to become actively involved in the monitoring of gillnet fisheries; (3) investigate alternative fishing methods that could reduce or eliminate incidental mortality; (4) develop studies to assess the abundance of cetaceans incidentally killed in order to understand the impact of increased mortality due to fisheries (especially for the vaquita); and (5) design and implement regional educational programmes to increase the awareness of local fishermen and the general public to the problems faced by cetacean populations interacting with gillnet fisheries.

Urgent attention should be given to the endangered vaquita in the upper Gulf of California, Mexico (see Mexico for recommendations). Special attention should also be given to the tucuxi, *Sotalia fluviatilis*, along coastal waters of Honduras, Nicaragua, Costa Rica, Panama, Colombia, Venezuela, Guyana, Surinam and French Guiana. This may be the most commonly killed small cetacean in the Caribbean. Monitoring of incidental mortality is also important for: the coastal pantropical spotted dolphin, *Stenella attenuata graffmani* (Pacific coast of Mexico, Central America and Colombia); spinner dolphins (*Stenella longirostris centroamericana* off the Pacific coast of Mexico and Central America, *S. l. orientalis* off the Pacific coast of Mexico, Central America and Colombia); the offshore pantropical spotted dolphin, *Stenella attenuata attenuata* (off the Pacific coast of Mexico, Central America and Colombia); and common and bottlenose dolphins for all countries.

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[12] Information was provided by C. Ninnes (*in litt.*, 17 July 1990), Turks and Caicos Islands Ministry of Natural Resources.

[13] Information was provided by P. Bush (*in litt.*, 10 October 1990), Natural Resources Laboratory, Cayman Islands Government.

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SC/46/SM24

A Note on Artisanal Fisheries Interactions with Small Cetaceans in Mexico

Alfredo Zavala-González[1], Jorge Urbán-Ramírez[2] and Carlos Esquivel-Macías[3]

ABSTRACT

Between 1982 and 1993, 55 coastal locations throughout Mexico were visited to investigate mortality of small cetaceans. A total of 139 records concerning the use of small cetaceans by fishermen were obtained. The species recorded were, in decreasing order of frequency: *Delphinus* sp., *Stenella attenuata*, *Tursiops truncatus*, *Phocoena sinus*, *Globicephala macrorhynchus* and *Stenella frontalis*. Areas with the highest relative abundance of cetaceans coincided with major fishing areas, making fishery/cetacean interactions likely.

KEYWORDS: INCIDENTAL CAPTURE; NORTH ATLANTIC; NORTH PACIFIC; FISHERIES; COMMON DOLPHIN; SPOTTED DOLPHIN; BOTTLENOSE DOLPHIN; VAQUITA; PILOT WHALE-SHORT FINNED; WHITE-SIDED DOLPHIN.

INTRODUCTION

México has more than 10,000km of coastline, including the Gulf of California and portions of the Gulf of Mexico, the Caribbean Sea and the Pacific Ocean, resulting in great marine biodiversity. A total of 39 cetacean species have been recorded in Mexican waters (45% of known species), including coastal and oceanic species, migratory and resident species, and species from both tropical and temperate waters (Urbán-R, 1994). All marine mammals are protected by Mexican law (Secretaría de Pesca, 1992).

This note considers interactions between small cetaceans and fisheries in Mexican waters. The data presented were obtained mainly from the remains of small cetaceans found during visits to 55 coastal locations between 1982 and 1993 by researchers from the Laboratorio de Mamíferos Marinos of the Facultad de Ciencias, Universidad Nacional Autónoma de México and the Programa de Investigación de Mamíferos Marinos of the Universidad Autónoma de Baja California Sur.

The remains of small cetaceans were considered to be the result of interactions with artisanal fishermen if they were found: (a) in fishing camps or within a 100m radius (if piled up in organic dumps with fish remains); or (b) further than 100m away from fishing camps but with evident human-induced wounds.

RESULTS AND DISCUSSION

Throughout Mexico we obtained 139 records of small cetaceans whose mortality was attributable to interactions with humans. Seven species were recorded (Fig. 1): the common dolphin, *Delphinus* sp. (51.8%), the coastal form of the Pacific spotted dolphin, *Stenella attenuata* (23%), the bottlenose dolphin, *Tursiops truncatus* (18%), the vaquita, *Phocoena sinus* (4.3%), the short-finned pilot whale, *Globicephala macrorynchus* (1.4%), the Pacific white-sided dolphin, *Lagenorhynchus obliquidens* (0.7%), and the Atlantic spotted dolphin, *Stenella frontalis* (0.7%).

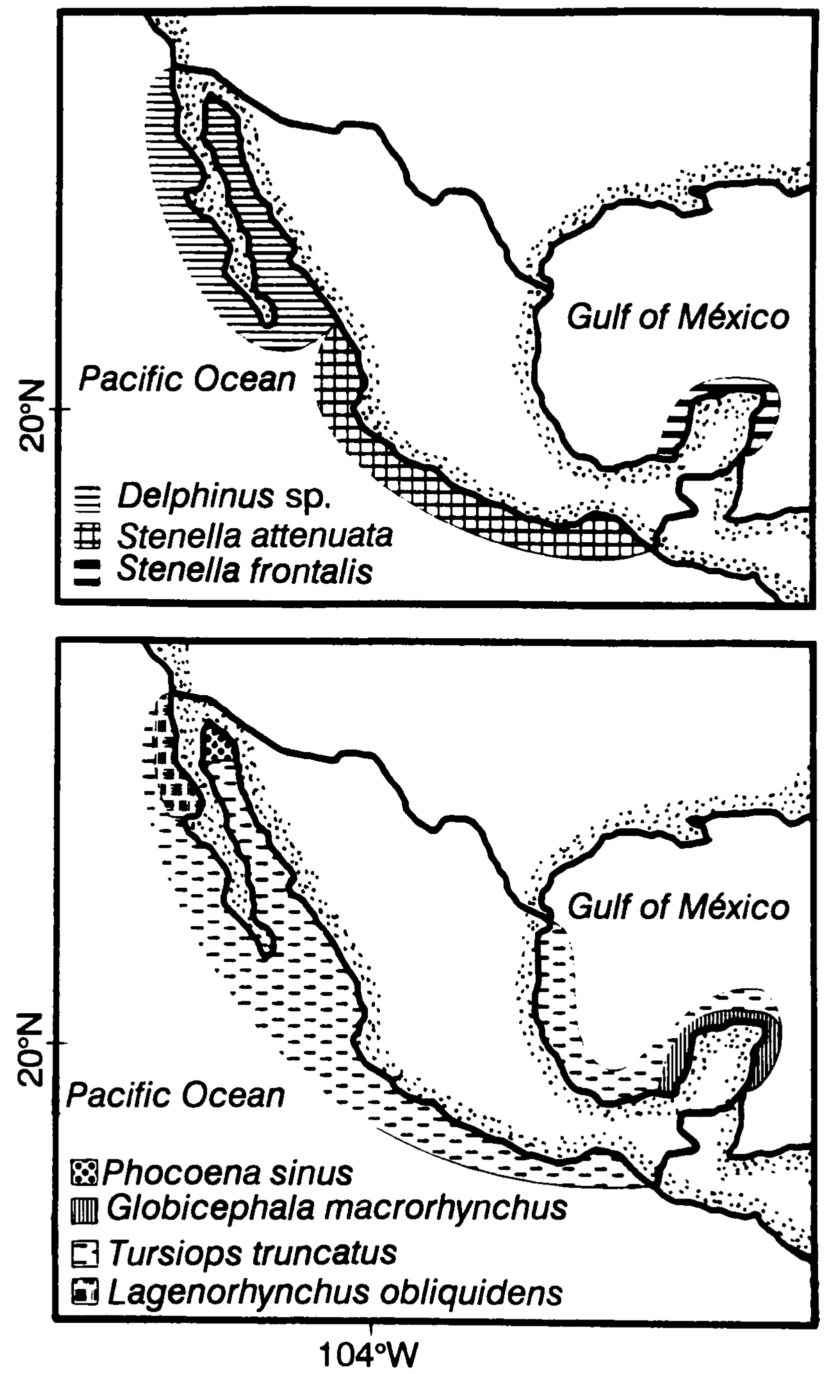

Fig. 1. Areas where the interactions with the different species occur or potentially happen.

The records of common dolphins were not differentiated between the two species proposed by Heyning and Perrin (1994) for the Eastern North Pacific; nevertheless their distribution suggests that the majority would correspond to the long-beaked common dolphin (*Delphinus capensis*).

[1] *Centro de Investigación Científica y Educación Superior de Ensenada, Ap. Postal 2732. Ensenada Baja California, Mexico*
[2] *Departamento de Biología Marina, Univ. Aut. de Baja California Sur, La Paz, B.C.S., Mexico*
[3] *Departamento de Biología, Facultad de Ciencias, UNAM, Mexico, D.F.*

Table 1

Killing procedure and use of the dead small cetaceans by artisanal fishermen.

Species	Killing method	Use
Lagenorhynchus obliquidens	Nets(?)	Sometimes for bait (?)
Tursiops truncatus	Gillnets (incidental). Harpoon	Sometimes for bait
Delphinus sp.	Harpoon (54%), Firearms (7%)	Sometimes as shark bait. They are relatively easy to catch.
Stenella attenuata	Highest frequency in Punta Mita, Nay. Harpoon (73%)	Occasional use as shark bait.
Stenella frontalis	Gillnet	Shark bait
Globicephala macrocephalus	Harpoon	Shark bait
Phocoena sinus	Gillnets (incidental). Less frequent in shrimp trawlers	Human food(?). Sometimes as shark bait

Table 2

Locations with records of deliberate or incidental small cetaceans deaths caused by artisanal fishermen.

Region	Location (see Fig. 2)	Species[1] Lo	Tt	Dsp	Sa	Sf	Gm	Ps	Total	Effort[2] (days)	Animal/ Effort
West coast of Baja California Peninsula	1. Estero de Punta Banda	1							1	15	0.07
Gulf of California	2. Golfo de Santa Clara	1						3	3	8	0.38
	3. San Felipe		2					3	5	7	0.71
	4. Isla Granito		1	2					3	98	0.03
	5. Los Cantiles		1						1	270	0.004
	6. Isla Estanque			3					3	6	0.5
	7. Isla Partida		1	8					9	10	0.9
	8. Isla Rasa			3					3	31	0.1
	9. Isla Salsipuedes		1	2					3	10	0.3
	10. Isla Las Animas		1	2					3	10	0.3
	11. Isla San Lorenzo		2	5					7	11	0.64
	12. Isla San Esteban			3					3	34	0.09
	13. Bahia de Agua Dulce			2					2	10	0.2
	14. Eusenada de Perros			25					25	16	1.56
	15. Guaymas			1					1	8	0.13
	16. Isla San Marcos		3	13					16	8	2.0
	17. Isla Monserrat			1					1	4	0.25
	18. Isla Santa Catalina		1						1	4	0.25
	19. Isla San José		1	1					2	4	0.5
	20. Isla Cerralvo			1					1	4	0.25
	21. Laguna Caimanero				1				1	2	0.5
	22. LagunaTeacapan				1				1	2	0.5
	23. Isla Isabel		3		1				4	35	0.11
	24. Punta Mita		2		20				22	730	0.03
	25. Cruz de Huanacaxtle		1		3				4	30	0.13
	26. Cabo Corrientes				1				1	10	0.1
South Pacific	27. Playa de Campos				2				2	51	0.04
	28. Deca de Apiza				1				1	15	0.07
	29. Playa San Jerónimo				1				1	1	1.0
	30. Laguna de Chacahua				1				1	7	0.14
Gulf of Mexico	31. Laguna de Términos		3						3	170	0.02
	32. Dzilam de Bravo					1	2		3	3	1.0
Caribbean Sea	33. Bahia de Ascención		2						2	50	0.04
Total		1	25	72	32	1	2	6	138	1,532	

[1] Lo = *Lagenorhynchus obliquidens*; Tt = *Tursiops truncatus*; Dsp = *Delphinus* sp; Sa = *Stenella attenuata*; Sf = *Stenella frontalis*; Gm = *Globicephala macrorhynchus*; Ps = *Phocoena sinus*.
[2] Effort in days searching fish camps.

All the records of Pacific spotted dolphins where we collected the skulls, corresponded to the coastal form (Urbán-R *et al.*, 1986).

Deliberate or incidental deaths were caused by artisanal fishermen in four main ways: (a) with firearms (several kinds); (b) with harpoons; (c) in gillnets and (d) with clubs. In some cases the killing procedure or weapons could not be identified.

The harpoon was the most common weapon used by artisanal fishermen (60%); a considerably lower

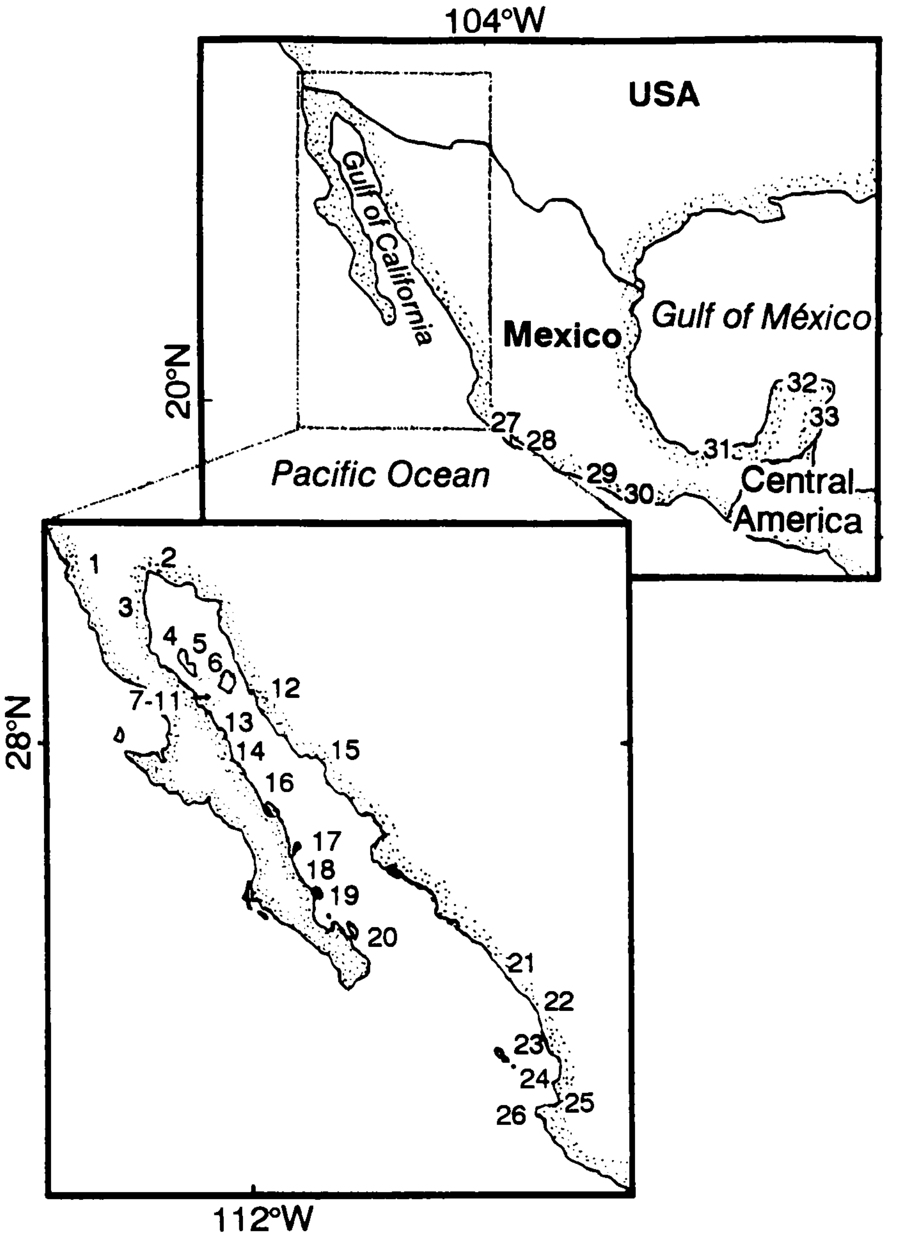

Fig. 2. Localities with records of small cetacean mortality attributable to interactions with humans (see Table 2).

percentage of animals were killed with firearms or gillnets (4.4% for each). Gillnet deaths were accidental. For 31% of the remains found we were not able to determine the weapon used or the method by which the animal was killed. Only 4.4% of the carcasses were flensed. It appears that 65% of the animals found were used by fishermen as shark bait (Table 1).

Most marine mammal/fisheries interactions in Mexico occur in the Gulf of California, and particularly the northern half which includes the Big Islands area. This is perhaps not surprising as the Gulf has both the highest relative abundance of cetaceans in Mexico and, especially in the north, the highest concentration of fishing activities (Table 2; Fig. 2).

Published information about the interactions of artisanal fisheries and cetaceans in Mexico is scarce and primarily concerns the vaquita, an endangered and endemic porpoise of the northern Gulf of California (Silber, 1990; Klinowska, 1991; Rojas Bracho and Urbán-Ramírez, 1993; Vidal, 1993; 1994; D'Agrosa *et al.*, 1994). Information on other species is limited to Vidal *et al.* (1994) which discusses interactions of bottlenosed and common dolphins in the northern Gulf of California, and Urbán *et al.* (1986) which examines the use of coastal Pacific spotted dolphins for shark bait on coasts of Sinaloa and Nayarit. Except in the case of the vaquita, there is no information about the status of the different populations affected.

We consider it especially important to: (a) evaluate the impact of these interactions for common dolphins in the Gulf of California, the coastal form of the Pacific spotted dolphin in the south Pacific coast of Mexico and the different populations of bottlenose dolphins in all Mexican coastal waters; and (b) monitor the artisanal shark fishery on both coasts of Mexico, especially in the Gulf of California and the Caribbean region.

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Western South Atlantic

SC/46/SM10

Review of Small Cetaceans and Fishery Interactions in Coastal Waters of Brazil

Salvatore Siciliano

Fundação Brasileira para a Conservação da Natureza-Rua Miranda Valverde, 103 – Botafogo Rio de Janeiro, RJ 22281–000 Brazil

ABSTRACT

This paper reviews the incidental mortality of small cetaceans in fishing operations along the coast of Brazil. In addition to reviewing the available literature, it includes information from visits to selected fishing ports and from ongoing programmes (up to February 1994). Although a number of cetacean species (including occasional great whales) are incidentally caught, the most common are the tucuxi and the franciscana. In some areas incidentally caught animals are used as fish bait or for human consumption. Further effort is needed to monitor poorly covered areas, especially in the north and northeast regions where direct takes may occur; law enforcement and educational programmes are required. Only the establishment of a long-term plan for monitoring incidental catches and a programme to assess population size and stock identity will allow the rational conservation of small cetaceans in Brazilian waters.

KEYWORDS: SOUTH ATLANTIC; INCIDENTAL CAPTURE; FISHERIES; STRANDINGS; TUCUXI; PILOT WHALE – SHORT-FINNED; PILOT WHALE – LONG-FINNED; BOTTLENOSE DOLPHIN; FRANCISCANA; HUMPBACK WHALE; SPERM WHALE; ROUGH-TOOTHED DOLPHIN; SPOTTED DOLPHIN; COMMON DOLPHIN; SPINNER DOLPHIN; BEAKED WHALE; RISSO'S DOLPHIN.

INTRODUCTION

Although knowledge of cetaceans along the Brazilian coast has increased in recent years (e.g. Borobia and Barros, 1989; Barros, 1991; Borobia *et al.*, 1991) much remains to be learned about their biology and conservation. Of major concern throughout the world is the mortality of cetaceans caused by entanglement in nets during various fishery activities. In Brazil, the problem has been documented for some sites in the states of Rio Grande do Sul, Santa Catarina, São Paulo and Rio de Janeiro (Lodi and Capistrano, 1990; Monteiro Filho, 1990; Borobia, 1991; Simões-Lopes and Ximenez, 1993; Barros and Teixeira, 1994; Pinedo, 1994). Cetaceans are legally protected in Brazilian waters.

METHODS

In addition to reviewing the available literature, this paper includes information on fishery activities and cetaceans obtained during visits to a number of localities along the Brazilian coast (Fig. 1). Data on cetacean mortality was gathered through the collection of specimens from accidental captures. Skeletal and other material was given to the mammal collection of the Museu de Zoologia da Universidade de São Paulo (MZUSP), São Paulo, Brazil. Informal discussions with fishermen provided information on fisheries, fishing methods and cetacean bycatches as did the collection of fish retrieved from gillnets and more formal interviews with fishermen at selected ports. A list of target fish species is provided in Table 1. Most information is available for Rio de Janeiro, Espírito Santo, Paraná and Rio Grande do Sul. The coastal areas in northern Brazil have been less studied and consequently less is known of fishery activities or the presence and interactions with cetaceans. More extensive research facilities must be set up there in order to monitor mortality rates of cetaceans. A recent joint-project funded by UNEP/IUCN should improve our knowledge of small cetaceans and fisheries in northeastern Brazil.

SELECTED PORTS: CASE STUDIES

Pará

Algodoal and Marudá

The fishing villages of Algodoal (00°30′S, 47°28′W) and Marudá were visited on 28–31 January 1990. In Algodoal, 46 boats were counted using both gillnets and longlines. Fishery operations are conducted from wooden sail boats. Information on dolphin bycatch was obtained through informal contact with fishermen. Partial skulls of the tucuxi[1] (*Sotalia fluviatilis*) were found and collected in both villages (MZUSP 27383, MZUSP 28413). Specimen MZUSP 27383 had the rostrum cut off indicating possible interaction with fisheries. Tucuxi (*S. fluviatilis*) were frequently observed in small groups in the area during the visited period.

Salinópolis

Salinópolis (00°37′S, 47°21′W) has been poorly surveyed and information is scant. Borobia *et al.* (1991) reported on a tucuxi that was harpooned and used as bait for the local shark fishery.

Marajó bay area and Vigia

An incidental capture of a tucuxi occurred at the bay of Marajó (01°00′S, 48°30′W) on 9 December 1982 (Borobia *et al.*, 1991). The specimen is held at the Museu Paraense Emílio Goeldi (MPEG 10945). The fishing village of Vigia has been monitored by a UNEP/IUCN funded project since September 1993. Intentional captures of tucuxis are reported to occur in the area (R.T. de Almeida, pers. comm.). Dolphins are captured with nets, killed with a

[1] Although the officially recognised common name for *Sotalia fluviatilis* is the tucuxi, fishermen along the Brazilian coast often refer to *Sotalia* as 'boto', which is usually reserved for *Inia geoffrensis*. For consistency I use tucuxi=*Sotalia* in this paper.

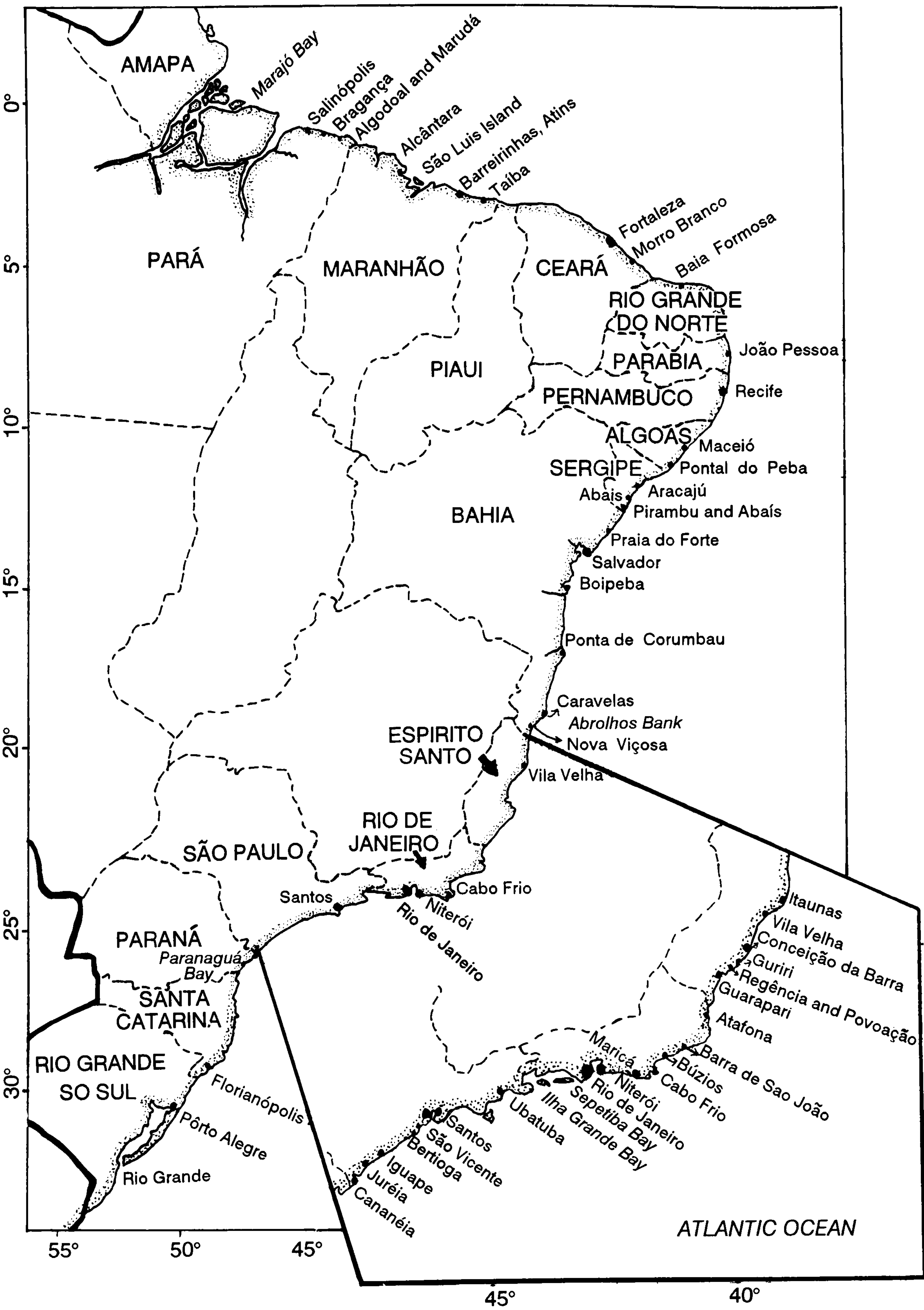

Fig. 1. Map showing localities visited along the Brazilian coast.

knife on the boat and the meat and blubber are saved. The genitals and eyes of males and females are sold as love charms in the markets of Belém Pará's capital. The mandibles are used in local handicraft and the teeth for making necklaces. Although the meat is usually consumed locally it is not considered 'tasty'. The blubber is thought to be the best bait for shark fishing and is stored by salting, and sold for about $1.50 per kilo[2].

General

Dolphin harpooning as well as intentional capture in nets seems to occur frequently along the Pará coast. This is also reported to be common practice in the locality of Bragança. An active market for bait exists in several

[2] Prices are given in US dollars throughout this paper.

Table 1

Local, scientific and English names of fish species from Brazilian waters known to be caught in gillnets by region (following Fabre and Batista, 1992; Barros, 1990; Borobia, 1991; Zanellato, 1994)

Local name	Scientific name	English name
North/Northeast		
Serra	*Scomberomorus brasiliensis* *S. maculatus*	Spanish Mackerel
Corvina-gó	*Macrodon ancylodon*	Weakfish
Pescada	*Cynoscion acoupa*	
Bonito	*Sarda sarda*	
Peixe-pedra	*Genyatremus luteus*	
Uritinga	*Arius proops*	Catfish
Gurijuba	*Arius parkeri*	Catfish
Cavala	*Scomberomorus cavalla*	King Mackerel
Cação	Carcharhiniformes	Shark
Guarajuba		
Ariacó	*Lutjanus synagris*	Lane snapper
Pargo	*Lutjanus purpureus*	Snapper
Cioba	*Lutjanus* spp.	Snapper
Bagre	*Bagre bagre, B. marinus*	Catfish
Guaiúba	*Ocyurus chrysurus*	
Camorim/camurim	*Centropomus* spp.	Snook
Corvina-uçu	*Cynoscion microlepidotus*	
Carapeba	*Diapterus olisthostomus* and *Eugerres brasilianus*	Mojarra
Piaba-do-mar	*Pempheris schomburgki*	
Tainha	*Mugil liza, M. curema* *M. gaimardianus, M. incilis*	Mullet
Camurupim/pirapema	*Tarpon atlanticus*	Tarpon
Mariquita	*Holocentrus ascensionis*	
Corvina/Cururuca	*Micropogonias furnieri*	Croaker
Arabaiana		
Curimã		
Salteira	*Caranx latus, C.hippos* and *Oligoplistes saliens*	Jacks
Arraia	?	Ray
Southeast		
Bagre-bandeira	*Bagre bagre*	Cocosea catfish
Vento-leste	*Caranx crysos*	Blue runner
Pescadinha	*Isopisthus parvipinnis*	Shortfin corvina
Pescada	*Macrodon ancylodon*	King weakfish
Corvina	*Micropogonias furnieri*	Croaker
Sarda/Sororoca	*Scomberomorus* spp., *Scomberomorus brasiliensis*	Mackerel
Gordinho	*Peprilus paru*	Butterfish
Linguado	*Paralichthys*	Flounder
Tainha	*Mugil spp.*	Mullet
Cação	Carcharhiniformes	Shark
South		
Robalao	*Centropomus undecimalis*	Common snook
Linguado	*Paralichthys* spp.	Flounder
Tainha	*Mugil liza*	Mullet
Cavala/Sororoca	*Scomberomorus maculatus*	
Salteira	*Oligoplistes saurus*	
Corvina	*Micropogonias furnieri*	Croaker
Bagre branco	*Netuma barba*	
Cação/cambeva	Carcharhiniformes	Shark
Cação-martelo	*Sphyrna* spp.	Hammer shark
Betara preta	*Menticirrhus americanus*	
Pescada	*Cynoscion* sp.	
Brota	*Urophycis* sp.	Gadid

fishing villages. A survey is needed in these areas to evaluate the extent of the direct take of dolphins for local shark fisheries. Law enforcement and educational campaigns are urgently needed in the area.

Maranhão

Alcântara

The locality of Alcântara was visited on 20–23 April and 1–3 May 1991. At least twenty boats using gillnets operate in the area. A 1.7m tucuxi was collected at Cajual Island and the skeleton was deposited at MZUSP (27999). It was reported by fishermen to have been incidentally caught in nets. The specimen was found in an advanced stage of decomposition and its sex and the cause of its death are unknown. Tucuxis were observed in small groups near Alcântara harbour.

São Luís Island

A short survey was conducted in the fishing villages of Raposa, Vieira (São José do Ribamar) and Quebra-Pote, on São Luís Island (02°31′S, 44°18′W) in February 1989. The village of Raposa is considered the largest producer and most important fishing community of Maranhão state (Stride, 1988) with 194 boats representing the potential fishing effort (Fabre and da Batista, 1992). A number of different kinds of boats are used in the fisheries, mainly dug-out canoes and small wooden sail boats. Operations are usually restricted to coastal waters (within 5 n.miles). Skeletal remains of at least four tucuxis were collected at Raposa on 1 February 1989 and were deposited at the Universidade Federal do Maranhão, Laboratório de Hidrobiologia (UFMA, LABOHIDRO). On 2 February 1989, a complete skeleton of a tucuxi caught in nets at the village of Vieira was collected (MZUSP 26867). Raposa has been monitored by a UNEP/IUCN funded project since September 1993. Direct takes of tucuxi have been observed and appear to have been increasing over the last two years. Fishermen use nets to capture dolphins which are then killed with a knife, and the meat and blubber are kept. The carcass is discarded at sea in order to avoid evidence of killing. Collection of skeletal remains and evidence of direct take is hard to obtain, but the researchers did collect two tucuxi skulls in January 1994 (R.T. de Almeida, pers. comm.). Dolphin blubber is used as bait for the local shark fishery and the meat is consumed locally as an alternative food source, but is not popular. The blubber is frozen and sold for about $1.50 per kilo. The collection of genitals, eyes and mandibles is not practiced on the coast of Maranhão.

Atins, Barreirinhas

Atins is a small fishing village located at the mouth of the Preguiças river, Barreirinhas county. A tucuxi skull (MZUSP 28001) was collected in June 1988 (M.A. Mendonça, pers. comm.). It was reported that dolphins were intentionally captured in the area for human consumption as salted meat (F.C.R. dos Santos, pers. comm.).

Ceará

Taíba

The small fishing village of Taíba is being monitored by a UNEP/IUCN funded project. The fishery uses small (4–8m) sail-rigged open boats called *jangadas* that use gillnets; *jangadas* are found in large numbers along the Ceará coast. Fishermen report that incidental catches of dolphins are frequent in the area (where the tucuxi seems to be relatively common). A juvenile tucuxi that was caught in nets was collected in October 1993 (Grupo de Mamíferos Aquáticos do Nordeste, unpub. data).

Fortaleza
A survey conducted in April 1991 revealed that six tucuxis were captured in gillnets in the area of Fortaleza (03°43′S, 38°30′W) between November 1987 and January 1991. Skeletal remains and photographs of entangled dolphins were recovered. Specimens collected were deposited at the Universidade Federal do Ceará, Laboratório de Biologia Marinha (UFCE, LABOMAR, in exhibition) and at MZUSP (28000). At least 60 *jangadas* were seen in Mucuripe, the largest port of Ceará's capital, Fortaleza. In one case dolphin meat was being sold for human consumption.

Morro Branco
The fishing village of Morro Branco was visited on 11–12 April 1991. At least 40 *jangadas* were found in the main village of Morro Branco. Gillnets or longlines are used, depending on the target species. The head of the local fishing village informed us that the total number of *jangadas* may reach 64, if the lesser fishing villages of Flexeiras, Diogo, Uruaú, Barra do Sucatinga, Praia do Ariós, Prainha do Canto Verde and Parajuru are included. No specimens were found during the short visit, but fishermen reported the incidental catches of some small cetaceans, mainly 'botos' (cf. tucuxi). Dolphins caught in nets are used for human consumption but no direct takes occur. Fishermen complained about the fact that dolphins cause damage to the net when they get entangled. Each *jangada* brings about 30–50 kg of fish, mainly *serra*, per trip. During casual interviews, fishermen informed us that dolphins come to the nets attracted by the fish caught and then get entangled. Nets are usually set at night and retrieved at early morning.

Rio Grande do Norte

Baía Formosa
Baía Formosa (06°22′S, 35°00′W) is a small fishing village located some 90km south of Natal, Rio Grande do Norte's capital. One tucuxi was caught '*ca.* 6km E Baía Formosa' on 8 December 1986 (A. Langguth, *in litt.*) and the skeleton was deposited in the mammal collection of Universidade Federal da Paraíba (UFPB 547). It was 1.675m and is listed in Borobia *et al.* (1991).

Paraíba

João Pessoa and Mamanguape
Paraíba's capital João Pessoa (07°07′S, 34°52′W) and the small fishing village of Mamanguape (06°50′S, 35°07′W) have been visited and surveyed at different times since the early 1980s. Gillnets are not often used and the fisheries are based on collecting small invertebrates (shrimp, mollusks, conchs). Tucuxi specimens have been collected (Borobia *et al.*, 1991) but there is no information on fishery interactions.

Pernambuco

Recife
Three adult tucuxis were caught in gillnets at Boa Viagem (08°03′S, 34°54′W) on 17 November 1989 (de Almeida *et al.*, 1990; Borobia *et al.*, 1991). Specimens are stored in the collection at the Museu de História Natural, Universidade Federal Rural de Pernambuco (UFRPE). Borobia *et al.* (1991) report on the collection of a specimen at Candeias on 23 September 1990 that had evidence of gillnet entanglement.

Longline fishery in northeast region
Longlines are used to catch tuna, marine catfish, half beaks, ballyhoo, tarpon and other species in coastal areas of northwest Brazil (IWC, 1994). Small cetaceans interact with long-line fisheries. It is reported by fishermen that dolphins (apparently only oceanic species) are attracted to fish caught in the longline, either to steal the bait and/or fish caught on the hooks. There is a case of a short-finned pilot whale (*Globicephala macrorhynchus*) and a bottlenose dolphin (*Tursiops truncatus*) incidentally caught in this fishing gear (R.T. de Almeida, pers. comm.).

Alagoas

Maceió
Fisheries in Maceió (09°40′S, 35°43′W) use *jangadas* and the total catches of artisanal fishermen can reach about 3,000 kg/year (Secretaria de Planejamento do Estado de Alagoas, 1990). A short survey conducted in January 1991 showed the wide use of gillnets and the potential involvement of small cetaceans in fishery operations (Borobia, 1991). Barros and Teixeira (1994) report on the incidental catch of two female tucuxis, 182 and 161cm in length, retrieved from the same gillnet on 23 September 1988 at Praia da Pajuçara, Maceió. Specimens were deposited at the Museu de História Natural, Universidade Federal de Alagoas (no number available). The nets involved were 200m in length, 2m in height and had a mesh size of 35mm. It is interesting to mention that no external evidence of entanglement, such as marks or cuts, were found on the dolphins, although the nets in which they were caught were heavily damaged (Barros and Teixeira, 1994).

Pontal do Peba
Pontal do Peba is a relatively large fishing village dominated by shrimp trawlers but gillnets are also used. Borobia (1991) reported incidental catches of small cetaceans in the area: on 10 February 1991, a 1.67m female tucuxi with net marks on its body was found dead ashore. A second tucuxi was also caught in nets during the same season.

Sergipe

Pirambu and Abaís
One tucuxi (a 1.05m calf, MZUSP 23814) was collected at Pirambu (10°44′S, 36°51′W) on 12 October 1986 (Borobia *et al.*, 1991) having been taken in gillnets about 3 n.miles off the coast together with a reported larger dolphin (probably its mother). Borobia (1991) reported a male tucuxi caught in nets in Pirambu and recovered on 8 January 1991 (MZUSP 27830) and the skull and partial skeleton of a tucuxi reportedly caught in nets in 1990 (MZUSP 28184) at Praia do Abaís in January 1991. All fishing villages visited in January 1991 make use of gillnets and reported the incidental catch of dolphins, mainly 'botos' (cf. tucuxi).

Aracajú
'Occasional' incidental mortality of small cetaceans at Atalaia Nova and Rio Sergipe was reported by the Grupo de Mamíferos Aquáticos do Nordeste (1992). As fishermen are aware of the law protecting dolphins and whales, dolphins are often discarded to avoid problems

with the environmental agency although they are sometimes consumed locally. Fishermen may butcher dolphins retrieved from nets, wrap them in plastic bags and drown the bags in the river in order to erase evidence of bycatch (R.T. de Almeida, pers. comm.). Groups of up to 100 tucuxi are reported to be observed in the area (Grupo de Mamíferos Aquáticos G.M.A.-N.E., 1992).

Bahia

Praia do Forte
Praia do Forte (12°31'S, 38°17'W) is a famous resort located some 80km north of Salvador Bahia's capital. One 1.78m male tucuxi was caught in a gillnet set about 1 n.mile off the beach of Praia do Forte by summer tourists on the night of 27/28 December 1986. The skull was collected (MZUSP 23802). Two marine turtles (unknown species) were also retrieved from the nets.

Salvador and Itaparica (including Todos os Santos bay area)
The Todos os Santos bay (12°55'S, 38°35'W) is the largest bay along the Brazilian coast with an estimated area of 1,110km². Tucuxis are relatively abundant in the area, as are fishing villages and gillnet operations (Reis and Queiroz, 1992). One male tucuxi (estimated length 1.60m) found stranded at Mar Grande, Itaparica on December 1988 had probably been caught in gillnets (known locally as *tainheira*); photographs showed that the peduncle was cut off indicating entanglement. Reis and Queiroz (1992) reported on four tucuxi incidentally caught in nets in the area.

Boipeba
Gillnets are commonly used in the fishing village of Boipeba (13°40'S, 38°55'W). The locality was regularly visited by Everaldo Lima de Queiroz of the Universidade Federal da Bahia, who provided information on small cetacean bycatches in the area. A 1.90m lactating tucuxi was caught in gillnets off the coast of Boipeba on 5 December 1987. The specimen was used as bait for the longline shark fishery (Borobia *et al.*, 1991).

Ponta de Corumbau
The small fishing village of Ponta de Corumbau (17°20'S, 39°13'W) was visited in September 1989. Small wooden boats and dug-out canoes operate in the area. Shrimp-trawlers from other localities were reported to operate in this region causing damage to local artisanal fisheries. The post-cranial skeleton of a juvenile tucuxi was found on 29 September 1989 and was collected (MZUSP 26873) and fishermen stated that it was caught in gillnets (Borobia *et al.*, 1991).

Caravelas
The fishing village of Caravelas (17°20'S, 39°15'W), as well as its main port, Ponta de Areia and Barra de Caravelas were visited in January 1987, and subsequently surveyed from September 1988 to October 1992. Although fishing activity is dominated by small shrimp trawlers, a small number of boats use gillnets and/or longlines. Boats from nearby cities also operate in the area. Skeletal remains of three tucuxis were collected at Barra de Caravelas: one skull on 12 January 1987 (MZUSP 23801); 25 vertebrae on 13 January 1987 (MZUSP 23800) and a partial skull on 6 November 1988 (MZUSP 25430). At least two of the animals had been caught in nets. On 7 March 1990, two tucuxis were captured in the same gillnet about 20 n.miles east of Caravelas. The net was 900m long and had a mesh size of 7cm. The skulls were collected (MZUSP 28182, MZUSP 28183).

Abrolhos Bank
Abrolhos Bank (17°20'-18°10'S, 38°35'-39°20'W) is an enlargement of the southern end of the eastern Brazilian continental shelf and encompasses a large coral reef ecosystem. Fishing boats from Espírito Santo and southern Bahia operate in the area using longlines and gillnets. A few cases of entanglements are reported by fishermen. One tucuxi skeleton (MSUSP 26866) was found on the island of Santa Barbara on 18 October 1988 (Borobia *et al.*, 1991). In June 1993, a pregnant female tucuxi was captured in nets (C.E. Leite Ferreira, pers. comm.). Details of the capture are not available and only a photograph of the full term foetus was examined for positive identification.

Nova Viçosa
Small motor powered wooden boats (*traineiras*) operate in coastal waters from Nova Viçosa and on the Abrolhos Bank. Boats from several localities of Bahia and Espírito Santo also fish in the area. One adult tucuxi was found stranded on the beach of Praia do Pontal, at Nova Viçosa (17°53'S, 39°22'W) on 4 September 1989 and the complete skeleton collected (MZUSP 26868); fishermen reported that it was caught in gillnets (Borobia *et al.*, 1991). Small pieces of blubber were taken from the dolphin to be used as bait in shark fishery, a common practice in this area.

Espírito Santo

Itaúnas
Local artisanal fisheries use a small number of dugout canoes, 6m in length, that usually operate within 1 n.mile of the shore. On 12 February 1991, a 117cm female franciscana calf was caught in a gillnet at the village of Itaúnas (18°25'S, 30°42'W). The net was some 250m long with a 70mm mesh. It was set 500m from shore at 0500h and retrieved at 1300h of the same day. Small sciaenids (cf. *Isopisthus parvipinnis*, 'pescadinha') were retrieved from the net. It had milk in its stomach and its length suggests that it would have been unweaned (Pinedo *et al.*, 1989). The complete skeleton is kept at MZUSP (27995). Two dolphins (unknown species) reported to be caught in nets were found dead ashore in the summer of 1994 (A. Higa, pers. comm.). Larger mesh sizes between 12–20cm are used to catch sharks. The above specimen indicates a northward extension of the known range of the franciscana by some 160km. This suggests that the species reaches well into tropical waters where the lowest annual mean surface temperature is 23°C. The Brazilian Current along the northern coast of Espírito Santo state is influenced by the discharge of the rivers Mucuri, Itaúnas, São Mateus and Doce. This discharge causes a lowering of both temperature and salinity of the current (Palacio, 1982). Groups of up to 20 tucuxi were reported to be found in the area.

Conceição da Barra
The city of Conceição da Barra is a traditional fishing port in northern Espírito Santo. Several boats operate in the area using gillnets, trawl nets and longlines. Trawlers are accused of causing damage to nets set by artisanal fishermen. In one case the fisherman reported the loss of 600m of net. Ramos *et al.* (1994) report on the incidental

capture of three tucuxi in March 1989 by boats operating in the area. Dolphins were stored in the freezer to be used as bait in the shark fishery.

Guriri

The locality of Guriri (18°42′S, 39°51′W) has a small fishing community spread along 40km of beach. Dugout canoes, 6m long, are found in small numbers along the beach and operate gillnets as long as 1,200m. The area has been monitored by personnel of a marine turtle project (Projeto TAMAR) since the summer of 1988. The beach is regularly surveyed for marine turtle nests and carcasses. Dolphins found stranded are collected and/or reported. A pregnant 1.41m female franciscana was found washed ashore at Guriri (18°42′S, 39°51′W) on 28 February 1991. Several marks indicating net entanglement and shark wounds were observed. The complete skeleton of the female and the foetus are kept at MZUSP (28410, 28411-foetus in formol). The carcass of a second franciscana was found washed ashore about 7km north of Guriri on 17 January 1992. The body length and sex could not be determined. The condylobasal length of the skull is 392(±1)mm and the tip of the rostrum is broken. The skull is kept at the Projeto TAMAR, Base de Guriri, ES. Although fishermen report that franciscanas are common in the area, the specimens reported here are the first collected. Artisanal operations in this area are known to have resulted in the accidental capture of at least 12 tucuxi (lengths 0.86m-1.90m) between December 1988 and August 1993, i.e. dolphins that have been found washed ashore with clear marks of net entanglement and/or tail, flippers and dorsal fins cut off. The specimens are kept at MZUSP 27520 (December 1988), MZUSP 26870 (January 1989), MZUSP 27521 (February 1989), MZUSP 27522 (February 1990), MZUSP 27523 (April 1990), MZUSP 27997 (November 1990), MZUSP 27996 (March 1991), MZUSP 27998 (March 1991), Base Projeto TAMAR, Guriri (January 1992), MZUSP 28405 (March 1992), MZUSP N/A (March 1993) and MZUSP N/A (August 1993).

Regência and Povoação

The small towns of Regência (19°38′S, 39°49′W) and Povoação are located at the mouth of the Doce river. About 12 small boats operate in the area and nets are usually set 1 n.mile offshore although they have also been seen set at the mouth of the river, the typical habitat of the tucuxi. The area has been relatively well studied. Geise and Borobia (1987) reported the collection of skeletal remains of two tucuxi and one franciscana known to have been caught in nets. Ramos *et al.* (1994) reported on the incidental catch of five franciscanas in March 1989 and of six tucuxi, between January and May 1989. These specimens were deposited at MZUSP. Four tucuxi specimens were collected by the author and are also kept at MZUSP 23809 (January 1987), MZUSP 26865 (May 1989), MZUSP 28181 (September 1990) and MZUSP 26871 (December 1988). The last is a skull collected at Pontal do Ipiranga, some 60km north of Regência and reported to have come from an animal entangled in nets set by Regência-based boats (C. Bellini, pers. comm.). A partially broken skull of a franciscana was collected in January 1987 (MZUSP 23793) and two other skulls in September 1989 (MZUSP 25428, MZUSP 25429). During a visit to Regência in January 1987, a fisherman was observed using the blubber of a franciscana, incidentally caught in nets, as bait in an artisanal lobster trap at the mouth of the Doce river. Dolphins captured in nets can also be used for human consumption. A total of 12 tucuxi and 10 franciscanas are known to have been caught in Regência.

Vila Velha

A 206cm female tucuxi, accidentally caught in a driftnet in waters 5–10m deep, 50–100m from shore, was found at Praia de Itapoã (20°21′S, 40°17′W), Vila Velha, on 5 June 1983 (Barros, 1991). On 28 October 1987, a 4.9m female humpback whale (*Megaptera novaeangliae*) was accidentally caught in a net about 700m from shore at Ponta da Fruta (20°30′S, 40°20′W), Vila Velha (Siciliano and Lodi, 1989; Barros, 1991).

Guarapari

Guarapari is about 50km south of Vitória. Gillnets are widely used in the area and are especially common in Meaípe. Barros (1991) reported on the collection of a mutilated carcass of a bottlenose dolphin in Guarapari on 23 April 1984 that appeared to have been caught in fishing nets. A sperm whale (*Physeter macrocephalus*) was caught in a fishing net set 200m from shore, at Meaípe (20°39′S, 40°27′W) on 6 August 1981 (Barros, 1991).

Anchieta

At least seven small (8–10m) motor-powered wooden boats operate gillnets in Anchieta and along the southern coast of Espírito Santo state. Gillnets are used seasonally and trawl nets and longlines are also used depending on the target species. No evidence of small cetacean mortality was found during a short visit in April 1992.

Rio de Janeiro

Atafona

The fishing operations from the village of Atafona (21°37′S, 41°01′W) are among the best known in terms of small cetacean fishery interactions in Brazil. Occasional visits were made there between 1983 and 1986 to study cetaceans and since June 1987 incidental mortality has been monitored continuously. Specimens of the tucuxi and the franciscana recovered up to 1990 are listed in Lodi *et al.* (1987), Lodi and Capistrano (1990) and Borobia *et al.* (1991). Ramos *et al.* (1994) reported the known mortality of 336 dolphins between June 1986 and January 1994, of which 197 were collected. These included: 96 tucuxi; 88 franciscanas; 6 rough-toothed dolphins (*Steno bredanensis*); 4 bottlenose dolphins; 2 Atlantic spotted dolphins (*Stenella frontalis*); and 1 common dolphin (*D. delphis*). About 60 boats using gillnets operate in the area between Atafona and Macaé (22°23′S, 41°47′W). The tucuxi and the franciscana account for over 90% of the total number of captures and are affected by coastal fishery operations. The boats that operate in deeper waters take bottlenose, rough-toothed, common and Atlantic spotted dolphins. Surface and mid-water/bottom gillnets are used in coastal operations and most animals are caught in surface gillnets. The cetacean bycatch appears to be lower in mid-water/bottom nets. The depth at which the nets are set depends on the target species. Dolphin meat is not consumed but the blubber is used for shark bait.

Barra de São João

The small fishing village at Barra de São João (22°35′S, 42°00′W), 180km north of Rio de Janeiro, was occasionally visited by researchers during the 1980s. Approximately 20 small wooden boats operate in the area using gillnets and shrimp trawl nets. On 20 October 1982, a 1.57m tucuxi was collected (skeleton lost) that had been taken in a gillnet (Borobia and Barros, 1989; Borobia *et al.*, 1991).

Cabo Frio
Although the town of Cabo Frio has a relatively large fishing industry there is almost no information on cetacean bycatches. On 21 January 1993, three spinner dolphins (*Stenella longirostris*) were caught in nets set for sharks (M.C. de Oliveira Santos, unpubl. data) during a fishing trip from Ubatuba, northern São Paulo, to Cabo Frio. The net was about 3,900m in length and 12m in height with a mesh size of 10–13cm. The dolphins were discarded at sea (the fishermen are aware of the prohibition on taking dolphins) and only photographs are available. Other bycatches taken during this trip included unknown species of sea turtles and manta rays, all discarded at sea.

Búzios
A small number of boats operate in the Búzios area using gillnets and longlines. Castello and Pinedo (1986) reported on a tucuxi stranded on the beach of Geribá, Búzios (22°44′S, 41°52′W) on 8 January 1977 with clear marks of entanglement in a gillnet. In April 1984 on Manguinhos Beach, Búzios, a tucuxi skull, probably from an incidentally caught animal was collected (Borobia *et al.*, 1991) and deposited at the Universidade Federal do Rio de Janeiro, Departamento de Anatomia Comparada (UFRJ, AC-03). A juvenile humpback whale (estimated length 9m) became entangled in gillnets off Manguinhos Beach on 25 July 1990. The whale was released alive from the nets with no large wounds.

Maricá
A small number of boats operate with gillnets around Maricá (22°55′S, 42°49′W). The record of a false killer whale (*Pseudorca crassidens*) cited with no details in Siciliano *et al.* (1987) and Geise and Borobia (1988) is of a specimen captured in a gillnet set off Barra de Maricá on 23 May 1981. The net was set at 1n.mile from the beach, close to Maricá Island and was retrieved the following morning. The specimen was not collected and only photographs are available. It measured about 3.5m and was of unknown sex. It is presumed that the meat was consumed locally. A juvenile tucuxi was collected in an advanced stage of decomposition on 21 September 1985 at Barra de Maricá (MZUSP 23810) but no signs of entanglement in nets were observed (Borobia *et al.*, 1991).

Rio de Janeiro and Niterói (including Guanabara Bay)
There is considerable fishing effort inside Guanabara Bay using various gear types, including fixed traps (*curral*), trawls, purse seines, beach seines and gillnets, as well as recreational fishing. Only gillnets are known to cause cetacean mortality in the bay. Studies on cetaceans have been conducted in the area since 1983. Stranded tucuxis are regularly collected and at least 18 were collected or reported to have been stranded on the beaches of Rio de Janeiro (22°56′S, 43°15′W) and Niterói (22°56′S, 43°04′W) including the Guanabara bay area between February 1983 and December 1993 (Penna *et al.*, 1990; Borobia *et al.*, 1991; R. Novelli, pers. comm.; L. Capistrano, pers. comm.; S. Siciliano, unpubl. data). Evidence of incidental capture in nets was found in at least two dolphins. One had had the tail cut off but was too decomposed to determine if net marks were present. The other, a 1.83m adult male collected on 20 October 1990, had distinctive net marks (Penna *et al.*, 1990). Two other tucuxis were caught in nets in January 1992 according to a local newspaper and were probably consumed locally as food. Other small cetaceans that are known to have recently stranded in the area include: 1 rough-toothed dolphin; 1 Atlantic spotted dolphin; 3 common dolphins; 3 bottlenose dolphins and 1 beaked whale (*Mesoplodon cf. layardii*) (Siciliano *et al.*, 1987; S. Siciliano, unpubl. data) but there is no positive evidence that they were entangled in nets i.e. any scars or other marks present may have been natural, occurred during stranding or been a result of entanglement in nets. The rough-toothed dolphin was found with a large cut in the belly and with no internal organs, a common practice for fishermen who remove the guts to avoid the smell and any contamination of the fish stored on the boat.

Sepetiba Bay
Until recently Sepetiba Bay (22°58′S, 44°02′W) was poorly surveyed for cetaceans. Fishery operations are conducted from small wooden boats and dug-out canoes. Bottom gillnets are usually set for croakers (*Micropogonias furnieri*) and flounders at the mouth of the bay but can also be found in many other areas inside the bay. Nets can reach 1,200m in length and use two mesh sizes. Tucuxi coming in and out of the bay may become vulnerable to the nets. Borobia *et al.* (1991) had reported on a tucuxi stranded off Ibicuí (22°58′S, 44°02′W), Mangaratiba county, on 1 February 1986. Although only colour photographs are available from this record, the animal had some scars indicative of entanglement in nets (S. Siciliano, pers. obsv.). During a recently started on-going study of tucuxi movements and behaviour in the bay, two carcasses were collected in the area. One was found in September 1993 and the other on 10 December 1993. According to local people they were caught in nets. Two other unidentified dolphins, referred to as 'botos' (cf. tucuxi) were observed floating dead on 15 December 1993 and 7 February 1994, but were not collected. Considering the short surveying period, these data suggest a relatively high incidental mortality.

Ilha Grande Bay
Siciliano (1986) reported on a 6.42m juvenile humpback whale caught in gillnets on the eastern side of the Ilha Grande bay (23°10′S, 44°20′W). The stranded whale was found dead on 2 December 1985 at Praia do Cardo, Sepetiba with a small piece of net (mesh size 3cm) attached to its right flipper and head. Several species of small cetaceans are seen in the waters of Ilha Grande, the Grande Bay and relatively high fishery activity suggests that interactions are likely. Atlantic spotted dolphins have been observed to approach fishing boats in the bay.

São Paulo

Ubatuba
Although gillnets are commonly used in the area, usually for capturing sharks, there is little information on cetaceans as the area has been little studied. Four franciscanas have been found stranded since September 1987, probably as a result of incidental catches (Santos and Siciliano, 1994). Siciliano (1986) reported a humpback whale calf incidentally caught in nets in October 1983.

Santos, São Vicente and Praia Grande
De Carvalho (1961) reported the capture of two franciscanas, a 105cm male and a 134cm female, and one tucuxi off José Menino Beach, Santos (23°57′S, 46°20′W),

in February 1961. De Carvalho (1963) reported that another tucuxi, a 1.51m male, was collected in October 1961 (MZUSP 9611). These areas have been poorly investigated since then and information is scant. Reported strandings of franciscanas in recent years may be related to entanglements in nets (Santos and Siciliano, 1994). A large gillnet was found drifting approximately 12 n.miles off Ponta do Itaipu, Praia Grande on May 1993 (A.F. de Amorim, pers. comm. in a letter, 30 March 1994) with at least three dolphins entangled in it. One was recently identified from photographs to be a franciscana. Fish and marine turtles in the net were in an advanced stage of decomposition, suggesting that it had been drifting for a long period. It is the first time that a drifting gillnet, probably lost by fishermen, has been reported to catch small cetaceans off Brazil.

Bertioga

Fishery activities in Bertioga are artisanal, involving small wooden boats. Three franciscanas were caught in a beach seine net at Bertioga on 25 January 1993. Fishermen were accused by tourists of intentionally killing one of the dolphins, which was reported to be retrieved from nets still alive. This incident was extensively covered in the local press.

Juréia

A small number of boats operate artisanal fisheries in Juréia. The only information on cetaceans was collected on a short visit to the village in January 1987. A 108cm female franciscana was captured in a mid-water gillnet set 1n.mile off the beach on 22 January. A few croakers (*Micropogonias furnieri*) and marine catfish (Ariidae) were also retrieved from nets. Fishermen in the area reported the incidental capture of six 'botos' ('larger than a franciscana', cf. tucuxi) that were released alive from nets.

Iguape and Cananéia

Iguape and Cananéia (25°01'S, 47°55'W) are in southern São Paulo state and have a relatively large fishing fleet. A total of 25–30 boats operate in the area with gillnets for capturing sharks. De Carvalho (1963) reported the collection of 13 tucuxi specimens in nets in Cananéia during the early 1960s and these skeletons are in the mammal collection of MZUSP and listed in Borobia *et al.* (1991). The tucuxi is particularly common in the region (S. Siciliano, pers. obs.) and interaction with local fisheries is likely. Schmiegelow (1990) conducted a two-year survey of stranded cetaceans along the beaches of Iguape and Cananéia and 100 odontocetes were measured and collected, including a pygmy sperm whale (*Kogia breviceps*), a short-finned pilot whale (*G. macrorhynchus*), a bottlenose dolphin, a rough-toothed dolphin, 3 Atlantic spotted dolphins, 13 common dolphins, 21 franciscanas and 58 tucuxi. The carcass of a minke whale (*Balaenoptera acutorostrata*) was also found. He noted that the skulls of three common dolphins, the short-finned pilot whale and three tucuxis had knife marks probably made by fishermen trying to release the animals from nets. Most of the specimens were highly decomposed making cause of death difficult to ascertain. Although the author does not classify the specimens as bycatches, it seems that the number of dolphins collected during the survey period is unusually high to consider natural mortality to be the sole explanation. Monteiro Filho (1990) reports on the incidental catch of a young female tucuxi in a fixed trap (locally known as *cerco*) inside the estuarine complex of Cananéia.

Paraná

Paranaguá Bay

The large Paranaguá estuary (25°31'S, 48°30'W) was not surveyed for cetaceans until 1983, although Bittencourt (1984) reported on a netted tucuxi found floating on 30 July 1982. Studies on cetaceans conducted since 1987 revealed preliminary numbers of small cetaceans incidentally caught in fishery operations (Zanelatto, 1992). Between February 1993 and February 1994, 96 small cetaceans were incidentally caught in nets including 79 (82.3%) tucuxis and 17 franciscanas (17.7%) (Zanelatto, 1994). Drift gillnets and bottom gillnets account for 90% of the total number of captures; purse seine and beach seine nets can also capture dolphins. It was reported that 24 dolphins were known to be consumed locally.

Santa Catarina

Simões-Lopes and Ximenez (1993) reviewed the available information on small cetaceans and fishery interactions for the Santa Catarina coast based on specimens incidentally caught in nets and/or found dead ashore. Table 2 summarises the number of small cetaceans known to have interacted with fisheries in the collection of Laboratório de Mamíferos Aquáticos, Universidade Federal de Santa Catarina (LAMAQ, UFSC) and the number of specimens. Other species occur in the collection of UFSC, but with no information on interactions with fisheries, including the killer whale; the long-finned pilot whale (*Globicephala*

Table 2

Number of known specimens of seven small cetacean species caught in nets and long-line fisheries for each coastal state of Brazil.

	S. fluviatilis	*P. blainvillei*	*T. truncatus*	*S. bredanensis*	*S. frontalis*	*S. longirostris*	*D. delphis*
Pará	3	-	0	0	0	0	0
Maranhão	9	-	0	0	0	0	0
Ceará	5	-	0	0	0	0	0
Rio Grande do Norte	1	-	0	0	0	0	0
Pernambuco	4	-	1	0	0	0	0
Alagoas	4	-	0	0	0	0	0
Sergipe	4	-	0	0	0	0	0
Bahia	14	-	0	0	0	0	0
Espírito	21	11	1?	0	0	0	0
Rio de Janeiro	104	88	4	6	2	3	1
São Paulo	71	28	1	1	3	0	13
Paraná	79	17	1 +	?	?	0	?
Santa Catarina	3	7	3	2	3	0	3
Rio Grande do Sul	-	874	31	2	0	0	1

melas); the southern bottlenose whale (*Hyperoodon planifrons*); Blainville's(?) beaked whale (*Mesoplodon cf. densirostris*) and the sperm whale (*Physeter macrocephalus*). The only record of the Risso's dolphin (*Grampus griseus*) for the Santa Catarina coast is of a 1.64m young male (MZUSP 19480), 1.64m in length, that was accidentally captured during commercial tuna longline fishing in September 1983 (Geise and Borobia, 1987). Mr. Alberto F. de Amorim, from the Instituto de Pesca, Santos, who collected the dolphin, reported (pers. comm.) that it was a neonate Risso's dolphin caught in a long-line commercial fishery operating in deep waters of Santa Catarina ('between 28°S and 26°S') and brought to Santos on 12 September 1983 (in Geise and Borobia, 1987 the record is given to the year of 1984 but should be 1983), where the boat was based. The stomach contained squid beaks and other unidentified material. Considering the large coast of Santa Catarina and the magnitude of its fisheries, the information provided by Simões-Lopes and Ximenez (1993) probably underestimates the true number of specimens caught in the area.

Rio Grande do Sul

The mortality of small cetaceans in gillnets along the Rio Grande do Sul coastline is being monitored by a UNEP/IUCN funded project. Preliminary data collected indicate that the franciscana is the species most commonly taken in gillnets in the northern coast of Rio Grande do Sul (Danilewicz *et al.*, 1993) and fishermen report that other species are taken. There are indications that the bottlenose dolphin is involved and it appears that incidental capture may represent a major threat to coastal species such as the franciscana and the bottlenose dolphin. The 95 cetacean specimens recorded in the northern coast of Rio Grande do Sul between October 1991 and December 1993, include 77 franciscanas, 10 bottlenose dolphins, 2 false killer whales, 2 rough-toothed dolphins, 2 striped dolphins, 1 common dolphin and 1 killer whale.

Data collected along the southern coast of this state indicate that the franciscana is commonly taken in nets (Zerbini *et al.*, 1993). An estimated 150–300 boats operate in this area, depending on the season. About 25 boats are being sampled and, of these, 15 are cooperating with the research. Seventy-two franciscanas have been recorded since the beginning of the port monitoring, with most franciscanas being recorded in the 'Farol da Solidão' area, in depths of 16m to 24m (E. Secchi, pers. comm.). A killer whale was found dead ashore with marks suggesting interaction with fisheries. Incidental catches of a dwarf minke whale and a long-finned pilot whale (*Globicephala melas*) were recorded by the oceanic fishing fleet in deeper waters.

CONCLUSION

A large number of small cetaceans are incidentally caught in gillnets every year along the Brazilian coast. The tucuxi and the franciscana are the species most commonly taken during artisanal fishery operations. The cetacean bycatch seems to be higher during the austral spring and summer, with adult tucuxis and juvenile and sub-adult franciscanas predominating. The sex ratios for both species are about 1:1. Other species that are caught include the bottlenose, rough-toothed, Atlantic spotted, striped, spinner and common dolphins, and the long-finned pilot, false killer, killer and minke whales. Even rudimentary fishing gear can potentially cause mortality of small cetaceans, particularly along the northeast coast of Brazil. Reported mortality appears to be greatest where a combination of factors occur: regular fishing effort; relatively high cetacean abundance; and, of course, the presence of an observer. Some areas are poorly surveyed and this results in the absence of information on cetacean bycatch. Although gillnets are the major source of mortality, deaths can occur through entanglement in longlines. The direct take of dolphins in the north and northeast region needs to be evaluated and monitored and both law enforcement and educational campaigns are urgently needed.

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Review of Small Cetacean Fishery Interactions in Southern Brazil with Special Reference to the Franciscana, *Pontoporia blainvillei*

Maria Cristina Pinedo

Departmento de Oceanografia, Fundação Univeridade do Rio Grande
C.P. 474, CEP 96201-900 Rio Grande, RS, Brazil

ABSTRACT

The distribution, stock identity, growth, reproduction and feeding of nine small cetacean species interacting with fisheries in southern Brazil (23°16′S-33°45′S) is reviewed, based on published and unpublished data. The stock identity of most species is unknown. The most important cause of death is the incidental capture of animals in gillnets, particularly *Pontoporia blainvillei* in the Rio Grande do Sul and Santa Catarina states and *Sotalia fluviatilis* in Paraná state. Interactions with driftnets and longline fisheries is also recorded. The reported mortality and descriptions of these fisheries are presented. Assessing the status and abundance of *Pontoporia* population is a high priority.

KEYWORDS: FISHERIES; INCIDENTAL CAPTURE; SOUTH ATLANTIC; BOTTLENOSE DOLPHIN; FRANCISCANA; FALSE KILLER WHALE; KILLER WHALE; LONG-FINNED PILOT WHALE; COMMON DOLPHIN; ROUGH-TOOTHED DOLPHIN; STRANDINGS; TUCUXI; ATLANTIC SPOTTED-DOLPHIN.

INTRODUCTION

Thirty one species of cetaceans have been recorded in Brazil (Pinedo *et al.*, 1992; Simões-Lopes *et al.*, 1992). Table 1 lists the 17 small cetacean species recorded in the southern states of Rio Grande do Sul, Santa Catarina and Paraná (Bittencourt and Zanelatto, 1992; Pinedo *et al.*, 1992; Sacchi-Santos *et al.*, 1992; Secchi and Siciliano, 1992; Simões-Lopes *et al.*, 1992; Zanelatto and Domit, 1992). Interactions with fisheries have been reported for nine of these species as shown in Table 1. Since 1976, the coast of Rio Grande do Sul has been surveyed for stranded marine mammals (Pinedo, 1986; 1994) from Barra do Estreito (31°57′S) to Farol de Sarita (32°38′S) and occasionally up to Tôrres (29°20′S) and Chuí (33°45′S) (Fig. 1). In the northern Rio Grande do Sul (29°19′S-31°15′S) beach surveys have been conducted since 1991 (Danilewicz *et al.*, 1993). Most of the offshore Rio Grande do Sul sightings were recorded during 19 oceanographic cruises up to over 1900m depth, aboard R/V *Atlantico Sul* (FURG), from 1980–1987. In Rio Grande do Sul, the franciscana and the bottlenose dolphin are the most frequently stranded species, followed by the false killer, killer and long-finned pilot whales and the common and rough-toothed dolphins; on the continental shelf the common dolphin, long-finned pilot whale and killer whale are the most frequently sighted

Table 1

A list of the small cetaceans recorded in southern Brazil, by states. (From Pinedo *et al.*, 1992 and Simoes-Lopes *et al.*, 1992). RS = Rio Grande do Sul, SC = Santa Catarina and PR = Paraná.

Species	Common Name
Physeteridae	
Kogia breviceps (RS)	Pygmy sperm whale
Kogia simus (RS)	Dwarf sperm whale
Delphinidae	
*Delphinus delphis** (RS,SC)	Common dolphin
Stenella attenuata (RS)	Pantropical dolphin
*Stenella frontalis** (SC)	Atlantic spotted dolphin
Stenella longirostris (PR)	Spinner dolphin
Stenella coeruleoalba (RS)	Striped dolphin
Stenella clymene (SC)	Clymene dolphin
*Steno bredanensis** (RS,SC)	Rough toothed dolphin
*Tursiops truncatus** (RS,SC,PR)	Bottlenose dolphin
*Sotalia fluviatilis** (PR,SC)	Tucuxi
*Pseudorca crassidens** (RS,SC)	False killer whale
*Orcinus orca** (RS,SC)	Killer whale
Grampus griseus (SC)	Risso's dolphin
*Globicephala melas** (RS)	Long-finned pilot whale
Pontoporiidae	
*Pontoporia blainvillei** (RS,SC,PR)	Franciscana
Phocoenidae	
Phocoena spinipinnis (RS)	Burmeister's porpoise

* Information on fishery interactions available.

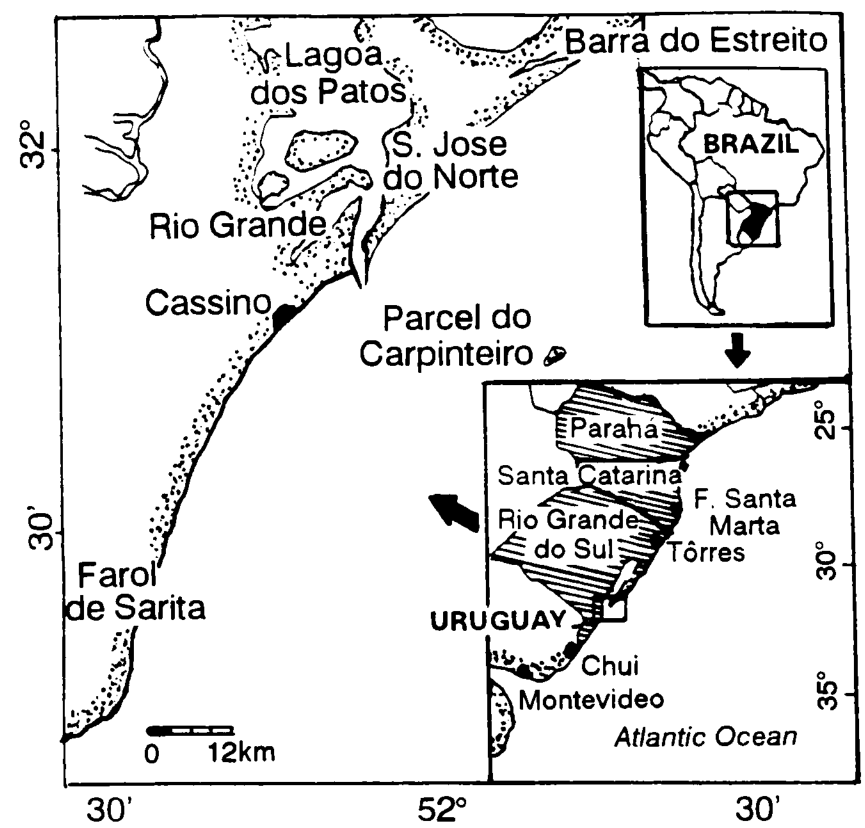

Fig. 1. Southern Brazil and study areas in Rio Grande do Sul.

(Castello and Pinedo, 1986; Pinedo, 1986; Danilewicz *et al.*, 1993; Pinedo, unpublished). In beach surveys begun in 1985 on Santa Catarina Island (27°10'S-27°50'S), most of the specimens were franciscanas (*Pontoporia blainvillei*), bottlenose dolphins (*Tursiops truncatus*) or tucuxis (*Sotalia fluviatilis*) (Paula *et al.*, 1992). In Paraná (25°14'S-25°59'S), where data collection began in 1989, most stranded animals are tucuxis (Zanelatto, 1992).

SPECIES SUMMARIES

Pontoporia blainvillei (franciscana)

The franciscana is an endemic dolphin of central eastern South America, occurring up to approximately 30 miles offshore (Praderi *et al.*, 1989). Its distribution is known to extend from Itaúnas in Espírito Santo State (18°25'S), Brazil (Moreira and Siciliano, 1991) to Rio Negro Province (41°09'S), Argentina (Crespo and Harris, 1992). It was recorded in Espírito Santo (Geise and Borobia, 1987; Moreira and Siciliano, 1991), Rio de Janeiro (Lodi *et al.*, 1987; Lodi and Capistrano, 1990), São Paulo (de Carvalho, 1961; Schmiegelow, 1987; 1990), Paraná (Bittencourt and Zanelatto, 1992), Santa Catarina (Ximenez *et al.*, 1987; Paula *et al.*, 1992) and Rio Grande do Sul (von Ihering, 1892; Gliesh, 1925; Cabrera, 1960; Pinedo, 1982; 1986; Mondin-Machado *et al.*, 1992). There are no records for the Uruguay River, Paraná River (Cabrera and Yepes, 1940; Brownell, 1981) or for the Lagoa dos Patos, in southern Brazil (Pinedo *et al.*, 1989; Pinedo, 1991).

Multivariate analyses of osteological measurements has revealed two geographical forms: a smaller form between 22°S-27°S and a larger form between 32°S-38°S (Pinedo, 1991). These two forms should be considered separately for management and conservation purposes. The species is also found between 27°S and 32° and morphometric data are being collected by the author. The status of the franciscana is still considered as 'insufficiently known' according to the IUCN (1991) Red List, although Perrin *et al.* (1989) had recommended that it should be classified as 'vulnerable'.

Along the Rio Grande do Sul coast (29°20'S-33°45'S) between 1976–1987 and between 1992–1993, at least 1,085 and 88 specimens, respectively, were found dead (Pinedo, 1986; Praderi *et al.*, 1989; Pinedo, unpublished). On Santa Catarina Island (27°10'S-27°50'S) 27 specimens were found dead between 1984–1992 (Ximenez, pers. comm.; Ximenez and Canella, 1992) and in Paraná (25°14'S-25°59'S) 3 dead specimens were recorded between 1989–1992 by Bittencourt and Zanelatto (1992).

The species has been threatened by incidental captures throughout its distribution and obtaining estimates of abundance and determination of stock identity were identified as research priorities by Perrin *et al.* (1989) and Crespo (1992). Crespo also attached importance to obtaining mortality estimates simultaneously with abundance estimates and the necessity of placing observers on fishing vessels. He suggested the area of Valizas-Cabo Polonio, in Uruguay, where there is a high concentration of franciscanas as an area for a pilot study to estimate abundance, along with the use of a number of methods to assess stock identity.

The biology and status of the franciscana was reviewed by Pinedo *et al.* (1989), from specimens taken incidentally in gillnet fishing operations. Males and females can reach 158cm and 177cm, respectively (Brownell, 1989). Age was estimated based on growth layer groups in the teeth (Pinedo, 1991). Females are larger than males and physical maturity is attained between 4 and 8 years, for both sexes (Pinedo, 1991). The oldest female was 21 years old (Pinedo, 1994) and the oldest male was 16 years old (Brownell, 1989).

Sexual maturation occurs between 2 to 4 years for both sexes and a 2-year breeding cycle has been reported (Brownell, 1989). In southern Rio Grande do Sul, calving occurs mainly in November (Pinedo *et al.*, 1989), at the same time that the peak of mortality in gillnets occurs.

Seventeen species of bony fishes were identified from the stomach contents of franciscanas collected from 1976–1981 in southern Rio Grande do Sul. Most fishes eaten were sciaenids of less than 50mm total length and *Cynoscion striatus* was the most abundant prey. The squid *Loligo sanpaulensis* and the shrimps *Pleoticus muelleri, Artemesia longinaris* and *Penaeus paulensis* were also part of the diet. Females eat more squid than males and juveniles eat more shrimps than adults (Pinedo, 1982). The same species of squid and shrimps and an overlap of 12 fish species was observed between the diet of franciscanas from Uruguay and southern Rio Grande do Sul (Brownell, 1975; Pinedo *et al.*, 1989).

Tursiops truncatus (bottlenose dolphin)

The bottlenose dolphin occurs in the coastal southwestern Atlantic from Rio Grande do Norte (*ca.* 5°47'S) in Brazil (Best *et al.*, 1986) to Chubut Province (43°20'S) in Argentina (Mermoz, 1977). In Brazil it is found on the continental shelf and at the entrance of estuaries and rivers (de Carvalho, 1975; Gomes, 1986; Pinedo *et al.*, 1992). It was recorded in Rio Grande do Norte, Paraíba (Best *et al.*, 1986), Bahia (Siciliano *et al.*, 1987a), Espírito Santo (Barros, 1991), Rio de Janeiro (Gomes, 1986; Siciliano *et al.*, 1987a; Geise and Borobia, 1988), São Paulo (de Carvalho, 1975; Schmiegelow, 1990), Paraná (Bittencourt and Zanelatto, 1992), Santa Catarina (de Carvalho, 1975; Ximenez *et al.*, 1987; Ximenez, 1990; Paula *et al.*, 1992) and Rio Grande do Sul (von Ihering, 1892; Gliesh, 1925; Castello and Pinedo, 1977; Pinedo, 1982; 1986; Möller *et al.*, 1992; Mondin-Machado *et al.*, 1992; Santos *et al.*, 1992).

In Rio Grande do Sul, the species is frequently seen along the coast, at the mouth of Tramandaí River and inside Lagoa dos Patos up to the São Gonçalo channel and, off Santa Catarina at the entrance of Lagoa Santo Antônio (Castello and Pinedo, 1977; Pinedo, 1986; Pryor *et al.*, 1990).

Between 1976–1993, 76 specimens were found dead along Rio Grande do Sul (29°19'S-33°45'S) (Pinedo, 1986; Danilewicz *et al.*, 1993; Pinedo, unpublished). In Santa Catarina, at least 17 specimens have been found (Barreto, pers. comm.) and in Paraná 1 stranding was recorded from 1989 to 1992 (Bittencourt and Zanelatto, 1992).

Age estimation based on the growth layer groups (GLGs) of the teeth (Hohn *et al.*, 1989) and the skull development of dolphins from southeast and southern Brazil is in progress (Barreto and Pinedo, in prep.)

There is no information on reproduction in this region, but in the estuary of Lagoa dos Patos juveniles are present year-round (Castello and Pinedo, 1977).

Eleven species of bony fishes, mainly white croaker (*Micropogonias furnieri*), were found in the stomachs of 12 stranded dolphins from Rio Grande do Sul between 1976–1981. Most fish eaten were above 150mm in length. No squid or shrimps were found (Pinedo, 1982).

***Pseudorca crassidens* (false killer whale)**
There are records of this species for Paraíba (Antonelli *et al.*, 1987), Rio de Janeiro (Siciliano *et al.*, 1987b; Geise and Borobia, 1988), Santa Catarina (Simões-Lopes and Ximenez, 1988; Ximenez, 1990; Paula *et al.*, 1992) and Rio Grande do Sul (Castello and Gianuca, 1976; Silva, 1984; Pinedo and Rosas, 1989).

Between 1976–1993, 11 animals were found stranded in Rio Grande do Sul (Pinedo and Rosas, 1989; Pinedo, unpublished; Ott, pers. comm.). White croakers from 460–610mm in length, black drums (*Pogonias cromis*) from 1,070–1,130mm in length and an unidentified serranid were found in the stomachs of two stranded animals (Pinedo and Rosas, 1989).

***Orcinus orca* (killer whale)**
The species occurs along the coasts of the following states: Paraíba (Antonelli *et al.*, 1987), Pernambuco, Alagoas, Bahia (Best *et al.*, 1986), Rio de Janeiro (Castello and Pinedo, 1986; Geise and Borobia, 1988), São Paulo (Daniel *et al.*, 1988), Santa Catarina (Bittencourt, 1983; Castello and Pinedo, 1986) and Rio Grande do Sul (Castello, 1977; Castello and Pinedo, 1986; Ximenez *et al.*, 1987; Secchi and Vasque, 1992).

In Rio Grande do Sul and Santa Catarina, killer whales have been seen in waters between 110–3,500m depth in groups of up to 10 animals (Castello and Pinedo, 1986; Secchi and Vasque, 1992). They were seen during two cruises of the R/V *Atlântico Sul* (Pinedo, unpublished). Six strandings have been recorded in Rio Grande do Sul, 3 prior to 1976 and 3 between 1976–1993, all in the summer or spring (Castello and Pinedo, 1986; Pinedo, unpublished).

Tooth plates of eagle sting rays, *Myliobatis* sp. were found in the stomach of a killer whale stranded in Rio Grande do Sul (Castello, 1977) and predation on swordfish, *Xiphius gladius*, and tuna was recorded by Secchi and Vasque (1992).

***Globicephala melas* (long-finned pilot whale)**
There are records of this species for São Paulo (de Carvalho, 1975) and Rio Grande do Sul (Pinedo *et al.*, 1986; Secchi *et al.*, 1991).

It was seen during six cruises of the R/V *Atlântico Sul* in groups of 6 to approximately 100 animals and at depths from 120 to 1,000m (Castello and Pinedo, 1986; Pinedo, unpublished). Seven strandings were recorded in winter and spring in Rio Grande do Sul, two between 1976–1987 and five between 1992–1993 (Pinedo *et al.*, 1986; Pinedo, unpublished; Secchi *et al.*, 1991). Three stranded specimens in Rio Grande do Sul had squid beaks of Ommastrephidae and Histioteuthidae in the stomachs. Species identification is in progress (Pinedo, 1986; Santos and Pinedo, in prep.).

***Delphinus delphis* (common dolphin)**
This species occurs in northeastern Brazil (Best *et al.*, 1986), Rio de Janeiro (de Carvalho, 1963; Gomes, 1986; Siciliano *et al.*, 1987b; Geise and Borobia, 1988; Lodi and Capistrano, 1990), São Paulo (de Carvalho, 1975; Siciliano *et al.*, 1987b; Schmiegelow, 1990), Santa Catarina (Ximenez *et al.*, 1987; Ximenez, 1990; Paula *et al.*, 1992) and Rio Grande do Sul (Castello and Pinedo, 1986; Secchi and Vasque, 1992).

Common dolphins are frequently seen along the coast of Rio Grande do Sul and Santa Catarina, from at least 50 miles offshore, in depths of 70 to 2,500m and in groups of up to 500 animals (Castello and Pinedo, 1986; Pinedo *et al.*, 1992; Secchi and Vasque, 1992). In Rio Grande do Sul, the species was sighted during 17 of 19 oceanographic cruises aboard R/V *Atlântico Sul* (Pinedo, unpublished). Although frequently sighted in offshore waters of Rio Grande do Sul, only two strandings have been reported (Castello and Pinedo, 1986; Danilewicz *et al.*, 1993).

***Steno bredanensis* (rough-toothed dolphin)**
Records are available for the states of Ceará (Themotheo-Sobrinho, 1992), Pernambuco (Best *et al.*, 1986), Rio de Janeiro (Pinedo and Castello, 1980; Siciliano *et al.*, 1987a; Lodi and Capistrano, 1990), Santa Catarina (Praderi and Ximenez, 1987; Ximenez and Praderi, 1988; Ximenez, 1990; Paula *et al.*, 1992; Ximenez and de Flôres, 1992) and Rio Grande do Sul (Mondin-Machado *et al.*, 1992; Sacchi-Santos *et al.*, 1992).

In Rio Grande do Sul, a sighting of eight animals at 18 n.miles from Tôrres (*ca.* 29°22′S) and 2 stranded specimens (*ca.* 30°09′S) were reported by Sacchi-Santos *et al.* (1992).

***Sotalia fluviatilis* (tucuxi)**
There are two forms of this species as described by Borobia and Sergeant (1989). The marine coastal form is commonly found from Pará (Borobia *et al.*, 1987) to Santa Catarina (Simões-Lopes, 1987), whilst the freshwater form is endemic to the Amazon river basin (Magnusson *et al.*, 1980; da Silva, 1983). The marine form was recorded in Pará, Paraíba, Bahia (Borobia *et al.*, 1987), Maranhão (de Almeida *et al.*, 1992) and Ceará (Themotheo-Sobrinho, 1992), Rio Grande do Norte, Sergipe (Siciliano *et al.*, 1987b; Magalhaes *et al.*, 1993), Pernambuco (de Almeida *et al.*, 1990), Bahia (Reis and Queiroz, 1992), Espírito Santo (Barros, 1984; 1991; Borobia *et al.*, 1987; Geise and Borobia, 1987), Rio de Janeiro (Castello and Pinedo, 1986; Geise and Borobia, 1988; Lodi and Capistrano, 1990), São Paulo (de Carvalho, 1963; Castello and Pinedo, 1986; Monteiro Filho, 1990; Schmiegelow, 1990), Paraná (Bittencourt, 1984; Bittencourt and Zanelatto, 1992) and Santa Catarina (Simões-Lopes, 1987; 1988; Ximenez, 1990).

Off Santa Catarina Island, a resident group of 50–60 animals has been observed in Baía Norte (de Flôres, 1992). In Paraná it was the most common cetacean stranded: from 1989 to 1992 fifty two animals were found dead on the beach, with a peak in mortality between June and July (Zanelatto, 1992).

According to de Flôres (1992) Baía Norte is a feeding and probably a breeding area.

***Stenella frontalis* (Atlantic spotted dolphin)**
There are records of this species for São Paulo (Schmiegelow, 1990; Pinedo *et al.*, 1992), Rio de Janeiro (Lodi and Capistrano, 1990) and Santa Catarina, where four strandings have been reported (Ximenez *et al.*, 1987; Ximenez and Praderi, 1988; Ximenez, 1990; Paula *et al.*, 1992).

SMALL CETACEAN FISHERY INTERACTIONS IN SOUTHERN BRAZIL

Incidental catches and fishery characteristics

Franciscanas
Incidental catches occur along Brazil, Uruguay and Argentina and are the major cause of mortality. The characteristics of these fisheries have been summarised by

Table 2

Gillnet fishery characteristics in Rio Grande do Sul during spring (southern) and year-round (northern) by year (Pinedo, 1982; Pinedo, 1986; Praderi *et al.*, 1989; Reis, 1992; Pinedo, unpublished; Ott *et al.*, 1992). Blank space means information not available.

Description	Southern				Northern
	1976-81	1986	1988	1991	1992
Net					
length(m)	Up to 3,000	3,000-5,000	<8,000	*ca.* 8,000	Up to 300
height(m)	2.5-16			4	
mesh(cm)	9.32			14-16	9-38[a]
twine mat.		Nylon			Nylon
twine const.		monofilament			
twine diam(mm)		6			
soak time(hrs)			2.5-4	x=4	
no. soaks/day			x=3	x=4	
Boat size (m)	8	8-15	12-20	12-20	10-18
number		1,560[b]; 60[d]	200[c]; 150[d]	150; 139[d]	35
crew		6	4-12	4-12	4-8
horsepower			90-325	90-325	90-160
Max. dist. (nm)	15	30	16	35	30
Depth(m)	25	20-30	13-26	13-44[e]	10-60[f]
Days/trip		1-7	1-4		1-6
Fishing areas	31°44'-32°38'		31°44'-32°30'	31°15'-33°00'	29°19'-31°15'
Target species		Sciaenids			Sciaenids, Gadids, Mugilids Flounders, Sharks

[a] Four franciscanas caught in mesh sizes 11-14cm. [b] 8m boats including estuary and coast licensed by SUDEPE (Rahn, pers.comm.). [c] Probably too high. [d] Only 15m coastal boats. [e] 25m preferred. [f] Four franciscanas taken between 23-29m.

Table 3

Gillnet fishery characteristics in Santa Catarina from data collected in 1993 (Pinedo, unpublished) and in Paraná (Zanelatto, 1992). South latitudes in parenthesis. Blank space means information not available.

Description	Santa Catarina				Paraná
	Garopaba (28°03')	Imbituba (28°15')	Farol Sta. Marta (28°29')	Passo Tôrres (28°40')	Paranaguá (25°32')
Net length(m)	1,500-2,225	500-1,200	1,500-2,225	4,500-6,000	100-1,000
height(m)	3	2-2.5	3	3.5	3-8
mesh(cm)	10-11	[a]	[b]	14-15	4-20
twine mat.	Nylon	Nylon			Nylon
twine const.	monofil.				
twine diam(mm)					4-6
soak time(hrs)	12		24	4	
no. soaks/day	1				
Boat size(m)	9-12	8-11		8-15	
number	25	8	70	33	
crew					
horsepower					
Max.dist.(nm)	8-9	[c]	[d]	1	
Depth(m)	30			70	
Days/trip					
Fishing areas			P.Campo Bom, P. Flora	I. Lobos	
Fishing period	Jul-Oct	Jul-Dec	Year-round		Jun-Jul
Target species	Sciaenids	Sciaenids	Sciaenids, Sharks	Sciaenids, Sharks	Flounder*, Snook, Drumfish, Sciaenids, Catfish, Mackerel, Sharks

[a] 8-10cm inside/35-50cm outside. [b] 10cm inside/40cm outside. [c] 1h 30' south. [d] 1h 30' offshore. * Correlated with high mortality of small cetaceans.

Pinedo *et al.* (1989), Praderi *et al.* (1989) and Crespo (1992). In Rio Grande do Sul, most catches occur in spring, in bottom gillnets set mainly for sciaenids. The white croaker, *Micropogonias furnieri*, is a major target species of both artisanal and industrial fisheries and is taken by gillnets (in spring) and trawls (year-round). The trawl fishery is directed at both small and large fishes while the coastal gillnet fishery is directed to spawning adults (Haimovici, 1987; Haimovici *et al.*, 1989; Reis, 1992). Artisanal fishing effort has been increasing since 1982 (Pinedo, 1986; Praderi *et al.*, 1989). The total catch of sciaenids, especially the white croaker, has decreased as a result of overexploitation (Haimovici *et al.*, 1989). The mean annual catch of sciaenids between 1984 and 1990 was about 28,000 tonnes, of which 35% was white croaker (IBAMA, 1993). Almost all (95%) artisanal catches were made with gillnets. Mesh sizes, height and lengths vary according to the season and the target species (Reis, 1992). Characteristics of the gillnet fisheries in Rio Grande do Sul and Santa Catarina are presented in Tables 2 and 3.

Between 1976–1987, 919 dead franciscanas were found along 120km of the Rio Grande do Sul coast, from 31°57'S to 32°38'S, with a mean annual catch of 84. Fewer dead animals were recovered yearly between 1982–1987 (n=69.5) than between 1976–1981 (n=83.6). In the two years 1992 and 1993, 64 dead animals were found (Pinedo, unpublished).

Off Santa Catarina Island, incidental catches of franciscanas, bottlenose dolphins and tucuxis account for 69% of the catches of the seven small cetaceans reported caught; mesh sizes range from 4 to 20cm (Ximenez, 1990; Paula *et al.*, 1992; Ximenez and de Flôres, 1992). According to local fishermen, in Farol de Santa Marta (28°29'S), franciscanas are more frequent in winter and approximately 20–30 animals are caught annually. Groups of 3–6 franciscanas were reported by fishermen of Farol de Santa Marta and Garopaba (28°03'S) and groups of 8–10 animals were reported for Passo de Tôrres (29°20'S) (Pinedo, unpublished). In Sombrio (28°40'S) and Passo de Tôrres, franciscanas seem to occur mainly in summer (November to February) and in November 1991, 2–3 animals per week were caught in Sombrio (Pinedo, unpublished). Characteristics of the gillnets used in southern Santa Catarina (28°03'S-28°40'S) and Paraná are presented in Table 3. Zanelatto (1992) reports catches of franciscanas in longlines set for sharks in Paraná, but gives no further information.

Tursiops truncatus

Incidental capture in fishing gear does not appear to be a major cause of mortality of the bottlenose dolphin in Rio Grande do Sul (Pinedo, 1986). Twenty of the 76 strandings

Table 4

Summary of incidental mortality of small cetaceans in southern Brazil (in gillnets unless otherwise indicated). South latitudes in parenthesis. Blank space means information not available. Source: [1] Pinedo, 1986; [2] Pinedo, unpublished; [3] Pinedo *et al.* 1989; [4] Rosas, unpublished; [5] Möller *et al.*, 1992; [6] Santos *et al.*, 1992; [7] Zerbini *et al.*, 1993; [8] Danilewicz *et al.*, 1993; Mondin-Machado *et al.*, 1992; [10] Pinedo *et al.*, 1986; [11] Ximenez, pers. comm; [12] Ximenez and Canella, 1992; [13] Paula *et al.*, 1992; [14] Simoes-Lopes and Ximenez, 1988; [15] Ximenez and de Flôres, 1992; [16] Bittencourt and Zanelatto, 1992; [17] Bittencourt, 1984 and [18] Zanelatto, 1992. [a] Caught between 16-52m depth by two fishing boats. [b] Estimates annual mortality. [c] Longline (for tuna). [d] Longline (driftnet). [e] Driftnet (for sharks).

Location and species	Year(s)	Estimated no. killed
Rio Grande do Sul		
P. blainvillei		
(31°57',32°38')	1976	13 [1]
	1977	23 [1]
	1978	20 [1]
	1979	97 [1]
	1980	129 [1]
	1981	168 [1]
	1982	35 [1]
	1983	76 [1]
	1984	39 [2]
	1985	70 [2]
	1986	135 [3]
	1987	59 [4]
	1992	14 [2]
	1993	50 [2]
(32°00',33°45')	1987-92	54 [5]
(31°51',32°37')	1987-90	58 [6]
(31°18',33°45')	1992	11 [a,7]
(29°19',31°15')	Oct 91-Apr 93	61 [8]
T. truncatus		
(29°19',31°15')	1976-83	5 [1]
	Oct 91-Apr 93	6 [8]
S. bredanensis		
(29°19',31°15')	Oct 91-Apr 93	2 [8,9]
D. delphis	Oct 91-Apr 93	1 [8,9]
S. coeruleoalba	Oct 91-Apr 93	1 [8,9]
G. melas	1986	1 [c,10]
	1992-93	4 [d,2]
	1990	1 [e,7]

Location and species	Year(s)	Estimated no. killed
Santa Catarina		
P. blainvillei		
(27°37')	1984-90	27 [11]
	Apr 90-Sep 92	0 [12]
(28°40')	Nov 91	8-12 [2]
(28°29')	-	20-30 [b,2]
T. truncatus		
(27°37')	-	- [13]
S. fluviatilis		
(27°37')	-	- [13]
D. delphis		
(27°37')	-	- [13]
P. crassidens		
(27°37')	-	1 [13,14]
S. frontalis		
(27°37')	-	- [13]
S. bredanensis		
(27°36')	1992	1 [15]
Paraná		
P. blainvillei		
(25°14'-25°59')	Jul 89-Apr 92	3 [16]
T. truncatus		
(25°14'-25°59')	Jul 89-Apr 92	1 [16]
S. fluviatilis		
(25°32')	1982	1 [17]
(25°14'-25°59')	1989	6 [16]
	1990	6 [16]
	1991	14 [16]
	Jan 92-Apr 92	7 [16]
	May 92-Sep 92	18 [18]

in Rio Grande do Sul were attributed to fishery interactions. Five were caught in 22cm mesh gillnets set for sharks two miles offshore (Pinedo, 1986; Pinedo, unpublished). A dolphin swimming with gillnet debris around its body was observed by Zerbini *et al.* (1993). From October 1991 to April 1993, six dolphins were caught in gillnets in northern Rio Grande do Sul (Mondin-Machado *et al.*, 1992). Incidental catches were also reported (Table 2) in Santa Catarina (Paula *et al.*, 1992) and Paraná (Bittencourt and Zanelatto, 1992). Mortality in nets may be higher than reported for this species, as most stranded animals were highly decomposed when found and the bodies could not be examined for net marks.

Long-finned pilot whales
The deaths of four animals found stranded in southern Brazil from 1992 to 1993 were probably related to the longline fishery for tuna.

Tucuxis
Mortality in gillnets has been reported for Santa Catarina by Paula *et al.* (1992) and for Paraná by Bittencourt (1984) and Bittencourt and Zanelatto (1992). According to Zanelatto (1992) there is evidence that the fishery for flounders, *Paralichthys* spp. (Table 3), is responsible for high mortality of tucuxi. This fishery uses large mesh sizes (18–20cm).

Other small cetaceans
Interactions between fisheries and small cetaceans have also been recorded for false killer whales, common dolphins, rough-toothed dolphins and spotted dolphins in southern Brazil (Table 4).

Intentional catches
Ximenez (1990) reported a directed catch of franciscana off Santa Catarina Island.

Predation on catches and fishery characteristics
Killer whales
Killer whale attacks on tuna and swordfish, *X. gladius* hooked by longlines have been reported off Rio Grande do Sul and Santa Catarina (27°S-34°S), in waters from 500 to 3,500m deep. Attacks on swordfishes were more common during autumn and spring, when higher catches occur. Killer whales may damage up to 50% of the catch on a single fishing trip (Secchi and Vasque, 1992).

Longline fisheries in Rio Grande do Sul began in 1977, using leased Japanese tuna vessels (and Chinese vessels since 1991). Fishing effort has increased from 3 vessels in 1977 up to 20 in 1993 (Silva, J.N.A., pers. comm.). The longline fishery is described by Silva (1992). Two fishing areas were reported: in autumn and winter south of 25°S (area 1) and in spring and summer north of 25°S (area 2). The catch per unit effort (CPUE) in area 1 is higher, accounting for 82% of the fishing. Fishing in area 2 depends on the result of the catch in area 1. In area 1 the most important species caught by weight, are the yellow fin tuna (*Thunnus albacares*), the bigeye tuna (*Thunnus obesus*), the albacore (*Thunnus alalunga*) and the swordfish (*X. gladius*). The first three species represented 62% and the latter 15% of the total catch by weight (Silva, 1992).

Changes in the composition of the catches
Franciscanas
The ages of 184 franciscanas collected in Rio Grande do Sul from 1976–1986 revealed a higher vulnerability of the species to gillnets in the first three years of life: 50% of the dolphins caught were up to 3 years old, i.e., before or at the age of sexual maturation (Pinedo, 1994). Between 1982–1986 the relative frequency of dead franciscanas older than 3 years increased compared to the 1976–1980 period (Pinedo, 1994).

An increase of fishing effort has occurred since 1982 in Rio Grande (Praderi *et al.*, 1989) but there is no information about possible shifts in fishing grounds. If it is assumed that fishing grounds have remained the same between 1976–1986, the apparent change in age composition may indicate that the franciscana population structure is being affected by this coastal gillnet fishery (Pinedo, 1994).

CONCLUSIONS AND RECOMMENDATIONS

Over the last ten years, the number of observers interested in cetaceans has increased in Santa Catarina, Paraná and Rio Grande do Sul, and this is reflected by a higher number of records. Although mortality for most species of small cetaceans in southern Brazil seems to be lower than other geographical regions, more detailed information, based on systematic monitoring of the fisheries and catches is needed (data collection methods and requirements should be standardised). Coastal fisheries mainly appear to affect the tucuxi in Paraná and the franciscana in Rio Grande do Sul and Santa Catarina. The known mortality of the franciscana is higher in Rio Grande do Sul but incidental takes in Santa Catarina might have been underestimated. More accurate reporting for both species is required, especially for Santa Catarina and Paraná. The mortality of long-finned pilot whales in southern Rio Grande do Sul has increased since 1992, associated with the increase in the longline fishery.

This review suggests a number of research and management priorities.

(1) Estimation of the abundance of the franciscana population is urgently needed.
(2) Gillnet fisheries in northern Rio Grande do Sul, Santa Catarina and Paraná should be monitored in order to assess the level of mortality of the franciscana and other small cetaceans and to enable the impact of such catches to be assessed.
(3) Incidental catches of the franciscana should be monitored in the fishing villages of Santa Catarina state.
(4) Gillnet fisheries should continue to be monitored in southern Brazil and fishery characteristics reported in accordance with the guidelines developed in IWC (1994).
(5) In Paraná from 1989 to 1992 fifty four specimens of small cetaceans were incidentally caught in gillnets and longlines, a third of which were eaten by fishermen (Zanelatto, 1992). The situation must be monitored to ensure that a shift from incidental to directed catches does not occur. The level of franciscana deaths due to longlines needs to be investigated.
(6) Studies on the age, sex composition and reproductive parameters of the franciscana should be initiated in northern Rio Grande do Sul, Santa Catarina and

Paraná and continued in southern Rio Grande do Sul, to allow comparisons with those of Uruguay and Argentina.

(7) Levels of incidental catches of long-finned pilot whales and other small cetaceans in longline fisheries should be assessed in view of the current development of such fisheries.

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Impact of Incidental Fishery Mortality on the Age Structure of *Pontoporia blainvillei* in Southern Brazil and Uruguay

Maria Cristina Pinedo

Depto. Oceanografia, Fundaçao Universidade do Rio Grande, C.P. 474, CEP 96500–900, Rio Grande, RS Brazil

ABSTRACT

Incidental catches of franciscanas occur in Argentina, Uruguay and Brazil. Ages were estimated for 430 incidentally caught dolphins from Uruguay and southern Brazil (Rio Grande area) taken from 1969 to 1982 and from 1976 to 1986, respectively, based on GLGs in teeth. A total of 62% of the combined sample was less than four years old. For Uruguay, no change in relative abundance was observed for dolphins in two age strata (<4yrs and ≥4yrs) before and after 1979, when a decrease of fishing effort occurred. For Rio Grande, relatively fewer animals less than 4yrs of age were observed after 1982, coinciding with an increase in fishing effort. This may reflect a long period of incidental mortality of dolphins and a consequent impact on the species in southern Brazil.

KEYWORDS: SOUTH ATLANTIC; FRANCISCANA; AGEING; INCIDENTAL CAPTURES.

INTRODUCTION

In Argentina and Uruguay *Pontoporia blainvillei* is known as the 'franciscana' whereas in Brazil its called the 'toninha' or 'cachimbo'. The species is incidentally caught in gillnets and trammel nets throughout its distribution in the coastal waters of these three countries (Fig. 1). This paper concentrates on incidental catches taken in Uruguayan and southern Brazilian waters.

A review of the characteristics of these fisheries was given by Praderi *et al.* (1989). In Uruguay, catches occur mainly during the summer whilst in southern Brazil they occur mainly during spring. These seasons coincide with the calving period of the species in both areas (Pinedo *et al.*, 1989). In Uruguayan waters, at least 2,499 dolphins were caught from 1969 to 1982 (Brownell, 1975; Praderi *et al.*, 1989). A change in fishing practice occurred in Uruguay in 1975, when nets began to be set at the extreme inshore range of the earlier fishing grounds, i.e. 15–20 miles from the coast instead of up to 20–30 miles (Van Erp, 1969). A decrease in fishing effort has occurred since 1979 (Praderi *et al.*, 1989). In southern Brazil (the Rio Grande area), at least 867 dolphins were caught from 1976 to 1986 (unpublished data) and an increase in fishing effort has occurred since 1982 (Praderi *et al.*, 1989).

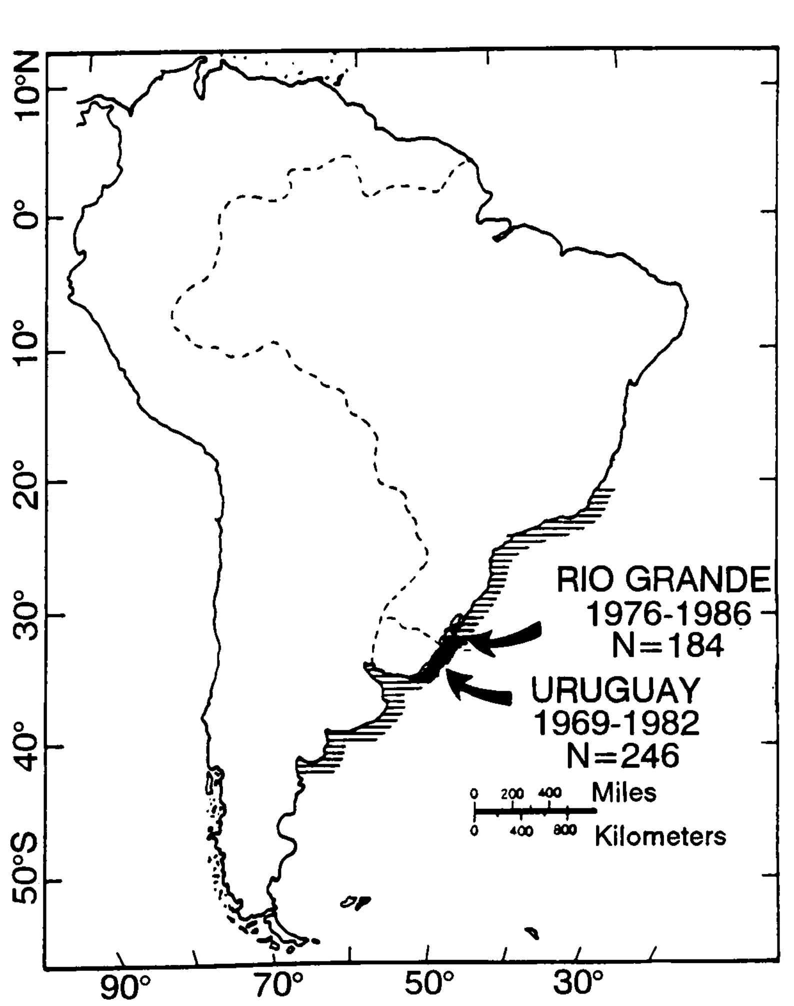

Fig. 1. Distribution of the franciscana in western South Atlantic with locality, time-period and size of samples (modified from Pinedo *et al.*, 1989).

Multivariate analysis of morphometric data has revealed two geographical forms: a smaller form between 22°S and 27°S; and a larger form between 32°S and 38°S (Pinedo, 1991). It is not yet known what form(s) the animals between 27°S and 32°S are. Thus the animals from this study are all from the larger form and probably from the same population (Pinedo, 1991).

The first study to examine age determination of the franciscana was that of Kasuya and Brownell (1979) who looked at teeth from 260 animals incidentally caught off Uruguay. Crespo *et al.* (1986) used the same method (decalcified, stained longitudinal ground sections) to look at further samples from Uruguay.

MATERIALS AND METHODS

Teeth collected from 246 Uruguayan specimens from 1969 to 1982 and from 184 Rio Grande specimens from 1976 to 1986 were examined in this study. Age was estimated based on growth layer groups (GLGs) present in dentine and cementum (IWC, 1980). Teeth were prepared as described by Hohn *et al.* (1989). A model series of ideal 'on-center' cuts was obtained. A comparison of on-center and 'close-to-center' cuts revealed that for most specimens readability was equal or similar for both types of cuts (Pinedo and Hohn, unpublished data). Both types were therefore used to estimate age in this study. Calibration for the first dentinal GLG was based on the mean length obtained by Kasuya and Brownell (1979) for one-year-old specimens and from one specimen aged by them and also available in this study. An annual GLG deposition was confirmed indirectly (Pinedo and Hohn, unpublished data). Although Kasuya and Brownell (1979) used slightly different techniques to those used here, the age frequency distributions for the Uruguayan specimens obtained in this study were similar to those obtained by them, suggesting that the results are comparable.

Based on an age of attainment of sexual maturity of 2–3 years for both sexes (Kasuya and Brownell, 1979), the sample was divided in two groups: 'immatures', from 0–3.9 years (<4yrs), and 'matures', above 3.9 years (≥4yrs). Specimens were classified to a specific age class based on complete formation of dentinal or cemental GLGs.

A chi-square goodness of fit test at the 1% significance level was applied to compare age distributions before and after changes in fishing effort, between and within areas, and to test homogeneity before pooling annual samples. Analyses were performed for specimens <4yrs and ≥4yrs and for individual age classes. In the latter, the age classes with smaller sample sizes were pooled to avoid introduction of bias due to expected frequencies less than 1.0 (Zar, 1984). The 1986 Rio Grande sample was treated separately, because it was unusual in containing a larger number of older specimens when compared with the samples from previous years. For the two group comparisons, since the degree of freedom was 1 (2 × 2 contingency table), the Yates correction for continuity was used, to better approximate the distribution to the confidence level set (Zar, 1984). Comparisons between areas were performed using the null hypothesis that the distributions of specimens <4yrs and ≥4yrs were the same for Uruguay and Rio Grande. Comparison within areas and homogeneity tests for annual samples were performed using the null hypothesis that the distributions of specimens in the years compared were the same. For each analysis, the alternative hypothesis was that the relative age frequency distributions were different.

RESULTS

Of the total pooled sample, 176 were males, 198 were females and 56 of unidentified sex. The oldest male and female were 15 and 21 years old, respectively. Of 18 pregnant females aged, the youngest and oldest were 2 and 14 years old, respectively. Thirty specimens were of age 12 or older (19 females) while 265 (62%) were less than four years old (Fig. 2). Results obtained from chi-square comparisons for specimens <4yrs and ≥4yrs are shown in Table 1. A comparison of the Uruguay and Rio Grande frequencies (Fig. 2, Table 1) revealed that a higher percentage of dolphins under 4yrs old was observed for the former area (70% vs 50%).

For the Uruguayan sample, no differences were observed in the relative frequency of dolphins <4 years over time (Fig. 3, Tables 1 and 2). By contrast, for the Rio Grande sample, a difference in the relative frequency of dolphins <4 years old was detected between 1982–1985 and 1986 (Fig. 4, Table 1). When individual and grouped age classes were compared, the distributions were not the same for individual age classes less than six years old and for age classes at age six or older between 1976–1980 and 1982–1985 and between the latter period and 1986 (Table 3). Age classes 2 and ≥6 contributed most of the difference, with lower and higher values in 1986 than expected, respectively.

DISCUSSION

On the basis of the pooled sample in this paper, females appear to have a greater longevity than males. The age range of pregnant females is in agreement with results from previous studies. Age frequencies obtained in the present study were similar to those obtained by Kasuya and Brownell (1979) and Crespo *et al.* (1986). In all three studies, a higher frequency of specimens <4 years old was observed, with the one-year age class being prevalent.

Table 1

Chi-square comparisons between and within areas by age groups.

Area and years/Age groups		< 4 years	> 4 years	N	Chi-square	DF
Uruguay	1969-1982	172	74	246	15.90*	1
Rio Grande	1976-1986	93	91	184		
Uruguay	1969-1972	67	35	102	0.40	1
	1980-1982	25	9	34		
	1969-1972	67	35	102	1.05	1
	1973-1975	79	29	108	0.03	1
	1980-1982	25	9	34		
Rio Grande	1976-1980	49	48	97	0.53	1
	1986	25	33	58		
	1976-1980	49	48	97	4.73	1
	1982-1985	18	5	23	6.82*	1
	1986	24	33	58		

* Statistically significant at $\alpha = 0.01$.

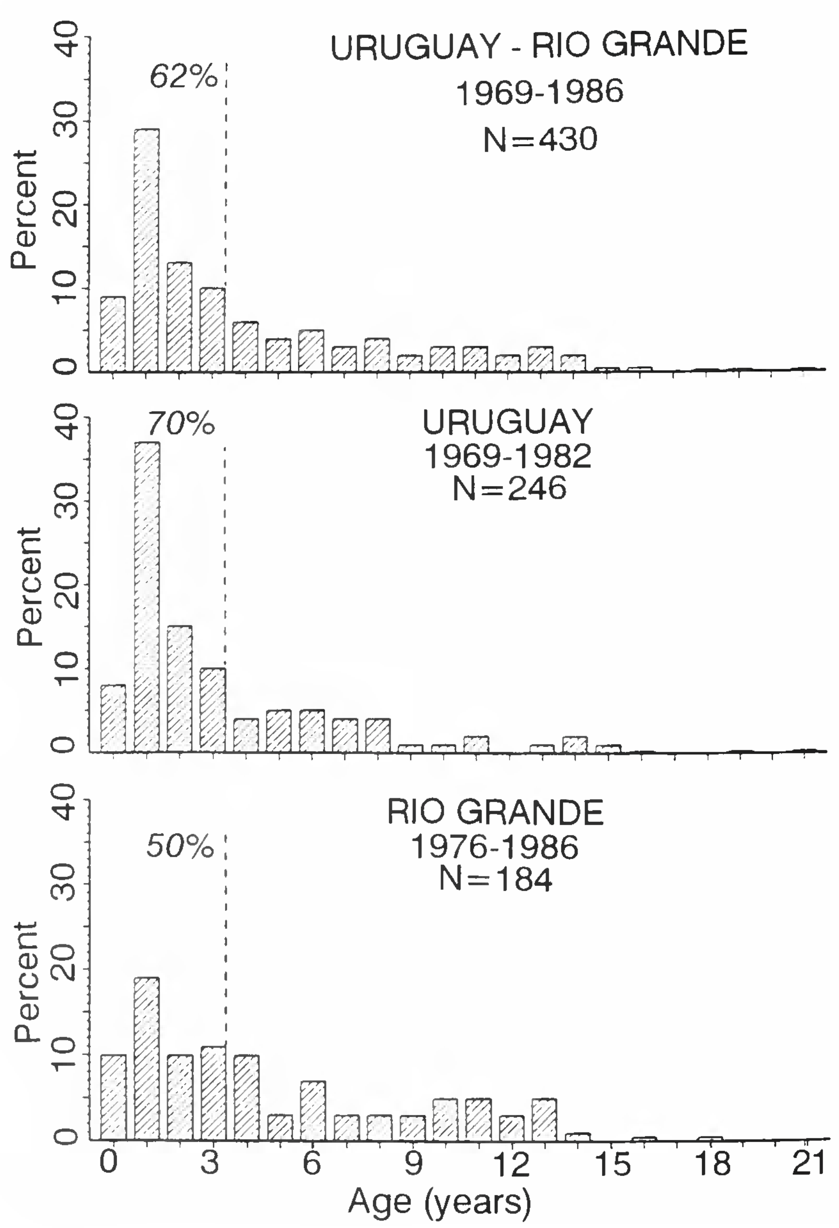

Fig. 2. Age frequency distribution of the total sample, Uruguay and Rio Grande combined, and by area.

Table 2

Chi-square comparisons between years for Uruguay by individual and grouped age classes. The expected frequencies predicted by the null hypothesis are given in parenthesis.

	Age (years)												
Years	0	1	2	3	4	5	6	7	8	>9	N	Chi-square	DF
1969-1972	8 (6)	30 (37)	15 (15)	14 (11)	5 (4)	4 (5)	4 (5)	6 (5)	4 (5)	12 (10)	102	12.93	9
1980-1982	0 (2)	19 (12)	5 (5)	1 (4)	0 (1)	3 (2)	2 (2)	1 (2)	2 (2)	1 (3)	34		
1969-1972	8 (10)	30 (34)	15 (15)	14 (12)	5 (4)	4 (4)	4 (4)	6 (4)	4 (4)	12 (10)	102	5.42	9
1973-1975	12 (10)	41 (37)	16 (16)	10 (12)	4 (5)	5 (5)	5 (5)	3 (3)	4 (4)	8 (10)	108		
1973-1975	12 (9)	41 (46)	16 (16)	10 (8)	4 (3)	5 (6)	5 (5)	3 (3)	4 (5)	8 (7)	108	12.01	9
1980-1982	0 (3)	19 (14)	5 (5)	1 (3)	0 (1)	3 (2)	2 (2)	1 (1)	2 (1)	1 (2)	34		

* Statistically significant at $\alpha = 0.01$.

Table 3

Chi-square comparisons between years for Rio Grande by individual and grouped age classes. The expected frequencies predicted by the null hypothesis are given in parenthesis.

	Age (years)									
Years	0	1	2	3	4	5	>6	N	Chi-square	DF
1976-1980	9 (10)	23 (20)	9 (7)	8 (9)	13 (11)	1 (3)	34 (37)	97	8.33	6
1986	7 (6)	9 (12)	2 (4)	7 (6)	4 (6)	4 (2)	25 (22)	58		
1976-1980	9 (9)	23 (20)	9 (14)	8 (11)	13 (11)	1 (2)	34 (30)	97	21.20*	6
1982-1985	2 (2)	2 (5)	8 (3)	6 (3)	1 (3)	1 (0)	3 (7)	23		
1982-1985	2 (3)	2 (3)	8 (3)	6 (4)	1 (1)	1 (1)	3 (8)	23	18.68*	6
1986	7 (6)	9 (8)	2 (7)	7 (9)	4 (4)	4 (4)	25 (20)	58		

* Statistically significant at $\alpha = 0.01$.

Some authors have speculated that juveniles might exhibit behaviour (e.g. curiosity) more likely to result in their entanglement than adults (e.g. IWC, 1994).

The higher proportion of dolphins <4 years old found in the Uruguayan sample might indicate that: (1) juveniles are more vulnerable to larger mesh size used in Uruguay (32–34cm) than those (10–32cm) used in southern Brazil (Praderi *et al.*, 1989); (2) in Uruguay the nets are set in areas mainly used by juveniles; (3) juveniles are more frequent in Uruguay; or (4) a combination of these.

In considering the Uruguayan results, some aspects of the fisheries need to be taken into account. During the first two periods (1969–1972 and 1973–1975) before the decrease of fishing effort, the characteristics of the fisheries from which the samples were obtained were similar: samples came from Punta del Diablo, a fishing village where nets were set up to 20–30 miles from the coast and at

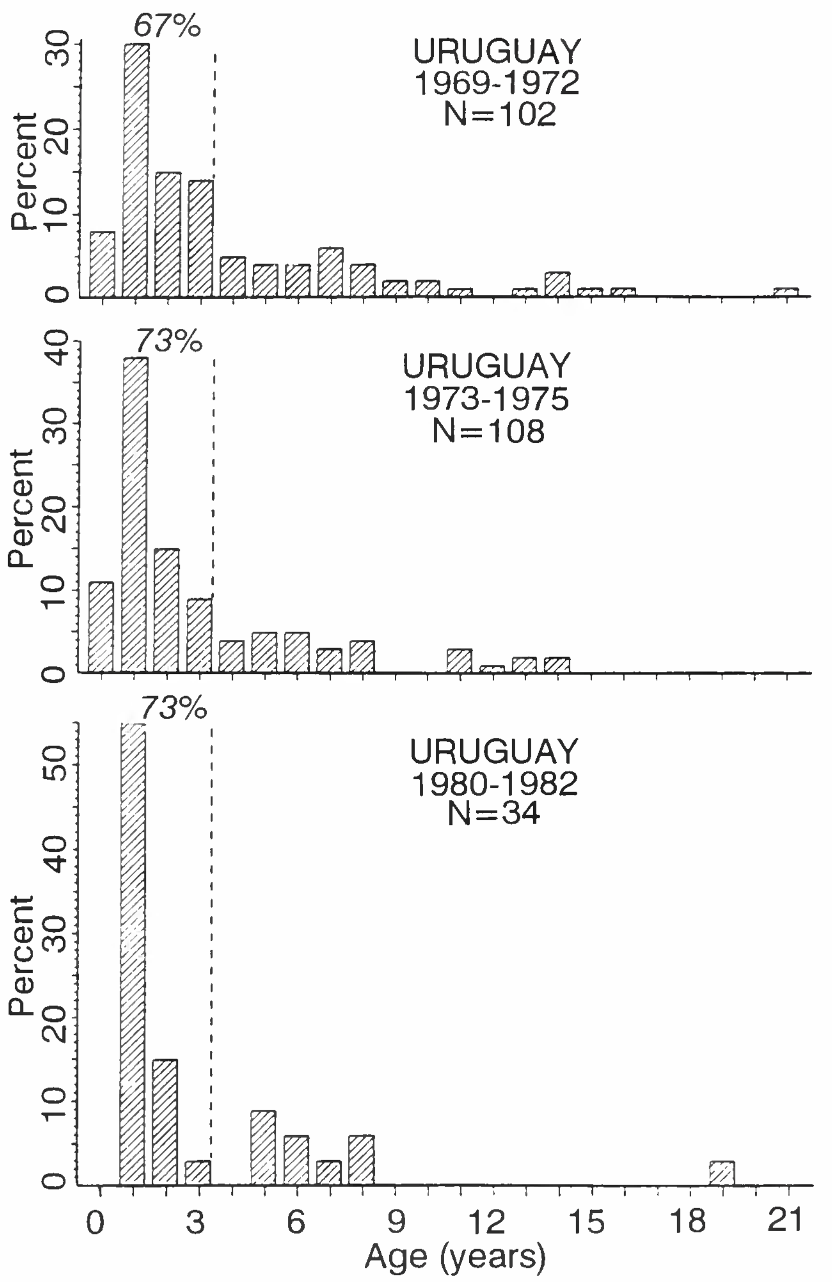

Fig. 3. Age frequency distributions for Uruguay.

depths of 20–30m (Van Erp, 1969; Brownell, 1975). However, during the 1980–1982 sampling period fishermen of this village (from which 35% of the aged dolphins came) had moved to mainly offshore (>20 miles). The remaining 65% of the sample came from another village, Barra Valizas, where nets were set in shallower waters, between

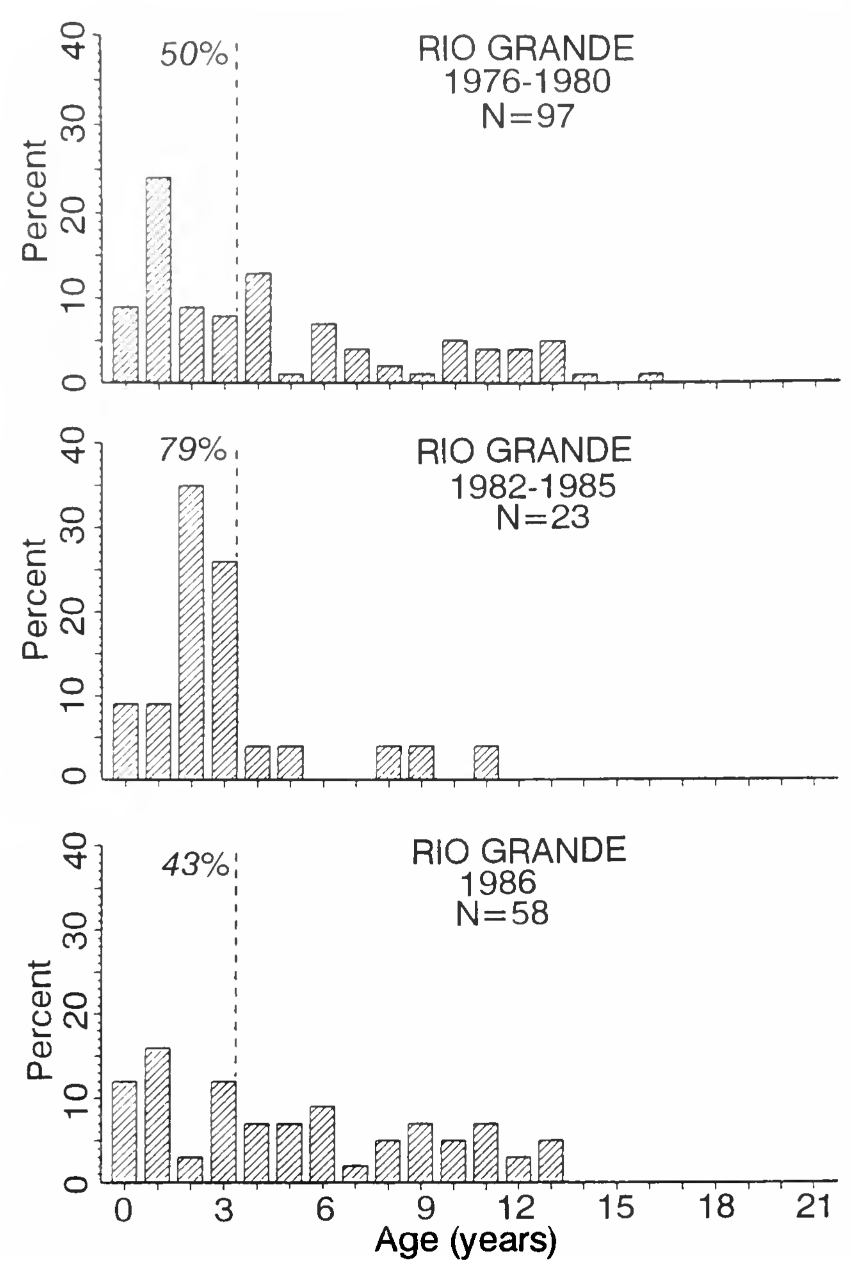

Fig. 4. Age frequency distributions for Rio Grande.

6–15m deep (Praderi *et al.*, 1989). According to Praderi *et al.* (1989), 68–75% of the dolphins died in nets set at 6–20m, while the remaining died in nets set in waters deeper than 20m. Although an annual increase of 25% in the catch of franciscanas was observed for this village between 1979 and 1982 (Praderi, 1984), no difference in the distribution of age frequencies for Uruguayan specimens was observed from 1969 to 1982. This suggests the possibility of a constant age distribution at different distances from the coast and different water depths. If this is true, alternative (2) above seems unlikely.

Unfortunately, there is less information about operations from Rio Grande during this period and in particular about possible shifts in fishing grounds. If it is assumed that they have remained constant and considering that the franciscana is most highly vulnerable to fishing nets in the first three years of life, the higher mortality of 2–3 year old individuals observed during the first three years since the increase of fishing effort, followed in 1986 by a decline in these frequencies and an increase of older specimens, could indicate that the age structure of the local population had been affected by the fishery. Unfortunately there are at present (November 1994) no post 1986 data with which to examine this further.

Since the dolphins from southern Brazil, Uruguay and Argentina appear to be from the same geographic population and since they continue to be killed in fishing nets in these countries (with an apparently greater impact at present in southern Brazil), the species may require further protection. In Argentina and Brazil, where legal protection exists, it should be more strongly enforced and legislation may need to be enacted in Uruguay as well. Further research and management recommendations are discussed in Pinedo (1994).

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Incidental Catch of Marine Tucuxi, *Sotalia fluviatilis*, in Alagoas, Northeastern Brazil

Nélio B. Barros[1]

Division of Marine Biology and Fisheries, Rosenstiel School of Marine and Atmospheric Science, University of Miami, 4600 Rickenbacker Causeway, Miami, FL 33149–1098, USA

and

Rogério L. Teixeira[2]

Laboratório de Ciências do Mar, Convênio Comissão Interministerial para os Recursos do Mar e Universidade Federal de Alagoas, Praça Sinimbu, 206 Maceió, Alagoas, Brazil 57025

ABSTRACT

We report the gillnetting of two marine tucuxi in northeastern Brazil. The stomachs of the dolphins contained fish that are also caught in artisanal fisheries. The entangled animals showed no external net marks. The magnitude of tucuxi mortality in nets is not known; management policies should include an assessment of fishery impact on local dolphin populations.

KEYWORDS: TUCUXI; INCIDENTAL CAPTURE; FEEDING; FISHERIES; COMPETITION; MANAGEMENT; SOUTH ATLANTIC.

INTRODUCTION

Small cetaceans are increasingly threatened worldwide by entanglement in various fishing gear (e.g. Mitchell, 1975; Northridge, 1984; Read and Gaskin, 1988; Brownell *et al.*, 1989). Only recently has gillnetting of the marine tucuxi (*Sotalia fluviatilis*) been reported at the southern portion of their range in southern Brazil (Lodi and Capistrano, 1990; Simões-Lopes and Ximenez, 1990; Barros, 1991). The magnitude of these catches has not been evaluated.

Fig. 1. Map showing place names mentioned in the text.

[1] Present address: Hubbs-Sea World Research Institute, PO Box 691602, Orlando, FL 32869–1602, USA
[2] Present address: Virginia Institute of Marine Science, PO Box 1346, Gloucester Point, VA 23062–1346, USA

Two distinct morphological forms of the tucuxi are recognized: a large, coastal (marine) form and a smaller, riverine form (Borobia and Sergeant, 1989). *Sotalia* is currently listed under Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora, i.e. is considered endangered and in need of protection.

We report the entanglement of two females of the marine form in Maceió, Alagoas State, northeastern Brazil (Fig. 1). Although sightings of tucuxi have been made in this region and in the adjacent States of Pernambuco and Sergipe (Borobia *et al.*, 1991), our specimens are the first collected from the waters of Alagoas.

The fisheries at Pajuçara Beach are artisanal. The distance from shore at which the nets are set is dependent on the size and type of boats used. Most fishermen in this region can only afford *jangadas* (small wooden rafts with a

Fig. 2. *Jangadas* used in the artisanal fishery at Pontal do Coruripe, Alagoas, northeastern Brazil. Photo by Wyb Hoek.

sail, Fig. 2) and thus nets must be set in waters very close to shore generally not exceeding depths of 20m and outside the breaker zones of the low-energy sandy beaches. Nets vary in length from 100–300m and are set at dawn and retrieved the following morning. According to our observations, the main target fish species are mullets (*Mugil liza*, *M. gaimardianus* and *M. curema*), with mojarras (*Diapterus olisthostomus* and *Eugerres brasilianus*), marine catfish (*Bagre bagre* and *B. marinus*) and jacks (*Caranx latus*, *C. hippos* and *Oligoplistes saliens*) caught in lesser numbers.

The fisheries in the area of Maceió are seasonal. From late spring until the end of the summer (Nov-Mar), the shrimp (mainly *Penaeus schmitti*, *P. subtilis* and *Xiphopenaeus kroyeri*) fishery is closed and most fishermen switch to gillnetting and/or fishing with hook and line. We believe that during this time the potential for incidental catches of the tucuxi increases.

RESULTS

The entangled specimens were retrieved on 23 September 1988 from the same gillnet, at Pajuçara Beach (9°41'S, 35°40'W). The net was 200m in length, 2m in height, had a mesh size of 35mm and was made of nylon approximately 0.6 mm in diameter ('nylon 30'). No external signs of entanglement, such as marks or cuts, were found on the dolphins, although the nets in which they were caught were heavily damaged.

Dolphin total lengths (measured along the curvature of the body) were 182cm (female No. 1) and 161cm (female No. 2). The skulls of both dolphins have been deposited at the zoological collection of the Federal University of Alagoas and a series of skull measurements is presented in Table 1. Examination of tooth sections revealed 14+ dentinal growth layer groups (GLGs) in female No. 1, and 2+ GLGs in female No. 2 (Borobia, pers. comm.). Whereas the former was clearly an adult animal, as indicated by the closed sutures on the skull, the latter was a young animal, with most of its skull bones unfused.

Recognized stomach contents from each specimen are listed on Table 2. Most fish in the two stomachs were only partially digested and identification could be made from external morphological characters. In female No. 1, mullets and mojarras accounted for 95% of the total wet weight of the contents. Cutlass fish (*Trichiurus lepturus*)

Table 1

Skull measurements (1-36 after Perrin (1975), 37-40 after Schnell *et al,* (1985), and 41-42 after Borobia and Sergeant (1989)) of marine tucuxi from Pajuçara Beach, Maceió, Alagoas, northeastern Brazil.

Measurement	Female No. 1		Female No. 2	
	mm	%CBL	mm	%CBL
1. Condylobasal length (CBL)	375.0	100.0	335.0	100.0
2. Length of rostrum	220.0	58.7	174.8	52.2
3. Width of rostrum at base	82.3	22.0	-	-
4. Width of rostrum 60mm anterior to No. 3	58.1	15.5	-	-
5. Width of rostrum at midlength	47.9	12.8	-	-
6. Width of premaxillaries at midlength	26.5	7.1	-	-
7. Width of rostrum at 3/4 length	32.1	8.6	-	-
8. Tip of rostrum to external nares	267.0	71.2	-	-
9. Tip of rostrum to internal nares	274.0	73.1	-	-
10. Greatest preorbital width	140.4	37.4	-	-
11. Greatest postorbital width	152.8	40.7	-	-
12. Least supraorbital width	139.0	37.1	-	-
13. Greatest external nares width	37.0	9.9	-	-
14. Greatest zygomatic width	164.4	43.8	-	-
15. Greatest premaxillary width	60.4	16.1	-	-
16. Greatest parietal width	123.2	32.9	-	-
17. Vertical external height of braincase	123.0	32.8	-	-
18. Internal length of braincase	10.4	2.8	-	-
19. Greatest length left posttemporal fossa	85.4	22.8	-	-
20. Greatest width left posttemporal fossa	61.4	16.4	-	-
21. Major diameter left temporal fossa	42.2	11.3	-	-
22. Minor diameter left temporal fossa	31.7	8.5	-	-
23. Nasals to occipital crest	24.6	6.6	-	-
24. Length of left orbit	43.8	11.7	-	-
25. Length of left antorbital process	33.2	8.9	-	-
26. Greatest width of internal nares	42.1	11.2	-	-
27. Greatest length of left pterygoid	50.2	13.4	-	-
28. Length of upper left tooth row	188.3	50.2	-	-
29. Number of teeth (upper left)	31	-	30	-
30. Number of teeth (upper right)	31	-	28	-
31. Number of teeth (lower left)	29	-	30	-
32. Number of teeth (lower right)	29	-	28	-
33. Length of lower left tooth row	189.9	50.6	-	-
34. Greatest length of left ramus	321.0	85.6	80.0	83.6
35. Greatest height of left ramus	72.0	19.2	63.0	18.8
36. Length of left mandibular fossa	103.7	27.7	101.9	30.4
37. Maximum separation of pterygoids	9.7	2.6	-	-
38. Length of left tympanic cavity	57.5	15.3	-	-
39. Length of right tympanic cavity	60.7	16.2	-	-
40. Width of pterygobasioccipital sutures	40.9	10.9	-	-
41. Greatest height of foramen magnum	39.7	10.6	-	-
42. Greatest width of foramen magnum	36.7	9.8	-	-

were found in the stomach of both dolphins, and accounted for about 60% of the total wet weight of the contents of female No. 2.

DISCUSSION

The food habits of marine tucuxi are poorly known. In Brazil, prey species such as *T. lepturus* and *Lolliguncula brevis* have been reported in their diet (Borobia and Barros, 1989). Prior to this paper, mojarras (*D. olisthostomus*), drums (*Stellifer* sp.) and mullets (*Mugil* spp.) had not been reported as prey items. Several specimens of marine tucuxi have been observed on different occasions chasing leaping mullets in Atafona, Rio de Janeiro (Lodi, pers. comm.) whereas anchovies (Engraulidae) are thought to be the preferred prey in Florianópolis, Santa Catarina (Simões-Lopes, 1988).

Local fishermen believe that the dolphins are present throughout the year in the Maceió area, but are more numerous during the austral spring and summer, supposedly to take advantage of the seasonal abundance of mullet. The observation by fishermen of an increase in dolphin numbers during periods of mullet abundance might indicate movements of adjacent populations of marine tucuxi into the area of Maceió. A similar seasonal increase in dolphin abundance has been documented for the west coast of Florida, where bottlenose dolphins (*Tursiops truncatus*) may follow migrating mullets from offshore to coastal waters (Weigle, 1990). Mullets are an important seasonal resource in the diet of bottlenose dolphins in southern Brazil (Pinedo, 1982) and also form the basis for a cooperative fishing interaction between fishermen and dolphins in this area (Pryor *et al.*, 1990; Simões-Lopes, 1991).

Table 2

Stomach contents of two marine tucuxi entangled in gillnets at Pajuçara Beach, Maceió, Alagoas, northeastern Brazil.

Stomach contents	Total length of prey (cm)	Wet weight of prey (g)	Number of prey
Female No. 1 (182cm long)			
Trichiuridae			
Trichiurus lepturus	31.2	8.1	1
	31.5	8.4	1
Gerreidae			
Diapterus olisthostomus	16.9	56.9	1
Mugilidae			
Mugil liza	22.1	127.0	1
Mugil sp.	25.9	105.1	1
Mugil sp. remains	-	43.1	-
Total		348.6	5
Female No. 2 (161cm long)			
Trichiuridae			
Trichiurus lepturus	33.2	13.9	1
	37.5	25.8	1
	34.2	15.1	1
	36.2	13.2	1
Sciaenidae			
Stellifer sp.	16.9	9.3	1
Unidentified remains	-	41.5	-
Loliginidae			
Lolliguncula brevis	8.6[3]	5.2	1
Total		114.7	6

[3] Mantle length.

On at least four different occasions, one of us (RLT) observed groups of up to five tucuxi close to shrimp boats operating around the Maceió harbour. We do not know if the dolphins follow shrimp boats to feed on the discarded fish (or fish perturbed by the trawling) nor do we have any information on the spatial/temporal extent of the apparent association with shrimp boats. Interestingly, the cutlass fish, present in the stomach of both dolphins in this study, is among the finfish species discarded by shrimpers, particularly in the smaller size classes. Cutlass fish was the dominant species in the bycatch of trawlers off Rio Grande do Sul state (Haimovici and Perez-Habiaga, 1982). In areas where other coastal species of dolphins (e.g. bottlenose dolphins) associate with shrimp boats, their food habits can be substantially altered (see Barros and Odell, 1990).

The overlap in the species composition of fish caught in artisanal fisheries and those consumed by female No. 1 (mullets and mojarras) suggests some competition between dolphins and fisheries for common resources. Fishermen from this area believe that the dolphins actually take mullets (fish of high local commercial value) directly from the nets, causing damage to fishing gear in the process. Direct competition between other odontocetes and commercial fisheries has been reported for other areas of the world (e.g. Cato and Prochaska, 1976; Schlais, 1984; Freeman, 1986).

Lodi and Capistrano (1990) report the capture of two marine tucuxi in the same net for the coast of Rio de Janeiro and on one occasion a fisherman reportedly caught eight dolphins in a single net (Lodi, pers. comm.). Dawson (1991) reported the entanglement of two or more Hector's dolphins (*Cephalorhynchus hectori*) in waters off New Zealand to be a common occurrence, young (< 3 years of age) dolphins being particularly susceptible to entanglement. Multiple capture of marine tucuxi may be due to cooperative feeding of small groups in this species, for which there is some evidence (Simões-Lopes, 1988; Borobia, pers. comm.).

The absence of scars or marks is not a reliable indicator that dolphins have not been entangled. For instance, over 60% of all small cetaceans caught in nets set between Atafona and Macaé, Rio de Janeiro, would not have been categorised as entanglements based solely on external examination (Lodi and Capistrano, 1990). Similarly, the specimens from this study were retrieved directly from the nets but did not show any external evidence of net capture.

Our findings indicate that incidental catches of marine tucuxi are not restricted to southeastern Brazil. Artisanal fisheries are found along much of the coast of Brazil, and coastal dolphins, such as tucuxi, may be at risk throughout their entire range. The magnitude of this incidental catch is presently unknown and cannot be estimated from our data. Accurate assessments of the impact of this catch require population estimates, which are not yet available for any portion of the dolphins' marine range.

Morphological differences indicating population discreteness within the marine form have not been found, despite an indication of residency in certain areas (Borobia and Sergeant, 1989). However, if the Maceió population of tucuxi is resident, as thought by fishermen, then incidental catches by the local fisheries could be considered a serious threat. Information on fish landings and fishing effort should be collected to evaluate the extent of these fishery interactions in Maceió and surrounding waters.

Small cetaceans have only recently been protected in Brazilian waters, after regulations (Portaria No. N-011, 21 February 1986) were passed by the former Federal

Fisheries Development Agency (Superintendência do Desenvolvimento da Pesca – SUDEPE). However, this protection is not effective because of the long coastline and limited human resources for enforcement. The mortality of marine tucuxi in such rudimentary fishery operations such as *jangadas*, shows how vulnerable these dolphins might be to larger scale commercial fisheries. We recommend that future studies determine the number of dolphins caught by this fishery and assess its impact on local populations of marine tucuxi.

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Interactions Between Marine Mammals and Fisheries in Some Coastal Fishing Areas of Argentina

Enrique Alberto Crespo

Centro Nacional Patagónico and Universidad Nacional de la Patagonia, Casilla de Correo 67, 9120 Puerto Madryn, Chubut, Argentina

Javier Francisco Corcuera

CONICET and Museo Argentino de Ciencias, Naturales Bernardino Rivadavia, Av. Angel Gallardo 470, 1405 Buenos Aires, Argentina

and Andrea López Cazorla

Universidad Nacional del Sur, Av. Alem 1256, 8000 Bahía Blanca, Argentina

ABSTRACT

Interactions between marine mammals and fisheries were monitored along the southwestern Atlantic coast of Argentina from Bahía Samborombón (Buenos Aires Province) to Tierra del Fuego Island. A variety of fisheries with several types of gear are used and in some fisheries there are incidental catches of small cetaceans. Different cetacean species are taken depending on area, gear and target fish species involved. However, throughout the region, information is scarce and good estimates of mortality and the stock identity and abundance of the affected marine mammal species are required. In Buenos Aires Province, the franciscana, *Pontoporia blainvillei*, is the species most frequently caught in shark and croaker gillnet fisheries. In some places in this province, such as Necochea (the best studied area of Argentina), gillnets also catch Burmeister's porpoises (*Phocoena spinipinnis*) and purse seines catch dusky, common, and bottlenose dolphins (*Lagenorhynchus obscurus*, *Delphinus delphis* and *Tursiops truncatus*). Passive fishing gear is not used in the area between San Matías Gulf and San Jorge Gulf, but bottom and mid-water trawls, mainly for shrimp and hake, catch dusky dolphins and to a lesser extent common dolphins, Commerson's dolphins (*Cephalorhynchus commersonii*) and spectacled porpoises (*Australophocoena dioptrica*). Although the dolphin mortality per fishing vessel and per month seem to be low, the high level of fishing effort may result in a high absolute number of dolphins killed. In southern Patagonia (Santa Cruz Province, south of Puerto Deseado) gillnets are used for *róbalos* (*Eleginops maclovinus*); Peale's dolphin (*Lagenorhynchus australis*), Commerson's dolphins and spectacled porpoise are caught incidentally. At Tierra del Fuego Island, gillnets are used for *róbalo*, hake and silverside on the northeast coast and take Pealé's and Commerson's dolphins and spectacled and Burmeister's porpoises. The use of marine mammals as bait for fishing *centollas* seems to have decreased recently in the Argentinean section of the Beagle Channel, but information on mortality rates is far from complete. In some localities the southern sea lion (*Otaria flavescens*) has been reported to damage catch and nets and is occasionally entangled. When considering management and conservation strategies, the economy and market conditions are important variables in less developed countries and should be studied along with biological parameters.

KEYWORDS: KEYWORDS: SOUTH ATLANTIC; INCIDENTAL CAPTURE; MANAGEMENT; FISHERIES; FRANCISCANA; BURMEISTER'S PORPOISE; DUSKY DOLPHIN; BOTTLENOSE DOLPHIN; COMMON DOLPHIN; COMMERSON'S DOLPHIN; SPECTACLED PORPOISE; PEALE'S DOLPHIN; PINNIPEDS

INTRODUCTION

In recent years, considerable attention has been given to the problem of incidental captures of marine mammals (and other species) in fishing gear (e.g. Brownell *et al.*, 1989). Argentina, with its long coastline (more than 3,000km) and extensive continental shelf, is home to several small-scale coastal and pelagic fisheries utilising a wide variety of vessels and types of gear.

Since 1974, the Uruguayan coast has been the most thoroughly surveyed region of the southwestern Atlantic with respect to marine mammals (Brownell and Praderi, 1974; Praderi, 1976; 1979; 1982; 1983; 1984; 1985; Kasuya and Brownell, 1979; Crespo *et al.*, 1986; Praderi *et al.*, 1989). The species most often incidentally caught by small-scale fisheries in the region was the franciscana, *Pontoporia blainvillei*. Fishery mortality involving this species was also observed along the southern coast of Brazil by Pinedo (1984; 1985; 1986) and Praderi *et al.* (1989). By comparison, Argentinian studies of marine mammals and their interactions with fisheries (e.g. Goodall and Cameron, 1980) began in the mid 1980s. Pérez Macri and Crespo (1989) carried out a preliminary survey of the coast of Argentina between 1984 and 1986, in a study of the incidental mortality of the franciscana and other cetacean species (bottlenose dolphins, *Tursiops truncatus* and dusky dolphins, *Lagenorhynchus obscurus*). They estimated an approximate annual mortality for the franciscana of at least 340–350 animals. Incidental captures of long-finned pilot whales (*Globicephala melas*) have also been reported for the region (Bastida and Bastida, 1986).

Although there remain few detailed studies, comprehensive data recording has recently been initiated in several areas of Argentina, including Necochea-Claromecó (Buenos Aires province, see Fig. 1), where surveys of interactions have been conducted since 1988 (Monzon *et al.*, 1990; Corcuera *et al.*, 1994). Biological studies of incidentally caught animals have also begun. These include studies of reproduction (Corcuera and Monzón, 1990; Monzon and Corcuera, 1990), physical maturity (Corcuera *et al.*, 1990), parasites (Raga *et al.*, 1990) and organochlorine levels (Borrel *et al.*, 1990). Studies in the north of Patagonia began in 1989. In the remaining areas, surveys have been rather sporadic.

METHODS

Fishing activities were monitored in the harbours of four areas of Argentina: Area I – the Province of Buenos Aires (including the ports of San Clemente del Tuyú, Necochea,

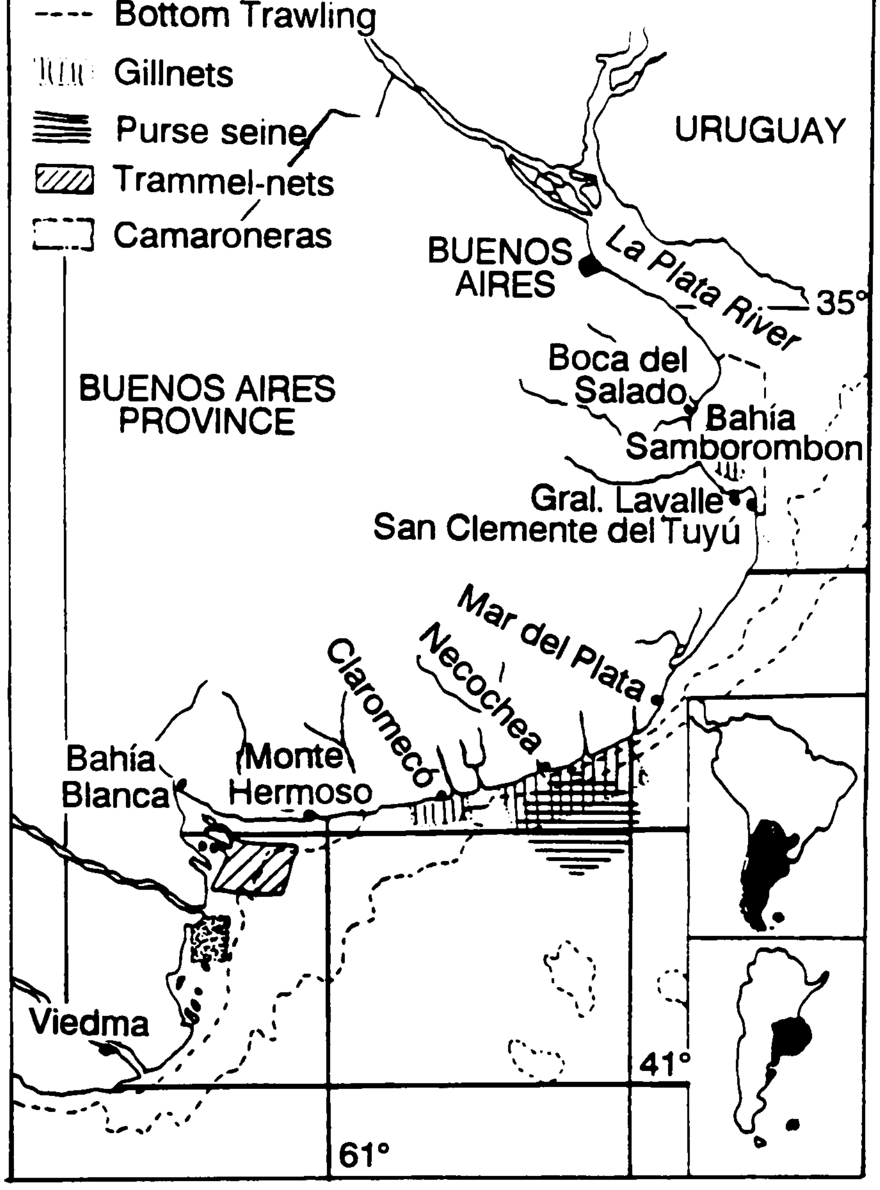

Fig. 1. Fisheries and fishing areas of Buenos Aires Province.

Claromecó and Bahía Blanca); Area II – northern and central Patagonia including the Provinces of Rio Negro (port of San Antonio Oeste) and Chubut (ports of Puerto Madryn, Rawson, Camarones, Caleta Córdova and Comodoro Rivadavia) and Puerto Deseado (Province of Santa Cruz); Area III – the Province of Santa Cruz (south of Puerto Deseado); and Area IV – Tierra del Fuego (the northeast coast of the island and the port of Ushuaia).

Three interview surveys were conducted between June and August 1990. The following harbours were visited: San Clemente del Tuyú, Bahía Blanca, Viedma, San Antonio Oeste, Rawson and Puerto Deseado. The purpose of the surveys was to obtain descriptions of fishing gear used locally and, when possible, estimate fishing effort and cetacean bycatch levels. Data collected included number of boats operating each day, type of fishing, net type, length and mesh size of nets employed, location of fishing ground, and number and species of dolphins caught.

In addition, Puerto Madryn has been monitored since September 1989, Necochea was monitored from 15 September – 17 October 1988 and 29 October – 12 January 1989 and Claromecó was monitored from 2–25 December 1989.

Information was recorded from interviews with fishermen and people associated with government fishery agencies, Coast Guard files, officers and captains of fishing vessels, investigators conducting fishery research projects and direct observation by the authors. We consider that the information obtained was reliable, especially that concerning descriptions of fishing gear and estimates of fishing effort. Contradictions among fishermen were resolved by direct observation (when possible) or by further interviews.

A number of vessels from each port co-operated with our studies and brought incidentally killed dolphins to Necochea-Claromecó and Puerto Madryn where biological samples were collected for several projects. Data are also available for Santa Cruz and Tierra del Fuego (R.N.P. Goodall and A.C.M. Schiavini, abstracts submitted to this symposium).

RESULTS

Area I. Province of Buenos Aires

Samborombón Bay (Fig. 1 and detail in Fig. 2)

The Samborombón Bay area was monitored between 1984 and 1987, and again in 1990. The area includes the ports of San Clemente del Tuyú (36°22'S, 56°43'W), General Lavalle (38°21'S, 56°55'W) and Boca del Salado (35°45'S, 57°22'W). Recent information shows that previous estimates of the number of boats were low, although fishing effort has apparently remained constant over time. Some 16 boats operate with perhaps no more than 7–8 using gillnets and the remainder operating bottom trawls.

Fishing gear used in the area include 10cm stretched mesh gillnets for silverside and mullet, 30cm stretched mesh gillnets for most croaker species and bottom trawls (worked by two boats) for another croaker species, corvina rubia (*M. furnieri*).

Although the areas fished using the different gear types overlap, the precise limits for each gear type have not been

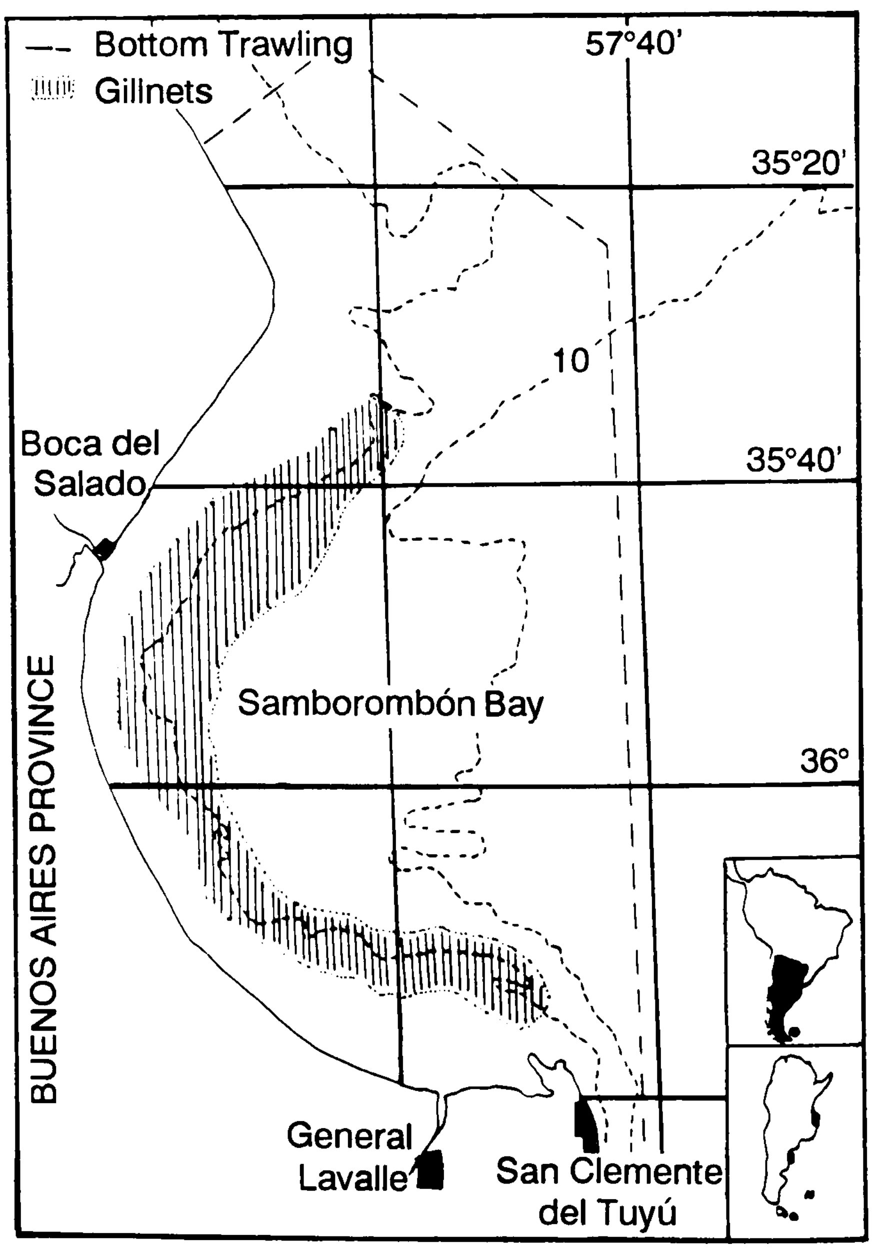

Fig. 2. Detail of the fisheries and fishing areas of Samborombón Bay, Buenos Aires Province.

determined. However, from the depth contours we estimate a fishing ground of around 1,500km² for croaker gillnets and about 7,500km² for bottom trawling operations.

Specific features of the Samborombón Bay fishery are presented below.

TARGET FISH SPECIES

The most important target species are the croakers: *Micropogonias furnieri* (local name: '*corvina rubia*'), *Pogonias cromis* ('*corvina negra*'), *Cynoscion striatus* ('*pescadilla*'), *Macrodon ancylodon* ('*pescadilla real*'), all of the Sciaenidae. Other species include mullet *Mugil brasiliensis* ('*lisa*') and silverside *Austroatherina* sp. ('*pejerrey*').

VESSELS, AREA OF OPERATION

The area of operation in Samborombón Bay is shown in Fig. 2. Sixteen boats operate in the area with 3–4 men per boat (mostly Argentinean and Italian). The wooden boats are about 8–10m in length, with 6–7 operating from San Clemente del Tuyú, 5 from General Lavalle and 4–5 from Boca del Salado. The fish is handled fresh and iced. Vessels from Uruguay also operate in the area (see below).

GEAR

Two gillnet types are used in the area: a 10cm gillnet for silverside and mullet and a 30cm gillnet for croaker. Both are made of nylon monofilament with a twine size of 2–3mm. The panels are 100m long and 2–3m deep. The boats now carry 2–3 panels of 100m each per boat, which are joined and called an *encollarada* (between 1984 and 1986 the panels were 50m and 4–6 units were carried in the boats and joined). The floats are 12cm in diameter and are spaced 1.2m apart. The gear is hauled on the side of the vessel.

OPERATIONS

Trips usually last 8–12hrs. During the fishing season, boats go to sea every day if the weather is good. The gillnets for croakers are set for at least two months (60 days on average) from October to December, 2–3 n.miles from the coast. The boats fish in water 1–15m in depth depending on the target species; 1m for mullet, 2–3m for silverside and 4–6m for croakers. The nets remain in the water for the entire season and are surveyed periodically by the fishermen.

ECONOMICS AND HISTORY

At present the markets are domestic although plans are being made to begin export of *M. furnieri*. The fish is sold both fresh and frozen and processors are located in the area and at Mar del Plata. There are no data available on the total landings of fish.

DEVELOPMENT OF THE FISHERY AND CURRENT TRENDS

The fishery for *M. furnieri* is economically more important for fishermen than that for *P. cromis* and catches of the former appear to be increasing.

The local fishermen believe that foreign and uncontrolled fishing, in this case from Uruguay and the Mar del Plata harbour fleet has led to the depletion of the croaker species. Although the Shared Fishing Area established by an international treaty between the Governments of Argentina and Uruguay does not include Bahía Samborombón, Uruguayan fishermen do, however, fish there.

EFFORT DATA

The gillnet fishery involves 7–8 boats that set 200m nets for approximately 60 days each season.

INTERACTIONS WITH CETACEANS

Franciscana are typically found dead in gillnets when fishermen retrieve their catch; in only one case was an individual found alive and released. The dolphins are thrown away or brought aboard if requested (carcasses were recovered in 1985 and 1986). In special cases when the animals are fresh they are eaten as *mushame* (see Pérez Macri and Crespo, 1989). Franciscana are caught throughout the season. No new information has been collected to allow us to modify the estimate of mortality given by Pérez Macri and Crespo (1989). Since fishing effort has remained constant, we consider their estimate of at least 50 dolphins per year to be the best for this fishery. Bottom trawling was first observed to cause deaths of franciscana in 1986. As in previous years, the 1990 survey confirmed this to be a rare event. No other significant mortality was recorded with other fishing gear in this area. Although cetaceans are protected by law (see Atkins, 1989) there is no special consideration of incidental mortality under Argentine legislation and to date there have been no efforts to reduce the bycatch. The impact on cetacean population(s) is unknown. Information on stock identity, stock size and better estimates of mortality rates are required.

DISCUSSION (SAMBOROMBÓN BAY)

The surveys carried out between 1984–86 and in 1990, reveal few changes with respect to gillnet fishing effort. Although a few individuals die in bottom trawls, the most dangerous gear for cetaceans (and then only the franciscana) seems to be the 30cm gillnet. The increasing trawl effort for *P. cromis* therefore, will not significantly increase franciscana incidental mortality. However, along with other croaker species, it has been reported as an important prey item of the franciscana (Pinedo, 1982a; b; Praderi, 1982; Pérez Macri, 1986) which may thus be affected indirectly by competition.

In view of this we recommend that a programme be established to (1) monitor operations to improve estimates of franciscana mortality; (2) develop a method to estimate its abundance in the area; and (3) examine stock identity between animals from similar areas (e.g. Bahía Blanca estuary) and open sea areas (Punta del Diablo in Uruguay and Necochea and Claromecó).

Mar del Plata harbour (Fig. 1)

A large (more than 180 vessels; both coastal and offshore) fleet operates from Mar del Plata using a wide variety of vessels and gear (e.g. gillnets, traps, lines, bottom trawls, dredge trawls, purse seine, etc.). Detailed information on the operation of the fishery, levels of fishing effort and marine mammal mortality data is scarce. One franciscana was brought back to port in mid 1990 (Bastida, pers. comm.). An unknown number of dusky dolphins are entangled during purse seining operations (Goodall and Cameron, 1980), probably in the same way as described below for the Necochea area (Corcuera *et al.*, 1994). Given the lack of information for this fishery we recommend that a detailed study of fishing effort and associated incidental mortality is carried out.

Necochea and Claromecó Harbours (Fig. 1)
This area has been the most intensively surveyed in Argentina thanks to an on-going project on the mortality of the franciscana begun two years ago (Monzon *et al.*, 1990). Most of the information contained in this section is a summary of that presented by Corcuera *et al.* (1994).

Three major types of fishing gear are used in the Necochea area: bottom trawls, purse seines and nylon monofilament bottom set gillnets. *Nasas* (traps; fishing baskets) are sporadically used by a few boats. In Necochea, the boats use different gear according to the target species and seasons but in Claromecó only gillnets are employed. Two types of fishing result in dolphin mortality: purse seining and gillnetting.

Purse seining is carried out by two co-operating vessels, which usually set their nets between 0.5 to 30 n.miles from the coast. The main target species are anchovies (*Engraulis anchoita*) and mackerel (*Scomber japonicus*). The presence of anchovies and mackerel is seasonal (October-November). Either birds or dolphins attract the attention of the fishermen. The fish are herded by the dolphins and the boats encircle the dolphins and set their nets around them. Although the frequency of incidental catches appears to be low at present (68–102 in 1989; 5 in 1990), fishermen report that the number of dolphins (dusky and common) captured was greater in the past. The dolphins die when they become entangled, not in the bottom of the purse seine, but in the sides of the net where the mesh size varies from 30 to 60cm. Live dolphins are usually returned to the sea, but some may be killed by the fishermen if they are heavily coiled in nets (in order to quickly discard the carcass and repair the damaged gear).

Bottom set gillnets for sharks are used both in Necochea (38°37′S,58°50′W) and Claromecó (38°50′S, 60°10′W). More detailed information is given below.

TARGET FISH SPECIES
The most important target species for the gillnet fishery are shown in Table 1.

Table 1
Main target species for the Necochea and Claromecó gillnet fisheries

Zoological name[1]	English name	Local name
Order **Carchariniformes**	Ground sharks	
Family Triakidae	Houndsharks	
Galeorhinus galeus	Tope shark	Trompa de Cristal
Mustelus spp.		Gatuzo
Order **Lamniformes**	Mackerel sharks	
Family Odontospididae	Sand tiger sharks	
Eugomphodus taurus	Sandtiger shark	Bacota
Order **Squatiniformes**	Angelsharks	
Family Squatinidae		
Squatina argentina	Argentine angelshark	Pez angel, Excuadro

[1] Following Compagno (1984)

AREA OF OPERATION
As shown in Fig. 1, the fishing area extends from 0.5 n.miles to 22–25 n.miles from the coast in the case of Necochea and less for Claromecó.

VESSELS AND CREW
There are 40–44 vessels at Necochea, of which 20 operate with gillnets. All three vessels from Claromecó use gillnets. Crew size ranges from 4–9 (mainly Argentinean and Italian). Most (60%) vessels are made of steel with the remainder being wooden. Vessel length ranges from 8 to 44.9m (mean=16.01m; SD=2.73; n=20). Fish capacity ranges between 7 and 64 tonnes (mean=23.6 tonnes; SD=13.3; n=20). The fish is handled fresh and iced.

GEAR
The nets have a mesh size (stretched) of 19–21cm and are made of nylon monofilament with a twine size of 2–3mm. The panels are 55–71m long (mean=66m; SD=11.3m) and 3.8m deep; 500m of net consists of 8–9 joined panels, or one *posta*. Each boat carries seven *postas* in Necochea (range = 4–9) and only two in Claromecó (range = 1–3). A mean of 57.75 panels/vessel are used at Necochea and 16.5 panels/vessel at Claromecó. The buoys are 10 to 14cm in diameter and are spaced 1.2m apart. The gear is located visually at sea by means of flags on the ends of the net. The net is hauled from the port side of the boat.

OPERATIONS
Trips usually last from 6–12hrs and each vessel makes about 70–90 trips per year. The depths in the fishing areas are between 2–30m (Claromecó) and 10–70m (Necochea). The nets are bottom set at a mean depth of 26.4m (SD=12.5m; n=26) from 1000 to 1600hrs and are retrieved from 0700 to 1300hrs. The time taken to retrieve nets depends on the extent of the nets and the number of sharks caught; it increases when dolphins are entangled. The mean time is 20–30 minutes for each 500m of net and typical catches (per panel) are 6–15 angelsharks or 1–20 of the other species.

ECONOMICS
The fishery has both a domestic and foreign market (mainly Europe, especially Italy). The sharks for export (mainly *Galeorhinus*) are cleaned and frozen. Fins are exported independently from the rest of the carcass. Sharks carcasses that are damaged (by *Mustelus* and/or southern sea lions, *Otaria flavescens*) are cleaned, salted and dried, producing a substitute for cod meat called *bacalao* that is sold locally. The fins are processed in the same way as *bacalao*. *Mustelus* spp. are consumed fresh or frozen locally. The price per kilo to fisherman for *Galeorhinus* (10kg size) varies from US$3–4 (for export) to US$1–2.5 when sold as *bacalao* in the local market. The prices for shark fins, *Squatina*, *Mustelus* and other fish species are not available. The total annual value of the catch per vessel is uncertain. The total annual catch may be around 5,000kg of product per vessel per year, but the rate of damaged *Galeorhinus* catch has not yet been calculated. The processing factories are all located at Necochea.

HISTORY AND DEVELOPMENT OF THE FISHERY AND CURRENT TRENDS
The *Galeorhinus* fishery in Buenos Aires Province was already important in the 1950s (López, 1954). At that time exploitation must have been severe as one of the first papers on this species called for conservation measures (Ringuelet, 1958). The main objective of the fishery was shark liver oil, exported to the US and Europe. *Bacalao* meat has been used to replace imported cod for some time, perhaps since the 1940s. In those times, fishing was at lesser depths and shorter distances from the coast.

Since the late 1980s, fishermen have claimed that the shark migration routes have moved farther from the coast each year. Similar behaviour has been reported for Uruguayan sharks, but in neither case has it been confirmed. Although this will raise the operating costs of the fishery, fishing effort has not decreased as it has in Uruguay. This seems to be due to the relative stability of the shark fishery profits, in contrast to the greater financial risks in catching the other local target-species (anchovy, mackerel). Thus, bottom-trawling and gillnet fisheries appear to be less risky than purse seining, and the country's economic instability may enhance the trend of increase in their use. Some vessels that did not operate with gillnets in 1988 or 1989 planned to use them during the 1990 shark season.

TOTAL LANDINGS

There are no reliable data available, but landings may reach up to 3,000–4,000 sharks/day during the peak of the fishing season (November-December). A rough estimate of 50–70,000 sharks per season seems reasonable. Official statistics of gillnet landings do not necessarily reflect all off-loaded sharks.

EFFORT DATA

In 1989, the total length of gillnets set at Necochea was around 76,230m while at Claromecó it was around 3,270m.

INTERACTIONS WITH CETACEANS

The entanglements of cetaceans in fishing gear in this area are discussed in detail by Corcuera *et al.* (1994). Only a brief summary of their work is presented here.

The franciscana and Burmeister's porpoise (*Phocoena spinnipinnis*) comprise most of the incidental cetacean catch in gillnets (77% and 19% respectively) although dusky and common dolphins are occasionally caught. Annual total catches are estimated to be around 50–70 per year. A similar number of dolphins (bottlenose, dusky and common) are caught in purse seine operations. There is little utilisation of the bycatch although in a few cases dried and salted meat is used for human consumption.

PINNIPED BYCATCHES

Southern sea lions do not get entangled but damage the sharks caught by biting the belly, exposing the viscera and eating only the liver. During a 1989 survey fishing trip, almost 60% of the sharks recovered (a vessel catches a mean of 150 sharks/day) from one *posta* were damaged in this way by one male sea lion observed from the vessel. *Mustelus* sp. sharks also prey on shark carcasses entangled in the gillnets, biting any exposed part of the body. The rate of occurrence of both phenomena needs to be evaluated as well as the resulting economic damage.

DISCUSSION (NEOCOCHEA AND CLAROMECÓ)

Partly as a result of discussions during the 1986 Workshop on River Dolphins (Perrin and Brownell, 1989), these two harbours have been carefully monitored. The 1988 and 1989 seasons showed that the conflict between small cetaceans and fisheries is not restricted to the franciscana but also affects the Burmeister's porpoise and the dusky and common dolphin (Monzon *et al.*, 1990; Corcuera *et al.*, 1994). Although fishing effort in Claromecó was smaller and the monitoring period was shorter, the catch of dolphins per day was 2.07 times higher than at Necochea. This may be because Claromeco's gillnets are set in shallower waters closer to the coast. Burmeister's porpoises appear to be caught in deeper waters than franciscanas and further from the coast.

The projected trend for fishing in this area (a gradual increase in the use of gillnets and bottom-trawls) suggests that incidental mortality of franciscana and Burmeister's porpoise may increase in the coming years.

In addition, although fishermen have suggested that the length of the purse seine fishing season for anchovies and mackerel has decreased in recent years due to over-exploitation of the stocks, the impact of purse seining on common and dusky dolphins cannot be ignored and still needs to be evaluated and monitored.

In view of the lack of biological information available, we recommend that projects be established to (1) obtain estimates of abundance for the affected cetacean species in the area; (2) examine questions of stock identity by examining genetic variation and establishing whether there are growth and reproductive pattern differences between the Uruguayan and the Necochean franciscana (Corcuera and Monzón, 1990; Corcuera *et al.*, 1990; Monzon and Corcuera, 1990); and (3) further examine the age distribution and reproductive status of incidentally caught animals and examine any trends over time. Information such as this will enable a rational management policy to be designed.

Monte Hermoso (Fig. 1)

A small-scale fishery operates in the area of Monte Hermoso for the croaker species *M. furnieri*. On the basis of a survey in 1986, Pérez Macri and Crespo (1989) report that this fishery is similar to that at San Clemente del Tuyú. They reported no dolphin mortality at that time. The area was not surveyed during 1990. We recommend that this fishery be surveyed briefly to determine the fishing gear employed and the level of fishing effort.

Bahía Blanca (Fig. 1)

This region has one main fishing harbour, Ingeniero White, near the city of Bahía Blanca and a seasonal (October-December) fishing camp near Riacho Azul, in Bahía Unión. About 15–16 wooden fishing vessels (mean length 13–15m) operate. A maximum of 12 small motor boats (canoes) operate in Bahía Unión, apparently at 5 n.miles from the coast, and depths of 14–15m, taking two shrimp species (*Pleoticus muelleri* and *Artemesia longinaris*). The Bahía Blanca area seems to be an important breeding region for several fish species (López Cazorla, pers. comm.).

In the Bahía Blanca estuary, the fishermen employ three different kinds of passive nets: *tapadura* or *tapacanal* (Fig. 3), *camaronera* (Figs 4 and 5) and trammel nets (Figs 6 and 7). No active fishing gear is used.

The *tapacanal* is used to block the small channels which are common in the area in order to catch croakers, particularly *M. furnieri*. The net is about 150–500m long and 3.5m high and the stretched mesh is 50mm. It is irregularly shaped with the bottom placed between two arms, one about one-third of the length of the net and the other of about two-thirds (Fig. 3). The nets are set with anchors by two small boats. Fishermen splash the water to scare fish and run them into the net. The net is recovered after six hours by the small boats and a mother vessel, beginning from the long arm. Fish remain alive in the bottom of the net and are retrieved live on board.

The *camaronera* takes its name from 'little shrimp' (*camarón* in Spanish) and it is set mainly to catch them (*P. muelleri* and *A. longinaris*) and the croaker *Cynoscion*

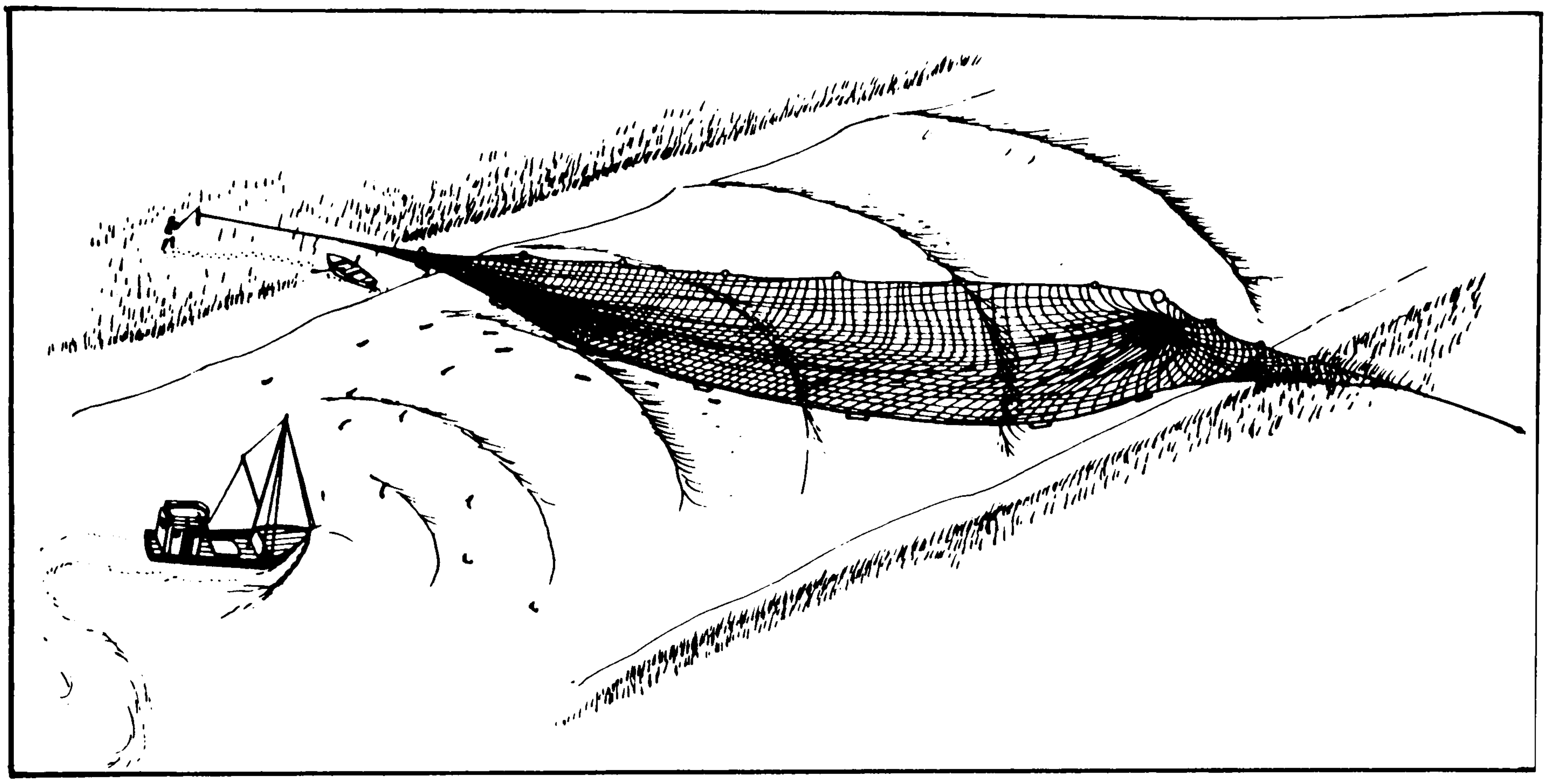

Fig. 3. *Tapadura* or *tapacanal*: net set for croakers in Bahía Blanca. During the decreasing tide water is splashed from the boat to scare the fish into the net before retrieving it.

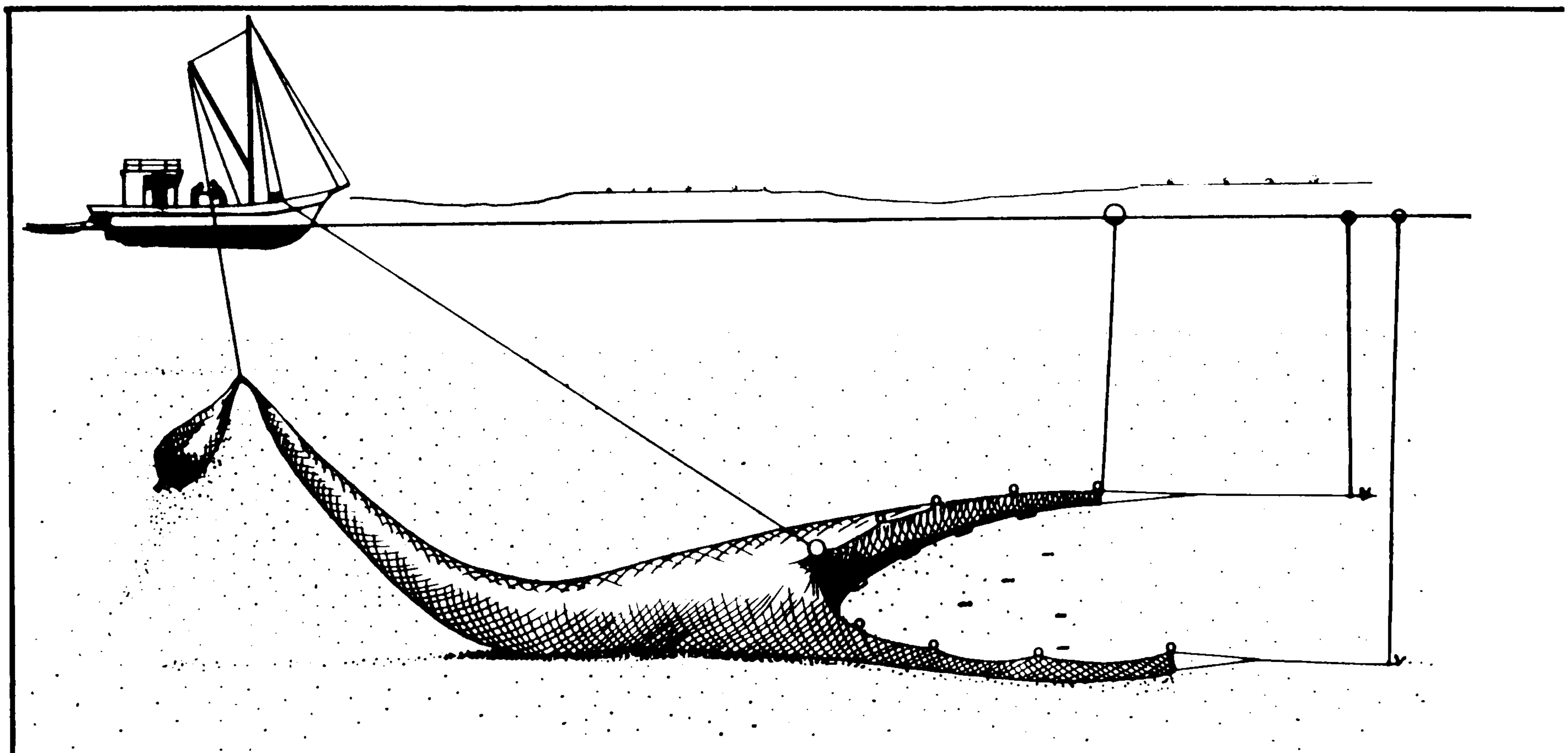

Fig. 4. *Camaronera* (shrimper): net used mainly for shrimps and small croakers. The mouth of the net is open to the water current. The catch is raised up from the bottom of the net 2–3 times during the tide.

striatus. It is funnel-shaped with walls and a pocket (Figs 4 and 5). The stretched mesh is 60mm in the walls, 40mm in the middle of the mouth and in the bottom of the pocket it is 20mm for shrimp and 60mm for the croaker. The net is set with anchors at a stationary tide and is recovered before the next stationary tide when the water current is slight. The fishermen decide to work with increasing or decreasing tides based mainly on the hours of light available.

Outside the channel areas, a few vessels use trammel nets to catch the narrownose smooth-hound shark, *Mustelus schmitti* (Fig. 6), a silverside species *Odontesthes bonaerensis* (Fig. 7) and the parona (*Parona signata*). The stretched mesh is 10cm, and the nets are 70m long and 5m high. They are set between August and October in the middle areas of the bay at depths of 7–13m for 24hr periods.

Information on marine mammal and fishery interactions in this area is scarce, partly because the bays are large and difficult to navigate. The estuary provides large areas of shallow waters, inhabited by franciscana (Pérez Macri and Crespo, 1989). Although it seems inevitable that incidental mortality of this species occurs both in Bahía Blanca and Bahía Unión, its extent is unknown. One fisherman from Bahía Unión reported that franciscanas are incidentally

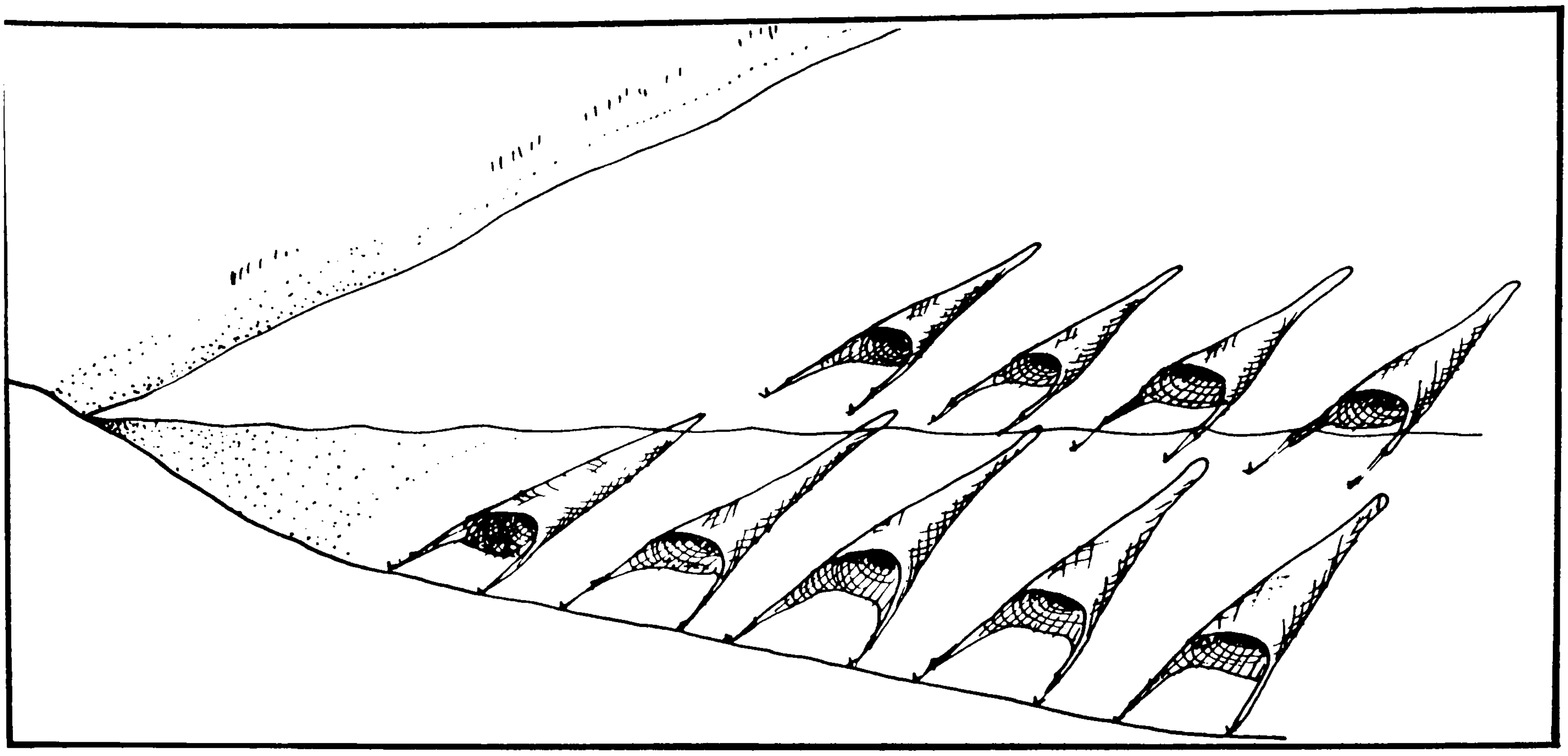

Fig. 5. Distribution of the shrimpers at sea.

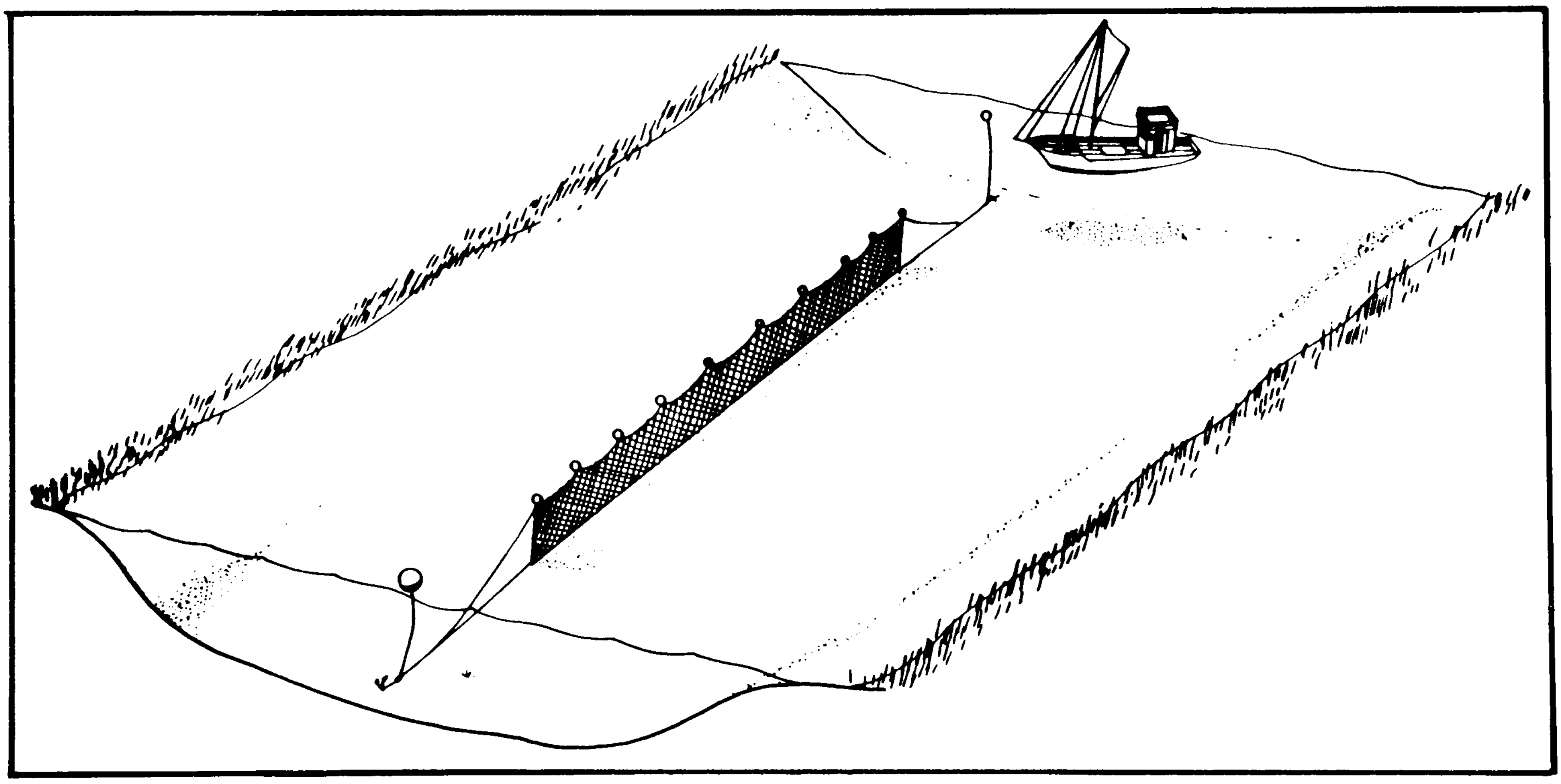

Fig. 6. Single trammel-net used for *gatuzo* (*Mustelus* sp. a requium shark species). The net is set along the channel, at 3–4m depth.

captured, but estimates of mortality cannot be made. It is also possible that dusky dolphins might sometimes be entangled. It is therefore impossible to determine which gear causes most entanglements, or where cetacean bycatches occur. Although local fishing effort might be slowly decreasing in the estuary for economic reasons, there may be an overall increase in effort due to the possible movement of vessels from neighbouring harbours into the area, due to its high productivity. A study of cetacean mortality for some of the Ingeniero White vessels has just begun, but monitoring needs to be carried out systematically for the whole area.

A further factor to take into account is that the coast surrounding Ingeniero White harbour includes one of the most important petroleum and chemical processing centres in the country. In addition, a major private development in this area is about to begin and levels of industrial waste may increase in the near future. Thus in addition to monitoring incidental capture, the monitoring of pollution levels is also necessary wherever there is a potentially high risk, for example in the Bahía Blanca estuary. Pollutants may affect the reproductive success of cetaceans including the franciscana (e.g. Addison, 1989).

Area II. North and Central Patagonia (Fig. 8)

Viedma and San Antonio Oeste

There are no fisheries near Viedma, almost at the mouth of the Río Negro. However, a small-scale fishery operates in the San Matías Gulf from San Antonio Oeste. This

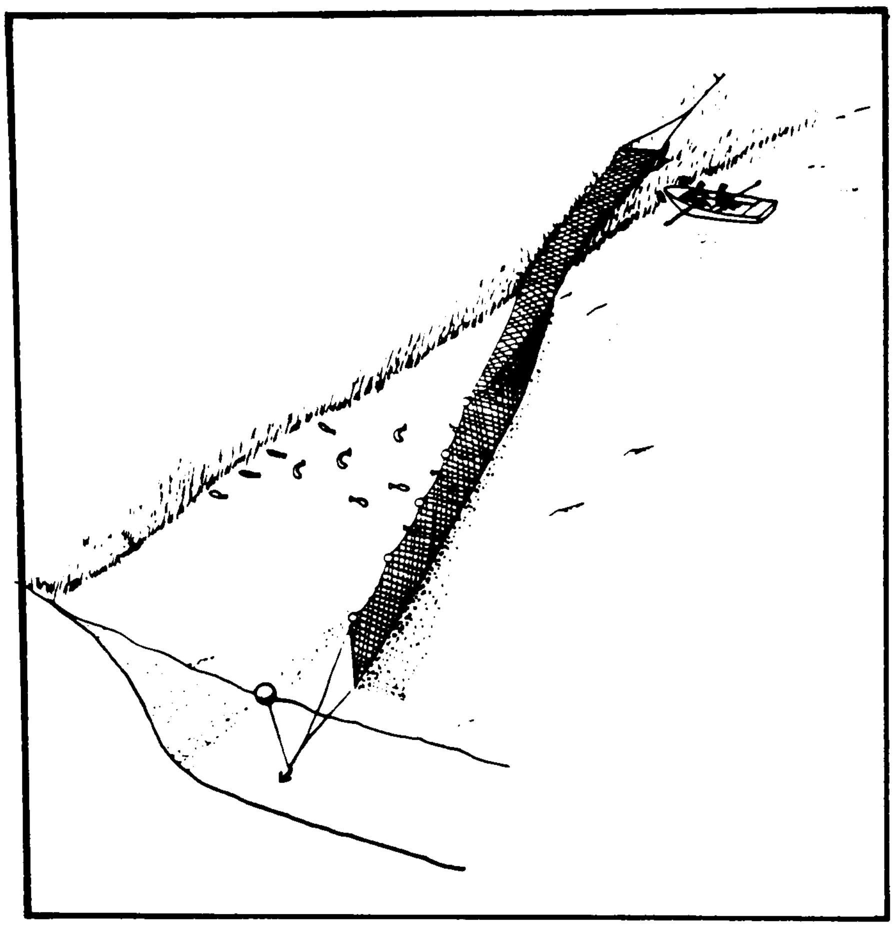

Fig. 7. Single trammel-net used for *pejerrey* (silversides). The net is set diagonally with one extreme on the beach and the other in the water.

includes two vessels bottom trawling for Argentine hake (*Merluccius hubbsi*) and another three vessles dredge trawling for shellfish such as the mussel species *Mytilus platensis* and *Aulacomya ater* and the scallop *Chlamys tehuelchus*. The most abundant cetaceans in the gulf are the common and dusky dolphins. No mortality of dolphins was recorded in 1986 or 1990. However, a project for mid-water trawling for anchovies is continuing and an experiment in the gulf with this gear led to the death of one dusky dolphin in 1989 (R. González, pers. comm.).

Harbours of Chubut Province (Fig. 8)

Fisheries in the northern waters of Patagonia involve not only vessels from fishing ports from Chubut Province (Puerto Madryn, Puerto Rawson, Camarones, Caleta Córdoba and Comodoro Rivadavia) but also an unknown number of fishing vessels from northern and southern harbours (e.g. Mar del Plata in Buenos Aires Province and Puerto Deseado in Santa Cruz Province). Bottom or mid-water trawling are the most common fishing methods in the area. Gillnets or other passive gear are not used in this area.

Detailed information on the bottom and mid-water trawling fishery in Chubut is given below.

TARGET FISH SPECIES

There are several target fish species in this area (see Table 2) but by far the most important is the red shrimp (*P. muelleri*) because of its extremely high export value. This is illustrated by the fact that fishermen will throw away any other fish if a shrimp school is found. The amount of fish discarded may reach 10 tonnes per ship per day during the shrimp season. The figures are very preliminary.

AREA OF OPERATION

The most important fishing areas (Fig. 8) are near Isla Escondida and in Golfo San Jorge. The major concentration of hake is between 43° and 44°30'S in summer. Spawning (in summer) is at Isla Escondida which

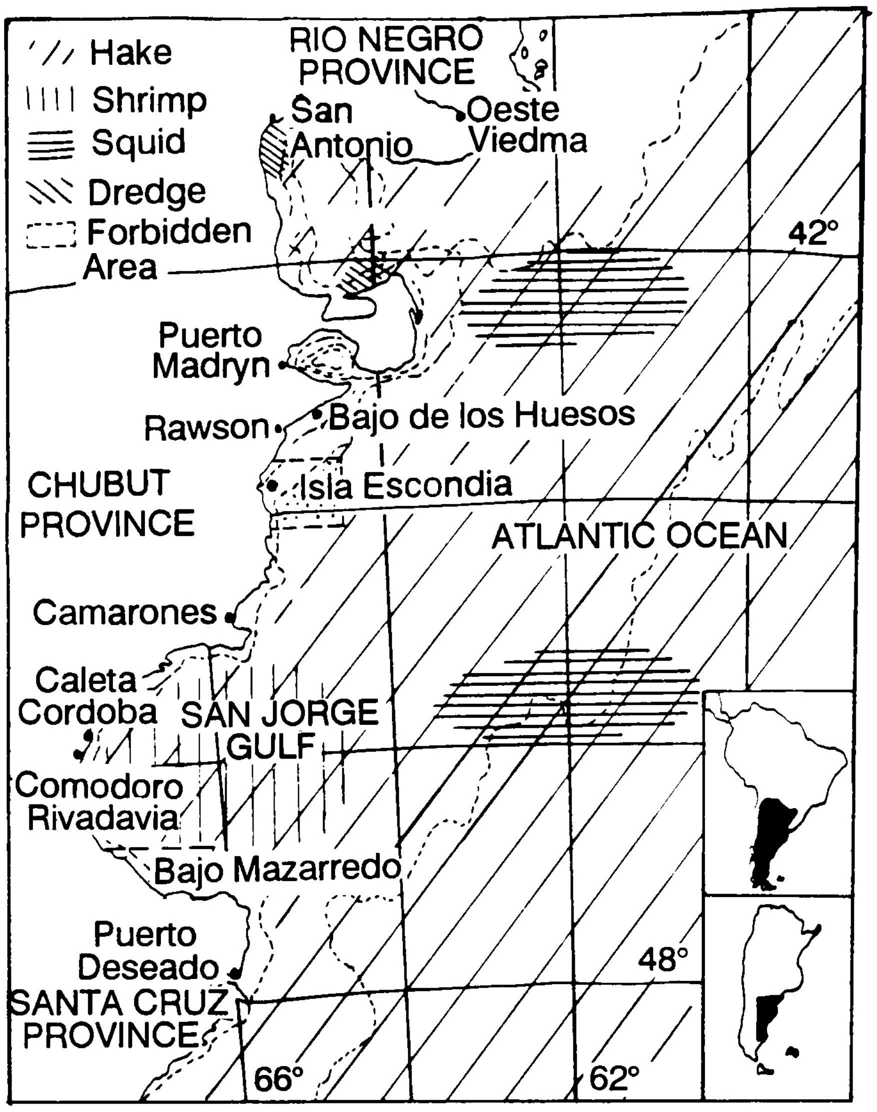

Fig. 8. Fisheries of northern and central Patagonia.

Table 2

Main target species for the bottom and mid-water trawling in Chubut Province

Zoological name	English name	Local name
Merluccius hubbsi	Argentine hake	Merluza
Merluccius australis	Southern hake	Merluza
Micromesistius australis	Southern blue whiting	Polaca Argentina
Pleoticus muelleri	Red shrimp	Langostino
Illex argentinus	Argentine shortfin squid	Calamar
Loligo gahi	Patagonian squid	Calamarete
Pinguipes spp.	Southern salmon	Salmon
Genypterus blacodes	Pink cusk-eel	Abadejo
Acanthistius brasilianus	Grouper	Mero
Paralicthys sp.	Sole	Lenguado

is a protected area. The most important areas for shrimp are Bajo de los Huesos and Bajo Mazarredo (a protected area). Areas for squid are between 42–43°S, 61–63°W and 45–46°S, 61–64°W.

VESSELS AND CREW

Fishing vessels range in length from 35–50m at Puerto Madryn, 18–25m at Rawson and 30–45m at Comodoro Rivadavia; the average engine power is about 1400 HP.

Only a few small vessels are made of wood, the larger ones are made of steel. Some of the smaller vessels are side-trawlers and the rest are bottom-trawlers. Detailed information is given in Tables 3 and 4.

GEAR

The mesh size of hake trawls is 6cm at the bottom and 10cm in the wings. For shrimp trawls the mesh size is 4cm at the bottom and 6cm in the wings. The nets are made of

Table 3

Fishing vessels operating out of Chubut harbours

Type of vessels	Length (m)	HP	Fish cap (kg)	Process	No. of trips	Nationality
Close coastal	16-25	up to 500	30,000	Fresh	5-8	Arg.
Distant coastal	25-32	500-800	50,000	Fresh	8-12	Arg.
Offshore ships	32-45	1,000-1,500	95,000	Fresh	10-15	Arg.
Freezing ships	40-55	1,500-2,700	180,000	Frozen	15-25	Arg., Jap.
Factory ships	80-110	3,500-4,000	900,000	Processed	50-80	Arg., Jap.

Table 4

Number of fishing vessels by port

Puerto Madryn	30-35 (distant coastal, offshore and freezer) 2 (factory)
Rawson	20 (close coastal)
Camarones	4-10 (distant coastal and offshore)
Cta. Cordova	4 (close coastal)
Cro. Rivadavia	15-20 (offshore)

multifilament. The wings are 50–60m in length and 30m in depth. Small vessels carry only one net, but vessels over 30m in length carry more. The float size is 20cm and floats are spaced 1.5m apart. The vessels carry echosounders on board and new foreign factory ships carry net echosounders in the mouth of the net.

OPERATIONS

The usual duration of trips varies with the size of the vessels and the success of the catch (nearshore coastal = 1 day; distant coastal = 4 days; offshore = 7–10 days; freezer ships = 25–40 days; factory ships = 50–70 days); the usual numbers of trips per year are 200, 50, 50, 8–10 and 6 per vessel type, respectively. From September to November at Puerto Deseado, the trips are shorter because fish are at their most abundant. The fishing depth for bottom trawling is up to 70–80m; in midwater trawling the depth is variable. The small vessels fish from early in the morning until night. The larger vessels fish continuously. It usually takes three hours to retrieve nets. The size of the catch depends on the equipment used; a full net may contain 3–4 tonnes in the small vessels and 6–7 tonnes in larger vessels.

ECONOMICS

The price per kilo to fisherman (during September 1990 in US$) is given in Table 5, for the various target species. As already noted, *P. muelleri* is the most valuable species.

In the local market the price of fish approaches the price of mutton and beef (beef is not produced in the area). This market situation, along with the problems of inflation and instability, serve to lead to the depletion of stocks of the target species.

MARKETS

The markets at Puerto Madryn and Puerto Deseado mainly deal with fish for export whereas those at Rawson, Caleta Córdova and Comodoro Rivadavia are mainly domestic. Fish is processed fresh, frozen and canned at Puerto Madryn, fresh at Rawson and fresh and frozen at Comodoro Rivadavia. Four freezing or canning processors operate at Puerto Madryn and eight more at Puerto Deseado; all use fish obtained locally. Another plant, at Caleta Córdova, uses fresh fish from Comodoro Rivadavia.

HISTORY AND DEVELOPMENT OF FISHERY AND CURRENT TRENDS

Although coastal fishing at Rawson and Caleta Córdova using small wooden vessels was recorded 80 years ago, in 1964 Patagonia was still considered to be 'unexploited' (Richardson, 1964). The shrimp fishery developed rapidly after 1980, with new and larger vessels (freezing and factory ships) appearing. This increasing trend continues. Three new, technically advanced vessels are to be added to the Puerto Madryn fleet, where only two factory ships are operating today. Most of the catch is exported to Spain, Japan and Italy (especially from Puerto Deseado) with lesser quantities going to the Netherlands, Germany, Greece, Hong Kong, South Africa, and some to the USA, Puerto Rico, Iran, Israel and Singapore. Local markets consume only a small proportion of the overall catch of all species.

EFFORT DATA

An estimated 130 vessels are licensed by the Chubut Fishery Agency. This does not include 'legal' vessels from other provinces. Additionally, probably more than 200 foreign vessels operate near the border of the EEZ. Information on duration and number of trips is given under 'OPERATIONS' above.

INTERACTIONS WITH MARINE MAMMALS

Entanglements of the following marine mammal species have been reported: dusky, Peale's (*Lagenorhynchus australis*), Commerson's and common dolphins, southern sea lions and probably also spectacled porpoises. Long-finned pilot whales, *G. melas*, are reported to be seen by the fishermen, but the species has not been reported caught. Dolphins and sea lions have been seen coming into and out of the mouth of the net catching fish. It would seem that the animals die when the net is retrieved and are thrown away or (if requested) are returned to port. A superstition exists regarding dolphin deaths and there is no apparent use of the cetacean bycatch.

Evaluation of marine mammal mortality rates is difficult. Many fishermen informed us that no dolphins are caught, although others say the opposite. There is some information from a few boats but it is not sufficient to estimate annual mortality. One fishing vessel brings one or two dolphins for biological research every trip; out of 10 dolphins recovered in less than one year, there were eight dusky dolphins, one common dolphin and one Commerson's dolphin. One ship at Puerto Deseado (belonging to a Japanese/Argentine Company) caught five dolphins (unknown species) in only one trawl. Information from another fisherman suggested an average catch of one dolphin per 45 days for his vessel.

Although the limited information suggests that catch rates per trip appear to be low, absolute numbers caught

Table 5

Type of vessels operating at Puerto Deseado

Type of vessels	Length (m)	HP	Fish cap (kg)	Process	No. of trips	No. of vessels
Distant coastal	25-32	500-800	50,000	Fresh	8-12	10
Offshore ships	32-50	1,000-1,500	95,000	Frozen	15-25	7
Freezing ships	50-70	1,500-2,700	180,000	Frozen	25-35	12
Freezing ships	70-80	1,500-2,700	180,000	Frozen	45-55	4
Factory ships	80-110	3,500-4,000	900,000	Processed	70-80	5

Table 6

Price of fish landed in port and the local market (in US dollars)

	Price to fishermen in port (kg)	Price in local market (kg)
Merluza (*Merluccius*)	0.14	2.00
Salmon (*Pinguipes*)	0.45	2.33
Mero (*Acanthistius*)	0.36	
Abadejo (*Genypterus*)	0.53	2.33
Langostino (*Pleoticus*)	1.35	8.33
Calamar (*Illex*)	0.54	2.33
Calamarete (*Loligo*)	2.17	
Lenguado (*Paralichthys*)	0.83	
Anchoita (*Engraulis*)	0.07	1.66

may be high given the level of fishing effort in the region. No effort has been made to reduce the cetacean bycatch.

Interactions with southern sea lions have been recorded but seem to be rare and mortality rates are not known.

DISCUSSION (AREA II: NORTH AND CENTRAL PATAGONIA)

The study of fishery/marine mammal interactions in this region began during 1989 and investigation of the age, reproductive status, stomach contents and parasites of incidentally caught animals (mainly dusky dolphins) is in progress. There are no gillnet fishing operations from Viedma and San Antonio Oeste in the San Matías Gulf to Puerto Deseado Harbour, south to San Jorge Gulf (Fig. 8). The fishing industry in the area uses mid-water and bottom trawls. Although, in general, trawls are not as dangerous for dolphins as gillnets, the magnitude of the effort may pose a threat to certain populations; and it appears that the fishing effort will continue to increase, even though fishermen believe the fish resources in the area are being depleted.

Studies so far have identified the species affected by the fishery. We recommend, as for other areas, that projects be initiated to obtain good estimates of dolphin mortality and the stock identity and population size of the affected species. In this regard, illegal fishing is a major uncontrolled variable. Despite the existence of protected areas there is a lack of official control of fishing: the total number of ships operating is unknown and vessels fish in forbidden areas. Companies put pressure on fishermen to catch only shrimp and to disregard protected areas or closed seasons. The Coast Guard finds it difficult to control these activities. In addition, foreign ships (from Spain, Korea, Japan and China, Taiwan, etc.) not only fish on the border of the 200 n.miles EEZ of Argentina, but also fish illegally inside it, as the profit to be made is far larger than the risk of being captured by the authorities.

Area III. South of Patagonia (Santa Cruz Province) (Fig. 9)

The Province of Santa Cruz (46°S to 52°20′S) has some 1,000km of coastline. It is sparsely populated, with few large towns. In the southern part of the province, fishing takes place sporadically during the summer months with fixed gillnets set in the tidal zone, perpendicular to shore. Coastal fishing with gillnets set from small boats is common in the northern part of the province and in rivers such as the Río Gallegos. Gillnets operate south of Puerto Deseado, mainly for *róbalo* (*Eleginops maclovinus*). The fleet operating at Puerto Deseado is similar to that for Area II (Chubut Province) in terms of gear, operation, fishing grounds and fishing vessels.

Goodall and Cameron (1980) reported some catches of Commerson's dolphins in gillnets in this region. During brief coastal surveys in 1983 and 1986, 31 Commerson's dolphins were found taken in nets at Bahía Laura, San Julián, Bahía Media Luna, Angelina and Cabo Buen Tiempo. Recovered carcases of Peale's dolphins and spectacled porpoises found during those surveys are also suspected to have come from net fisheries (Goodall *et al.*, 1990).

Small numbers of vessels operate from the ports of Santa Cruz and San Julián, working over the continental shelf with mid-water or bottom trawls, mainly for shrimp, pink cusk-eel (*abadejo*) and hake.

In some of these fisheries, especially mid-water trawling for *abadejo*, some cetaceans (Commerson's and Peale's dolphins) have been taken incidentally (Goodall *et al.*, 1990).

Monitoring for incidental catch in this province has begun only recently and data are far from complete. As yet there is no systematic study of incidental captures and almost no information on either the fisheries themselves or levels of marine mammal mortality. We recommend that a project be established to: (1) describe the gear used; (2) estimate levels of fishing effort and; (3) establish the systematic recording of incidental catches.

Area IV. Tierra del Fuego (Fig. 9)

There are three major fisheries off Tierra del Fuego (52°35′S to 55°10′S): coastal fishing with gillnets, mainly in the northern part of the island; trap fishing for king crabs *centolla* (*Lithodes antarcticus*) in the Beagle Channel; and offshore fishing with trawlers north of Tierra del Fuego (Goodall *et al.*, 1994).

Coastal fisheries use three types of nets: (a) gillnets 25–100m in length with a mesh of 10–14cm for *róbalo*, hake (*M. australis*) and trout (although fishing for trout (*Salmo salar* an introduced species for farming) with nets is illegal); (b) finer-meshed (3cm) gillnets for *pejerrey* (silversides) and small *róbalo*; and (c) three-walled trammel nets for all the above species (Goodall *et al.*, 1994).

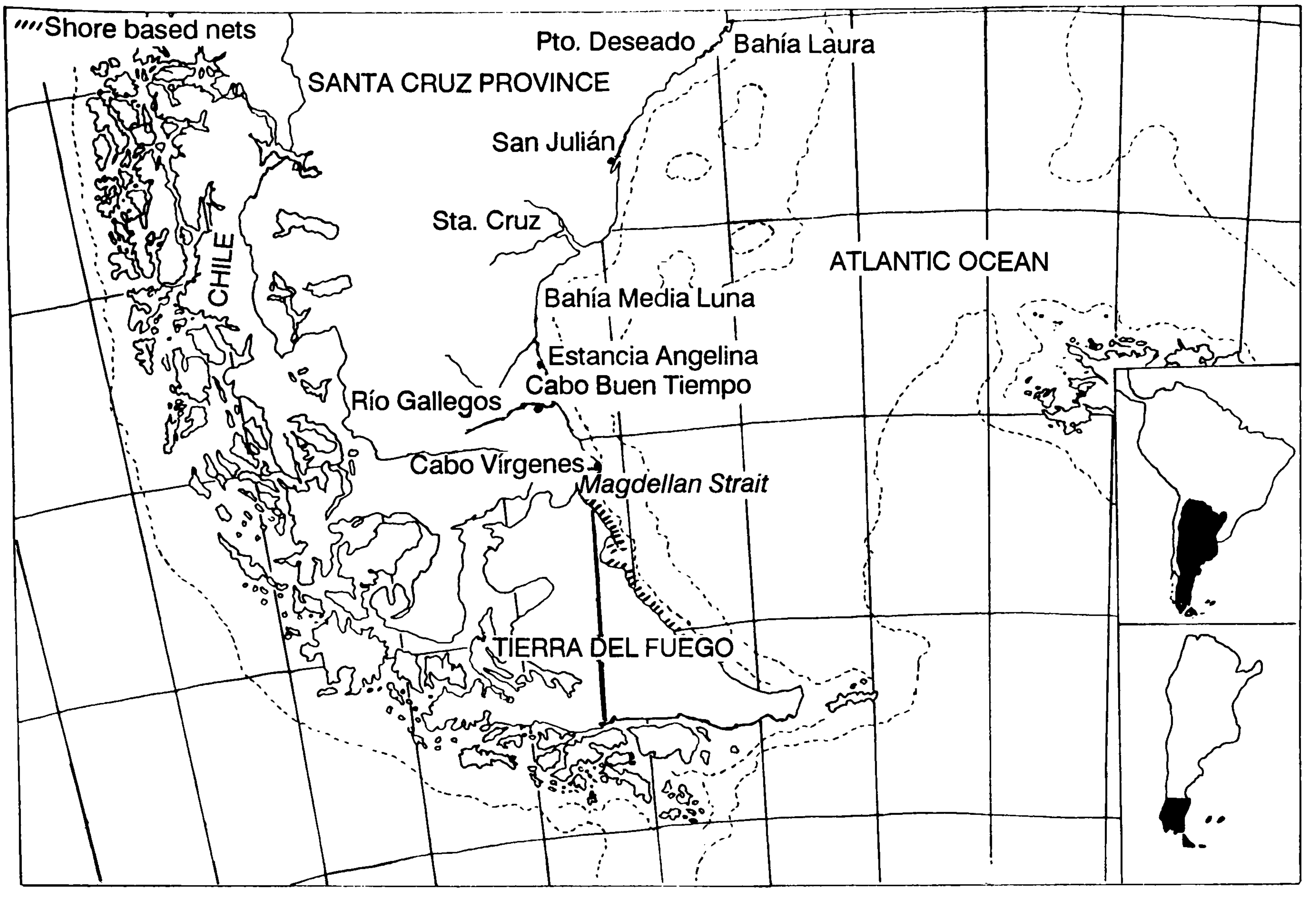

Fig. 9. Fisheries and fishing areas of southern Patagonia and Tierra del Fuego.

The nets are set perpendicular to the coast on stakes fixed in the tidal zone. They lie exposed at low tide and are lifted by the sea at high tide. Occasionally small boats are used, especially near river mouths, either with one end of the net held on shore or with two boats.

Coastal fishing takes place between October and April, with that for silverside extending into the austral winter.

The reported small cetacean species incidentally taken by this fishery during the last 15 years are, in decreasing order of importance: Commerson's dolphins, spectacled porpoise, Peale's dolphins and Burmeister's porpoise. Cetaceans are not trapped in the finer-meshed silverside nets, but they are trapped in nets for *róbalo*. Pinnipeds are taken occasionally, but usually break through the nets. Coastal fishing has recently increased due to the economic situation of the country (Goodall *et al.*, 1994).

In the past it has been reported (e.g. Goodall and Cameron, 1980) that marine mammals were caught for use as bait in the trap fishery for *centolla*, *Lithodes antarcticus* (southern king crab). This fishery has declined in recent years and now only two companies with three boats (some 1,500 traps) are working at present on the north coast of the Beagle Channel, although there is some clandestine crabbing. Cetaceans are not caught in the crab traps themselves. The use of marine mammals as bait is probably higher in the Chilean section of Tierra del Fuego, where *centolla* fishing is much more extensive.

Offshore fishing is increasing; four foreign ships operating with Argentine permission and with mixed crews are based in Ushuaia at present. These fish with trawl nets on the continental shelf off Patagonia, usually north of Tierra del Fuego, mainly for squid, octopus, hake and pink cusk-eel, southern blue whiting *Micromesistius australis*, producing tinned caviar and frozen fish. There is no recorded information on possible cetacean mortality in this fishery, but if the situation is similar to that in the north of Patagonia (Chubut Province) it is probable that a small take of dolphins exists.

DISCUSSION (TIERRA DEL FUEGO ISLAND)

The situation on the northeast coast of the island is similar to that in southern Patagonia, in part due to the use of gillnets for *róbalo*. Therefore, the same considerations should be addressed and the systematic recording of the same data recommended above for Area III is strongly recommended.

An overall review of the *centolla* fishery is required that should include the possibility of developing substitutes for the bait and obtaining information on the abundance of the affected marine mammal populations.

SUMMARY AND CONCLUSIONS

Gillnet interactions along the coast

The study of incidental mortality in gillnets started in the mid 1980s in many areas of Argentina and this work should be encouraged. Fishermen's distrust of researchers, an important factor of bias in obtaining mortality estimates, is more likely to be removed if the same researchers work at the same locality for several years. This continuity may be much more valuable than a single, expensive, short-term research effort.

Abundance estimates of affected cetacean species are essential if one is to evaluate the impact of gillnet mortality. This is true for both the franciscana and the

Burmeister's porpoise in Necochea, even if the latter appears to be less affected by gillnet mortality. The possibility that an off-shore shift of the fishing effort may change the species composition of the bycatch requires attention and the location of fishing effort should be monitored.

Studies of the bycatch similar to those being undertaken at Necochea-Claromecó should be encouraged for other areas. Stock identity is an important factor and genetic and other studies should be carried out using samples from southern Brazil, Uruguay and Samborombón Bay, Necochea and Bahía Blanca in Argentina. Pollution and parasitism studies are under way at Necochea and should be enhanced to cover the ability of franciscana and other dolphins to cope with mortality and/or potential reproductive failure. Pollutant analysis of franciscana caught in the Bahía Blanca estuary is required, given the intensive petrochemical industry in this area.

Gillnets are also used in southern Argentina, from Puerto Deseado to the northeast coast of Tierra del Fuego. The lack of information requires the establishment of a project to: (1) complete descriptions of the fisheries operations and the gear used; (2) begin systematic monitoring of mortality rates of marine mammals; and (3) estimate the abundance and stock identity of the species affected.

Purse seining, trawling and other gear

In Necochea, the area most closely examined to date, purse seining appears to affect mainly dusky dolphins. Other fisheries in the Buenos Aires Province should be examined to see if similar situations exist elsewhere. Once more the impact on populations cannot be assessed without knowledge of stock identity and good estimates of mortality and abundance.

Mid-water and bottom trawling operations do not seem to pose a threat to the small cetacean populations in Buenos Aires Province. Nevertheless, given that it is the most important gear along the coast of Patagonia (from San Antonio Oeste to Puerto Deseado) and that fishing effort is large and increasing (no less than 130 legal ships operate in a yet poorly defined fishing area), even a small number of catches per trawl may result in a large absolute number of dolphins deaths. Studies on the age, reproductive status and stomach contents of incidentally caught animals in the area are underway and should be encouraged. However, the most important needs are to obtain good estimates of mortality and abundance in conjunction with information on stock identity.

Pollution studies do not seem to be a priority for the area in the short term unless special cases are considered, such as Golfo Nuevo where industrial development is increasing. Nevertheless, oil and gas exploration and exploitation has just started along the continental platform of the country.

Marine mammals as crab bait in the Beagle Channel

Fishermen have used marine mammals as crab bait in the extreme south of the country for many years. This may have affected dolphin, fur seal and sea lion populations. Recent information suggests that these activities are decreasing at least on the Argentine side of the Channel, but catch data are lacking. In addition to the review of the crab fishery recommended above, a regional collaborative research program should be developed given the greater fishing effort in Chilean waters.

Other factors to be considered in addressing problems of incidental captures

One important obstacle to successfully addressing incidental catch problems is the lack of fisheries control by government agencies even if adequate regulations are adopted.

Inflation and economic and political instability are important variables in the use and management of resources in less developed countries. Fishermen themselves recognise that these factors lead to an undesirable depletion of fish stocks and many have declared their concern about depletion of the fish populations. An important factor here is that if the fishing companies are interested in short-term rather than long sustainable profit and thus deplete target species, how can we expect them to worry about marine mammals to whom the fishing effort is not directed? Before conserving dolphins, the fishermen must be interested in conserving the target species at sustainable levels of exploitation, in order to preserve their source of income. Only in an economically stable system will there be an acceptable basis to adjust fisheries to reduce the marine mammal catch. One aspect of this might be to achieve a more equitable ratio in the price of fish paid to fishermen and the price of fish in the market.

There are also social and cultural aspects to the problem. Many fishermen live in poor conditions, far from the large profit of large fishing companies. This kind of fisherman can be found along the coast of Uruguay and many places in Buenos Aires Province where gillnets are used. Market conditions should be studied along with the mortality of dolphin species in order to find ways to preserve the way of life of the fishermen while reducing the catch of cetaceans.

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Interactions Between Marine Mammals and the Coastal Fisheries of Necochea and Claromecó (Buenos Aires Province, Argentina)

Javier Corcuera

Museo Argentino de Ciencias Naturales 'B. Rivadavia' (MACN)-CONICET and Estación Hidrobiológica de Puerto Quequén, Av. A. Gallardo 470, 1405 Buenos Aires, Argentina

Florencia Monzon

MACN and Estación Hidrobiológica de Puerto Quequén, Buenos Aires, Argentina

Enrique A. Crespo

Centro Nacional Patagónico-CONICET, Blvd. Brown s/n, 9120 Puerto Madryn, Chubut, Argentina

Alex Aguilar

Depto. de Biología Animal (Vertebrats), Universitat de Barcelona, 08071 Barcelona, Spain

J. Antonio Raga

Depto. de Biología Animal (Zoología), Universidad de Valencia, Burjasot 46100 Valencia, Spain

ABSTRACT

Coastal and pelagic fishing activities in the area of Necochea harbour, where high mortality of franciscanas (*Pontoporia blainvillei*) in gillnets had been previously reported, and at Claromecó, a small gillnet fishing camp, were monitored in 1988–90 and 1989–90 respectively. Necochea has three main types of fishing operations: gillnetting (target species: sharks), purse-seining (target species: anchovy and mackerel) and trawling. In Claromecó, only gillnets are used. Gillnet and purse-seine operations cause dolphin mortality. Gillnet fishing effort has increased in Necochea since 1984. In Claromecó, the fishing effort also seems to be increasing. The estimated number of cetaceans killed by gillnets at both localities varied between 50.9 to 68 individuals per year (lower 95% CI 32.7-45.1; upper 95% CI 67.5–125.1). The main species affected are franciscanas (76.5%), Burmeister's porpoises, *Phocoena spinipinnis* (18.7%), dusky dolphins, *Lagenorhynchus obscurus* (2.2%) and common dolphins, *Delphinus delphis* (2.6%). Although the gillnet fishing effort in Claromecó is smaller, 75.4% of the 1989 and 94.9% of the 1990 estimated franciscana captures were in this locality. This may be because in Claromecó gillnets are set at lower depths and shorter distances from the coast, where franciscanas appear to be more common. Thus fishing from several similar small fishing camps, located all along the coast of Buenos Aires Province, might be more dangerous to the franciscana population than vessels from larger harbours. Mortality of dusky and common dolphins in the purse-seine fishery was also observed. The kill due to this fishery in the Necochea area is estimated at 68–102 individuals in 1989 and 5 in 1990.

KEYWORDS: SOUTH ATLANTIC; INCIDENTAL CAPTURE; FRANCISCANAS; BURMEISTER'S PORPOISE; DUSKY DOLPHIN; COMMON DOLPHIN

INTRODUCTION

Interactions between franciscanas (*Pontoporia blainvillei*) and gillnets set in the area of Necochea have been reported by Pérez Macri and Crespo (1989). Necochea harbour is the base for one of the largest gillnet fisheries of the western South Atlantic. From information provided by fishermen, those authors estimated that the potential annual mortality of franciscanas in the area could be around 260 individuals. Other small cetacean species known to be abundant in the region (Goodall and Cameron, 1980) may also be subject to incidental mortality.

Given the potential magnitude of the conflict in Necochea, a survey to ascertain the nature of these interactions was begun in 1988 (Monzon *et al.*, 1990). Studies on the age, reproductive status, physical maturity and nutrition of incidentally caught animals, and on other biological factors (e.g. pollutants and parasites) that might affect mortality or reproduction of cetaceans, began at the same time. This paper covers the period up to the end of 1990. Later developments are discussed in Corcuera (1994).

Purse-seine vessels also operate out of Necochea. A brief summary of the available information on interactions with marine mammals and this fishery is given in Appendix 1.

MATERIALS AND METHODS

Necochea

Fishing activities were monitored in Necochea (38°37'S, 58°50'W) during 1988 (22 September-17 October), 1989 (29 October-25 December) and 1990 (1–12 January; 14 October-25 December). Collected data included number of boats operating per day, type of fishing operation and fishing grounds (Fig. 1), type and length of nets employed, distance to the coast and number and species of dolphins caught. One of us (JC) interviewed five captains of fishing vessels in 1989 and twelve in 1990. Data on cetacean mortality, fisheries economics, fishing effort and related subjects were recorded. The same person also went out occasionally with the fishermen during fishing operations. We monitored 7 of the 17 gillnet boats in 1988 (41%), 17 out of 21 in 1989 (81%) and all 21 in 1990. For each dolphin caught, fishermen were asked to provide data on location, water depth and distance to the coast and, whenever possible, to bring the dolphins back to port. Since 29 November 1989, a small fee (US$10) was paid to cover the transportation and handling costs of each dolphin. From the obtained specimens, morphometric and life history data were collected together with samples for studies on parasites, pollutants, nutrition and feeding.

Claromecó

While working in 1989 in Necochea, we learned of incidental mortality of dolphins in Claromecó (38°52'S, 60°05'W), a small fishing camp about 140km away. Monitoring of the three to five boats that operated there was carried out from 9 December 1989 to 12 January 1990 and from 14 October to 20 December 1990. A US$15 retrieval fee was paid for each dolphin from this fishery brought to Necochea.

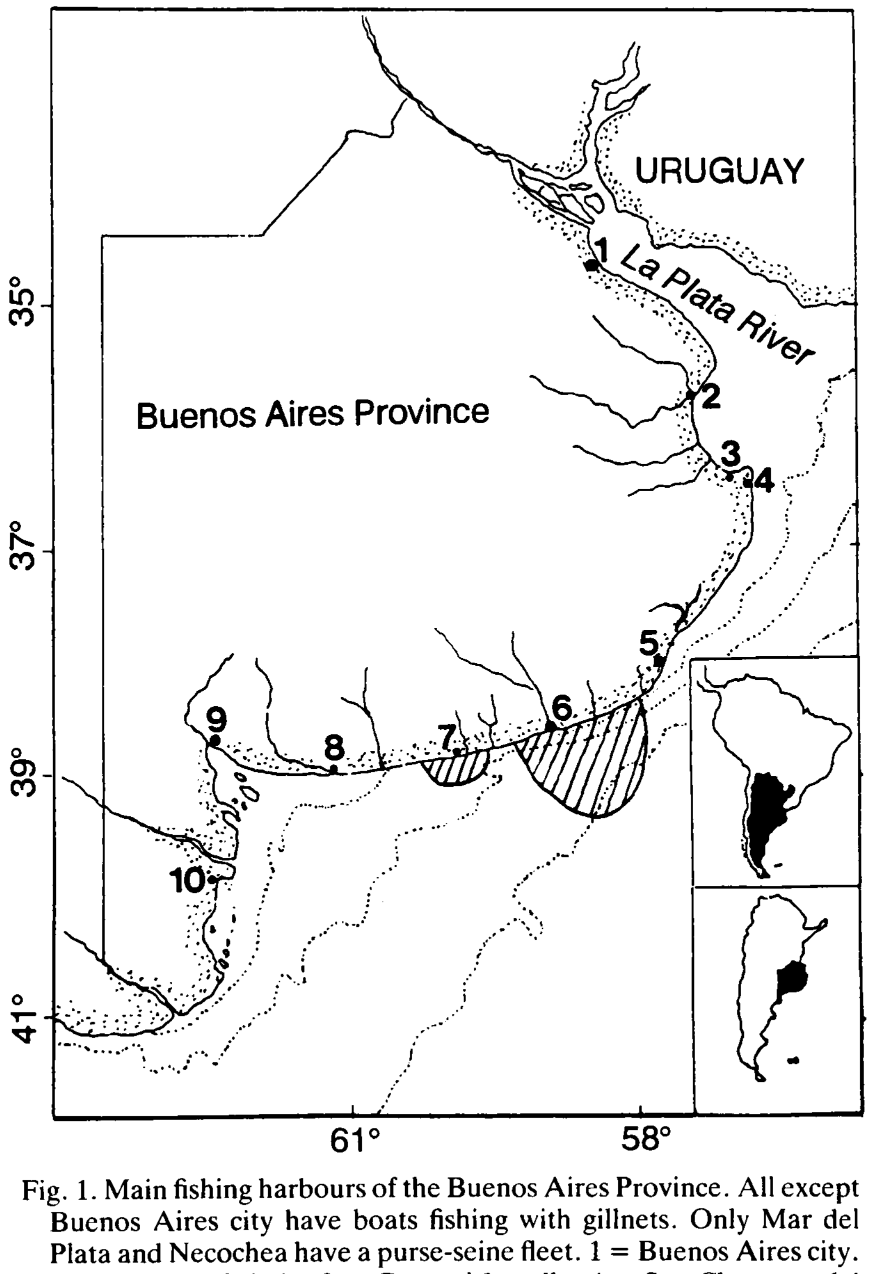

Fig. 1. Main fishing harbours of the Buenos Aires Province. All except Buenos Aires city have boats fishing with gillnets. Only Mar del Plata and Necochea have a purse-seine fleet. 1 = Buenos Aires city. 2 = Boca del Salado. 3 = General Lavalle. 4 = San Clemente del Tuyú. 5 = Mar del Plata. 6 = Necochea-Puerto Quequén. 7 = Claromecó. 8 = Monte Hermoso. 9 = Bahía Blanca (Ing. White). 10 = Riacho Azul. The 20, 35 and 60m isobaths are shown. Hatched areas indicate primary regions of shark gillnet fisheries.

Annual mortality estimation

Mean annual mortality estimates by species caught were obtained for the years 1988–1990. In order to estimate the annual catches it was assumed that mortality is constant throughout the whole fishing season and that the fishing season lasted 70 days. The previous mortality estimate of Perez Macri and Crespo (1989) for 1984 was recalculated using these assumptions. In order to compare annual mortalities we estimated 95% confidence intervals (CI) of each estimate using a Poisson model which assumes that entanglement events occur randomly in time. This model, that of Pearson and Hartley (1976) as described by Zar (1984), is consistent with the occasional observation of dolphins being caught as pairs in the same net.

$$\text{Upper CI} = \frac{\chi^2(0.025,\ 2\ (c+1))}{2}$$

$$\text{Lower CI} = \frac{\chi^2(0.975,\ 2c)}{2}$$

where c = observed captures

Because the recorded data on cetacean captures were obtained from partial surveys (a variable proportion of the operating boats were monitored during a variable proportion of the fishing season), we adjusted each mean and its CI to account for both the number of boats and fishing season days not monitored as a straight proportional correction.

Catch per unit effort (CPUE) values by year, species and locality were calculated using the estimated annual mortalities. Confidence limits for each CPUE were obtained by dividing the confidence limits of the mortality estimates by the fishing effort recorded for the respective year and locality.

Age determination of the franciscana sample

Teeth of each available specimen were cleaned and immediately preserved in a 10% buffered formalin solution. Two complete teeth from each franciscana were then decalcified with 5% formic acid for 2–12 hours. Longitudinal sections of 18–30μm thick were obtained using a freezing microtome. The sections were stained with Hematoxilin and then dehydrated and mounted. Annual growth layer groups (GLGs) as defined in IWC (1980) were counted under transmitted light with a 50cm screen microprojector (30x) and a compound microscope (120x) and analysed following Kasuya and Brownell (1979). Three investigators (JC, FM and EAC) independently counted GLGs in tooth sections from each specimen. The 'determined' age was the majority opinion of these readers. If all three disagreed, biological data of the specimen were taken into account to reach consensus on the age. As the parturition of franciscanas in the Necochea area seems to occur around mid-November to mid-December (Corcuera et al., 1990), ages were estimated as fractions of years relative to these months.

RESULTS

Three major types of fishing activities are carried out in the Necochea area: bottom trawling, purse-seining and gillnetting with bottom set nylon monofilament gillnets. *Nasas* (traps, fishing baskets) are also used, but only sporadically and by few boats. In Necochea the boats use different gear according to the species harvested and the season; in Claromecó only gillnets are employed.

Two types of fishing activities produce dolphin mortality: purse-seining (target species: anchovies, *Engraulis anchoita* and mackerel, *Scomber japonicus*) and gillnets set for sharks (the houndsharks, *Galeorhinus* *galeus* and *Mustelus spp.*, the sandtiger shark, *Eugomphodus taurus* and the Argentine angel shark, *Squatina argentina*).

General description of the gillnet fishery

Panels are set together in pieces called *postas*, each carrying 5–10 panels. In Necochea, a mean *posta* has 547.8m (range = 394–727m) of almost continuous (space intervals = 5–10m) gillnet with a mesh size of 18-21cm, or for the sandtiger and other large shark species, 28cm. Although the panel length and the number of panels per *posta* used in Claromecó do not differ significantly from those in Necochea, the number of *postas* set is smaller. A mean of seven *postas* (range = 4–9) are used by Necochea vessels, while a mean of two (range = 1–3) *postas* are set in Claromecó. Necochea's boats are larger and have a greater cruising radius, and usually set more nets.

Field observations indicate that up until 1989, a mean gillnet panel was 66m long, whereas one made in 1990 was 70–100m. The mean depth of gillnets has also increased with time. Gillnets made *ca* 1980–85 were, according to fishermen, 2.2m deep. In 1989 they were 3.8m deep while 1990-made gillnets had a depth of 4.6m. However, the underwater gillnet depth is less (around 40% of the dry depth), because the perpendicular coastal currents tend to deform the vertical gillnet into a semi-tubular shape.

Fishermen examine the gillnets each day or every other day, depending on the size of the last catch and weather conditions. The operation begins early in the morning, when they locate their *postas* visually. The ends of each posta are marked with canes that carry pieces of colored cloth called *banderas* (flags), kept straight by means of buoys and weights. The gillnet is then hauled on board by hand, with the help of a rotating cylinder system powered by the vessel's motor. The whole trip takes 6–12 hours. If the catches have not been satisfactory, the net location is changed.

The gillnet fishing season lasts from September to December (around Christmas) in both localities. The estimated mean length of an active gillnet fishing season is 70 days (from September to December) with a mean of 17.5 active days per month.

Gillnet fishing effort

The gillnet fishing ground around Necochea covers about 4,800km^2 (Fig. 1). Direct observations and interviews with fishermen indicate that gillnet location has changed in recent years. While most of the nets were set in shallow waters close to the coast in 1988 (approx. range = 1–10 n.miles), an offshore shift occurred in 1989, when gillnets were set at a mean distance of 7.6 n.miles (SD = 6.3, range 1–19 n.miles) from the coast at a mean depth of 38.5m (SD = 14.6, range = 18–57m). This trend continued in 1990 (approx. range = 8–25 n.miles).

In Claromecó, only three to five (usually four) boats operate. Gillnets are set 1.6 n.miles (SD = 0.4, range 0.2–2.2 n.miles) from the coast at a mean fishing depth of 21.6m (SD = 6.6, range = 4–35m). The fishing ground in Claromecó waters only covers around 200 km^2 (Fig. 1).

Gillnet fishing effort by year is shown in Table 1. The higher mean net-length per boat for Necochea is due to the fact that the boats are larger and carry more *postas*. The mean net-length per boat for both Necochea and Claromecó has not changed significantly between 1984 and 1990 but the mean obtained for 1988–89 may be an overestimate due to the extrapolation from the smaller sample size.

Cetacean mortality

Gillnet incidental mortality in the study area affects mainly the franciscana dolphin (76.5% of the estimated mortality), but the Burmeister's porpoise, *Phocoena spinipinnis*, is also involved (18.7%). Catches of common dolphins, *Delphinus delphis* (2.6%), dusky dolphins, *Lagenorhynchus obscurus* (2.2%) and other species (e.g. killer whales, *Orcinus orca*) seem to be only sporadic. According to fishermen, dolphins get entangled in any part of the net.

The total number of dolphins retrieved from gillnets and brought back to both localities was 8 in 1988, 23 in 1989 and 28 in 1990; the *minimum known catch* (number of dolphins brought back to port + verified number of dolphins thrown overboard) was 10 in 1988, 31 in 1989 and 48 in 1990. However, in 1988 and 1989 the number of monitored boats was less than the total operating with gillnets. If the minimum known catches are corrected for this, the estimated minimum catches are 24.3 for 1988 and 38.3 for 1989. The total estimated minimum is thus 110 small cetaceans for those three years of which 59 (54%) were retrieved.

Table 2 shows the mortality estimates by species and locality for 1984 and 1988–90. Pérez Macri and Crespo (1989) estimated a mortality of 260 franciscanas for 1984; our estimate of 303.3 is different only because we assume a longer fishing season (70 days instead of 60). The 1984 estimate may be upwardly biased because the only one of the five vessels recorded as actively fishing with gillnets monitored was a small boat that might have operated in a similar manner to the Claromecó boats (see below). The proportion of the small vessels that operated during 1984 is unknown. The franciscana was the only species monitored in 1984 and 1988 and so there are no mortality estimates for Burmeister's porpoise and delphinids in those years.

Table 1

Gillnet fishing effort by day and locality. Necochea's data for 1984 is obtained from Pérez Nacri and Crespo (1989). Net-meters/boat assigned to Necochea in 1988 (*) are assumed the same as 1989.

	Mean net-meters/boat		No. of boats		Total net-meters	
	Necochea	Claromecó	Necochea	Claromecó	Necochea	Claromecó
1984	3350.0	?	5	?	16750	?
1988	3811.5*	?	17	3-5	64796	?
1989	3811.5	1089.0	21	4	80042	4356
1990	3088.3	2275.0	21	4	64854	9100

* Because the data for 1988 were scarce, the mean value obtained for 1989 was used.

Table 2

Mean estimated mortality and Poisson 95% confidence limits of the small cetaceans caught by gillnets in the Necochea area (1984-1990). Data of 1984 mortality recalculated from Pérez Macri and Crespo (1989). PBLA = *P. blainvillei*, PSPI = *P. spinipinnis*, DDEL = *D. delphis* and LOBS = *L. obscurus*. ND = No data available.

Year		Necochea				Claromecó				All areas and species
		PBLA	PSPI	DDEL	LOBS	PBLA	PSPI	DDEL	LOBS	
1984	Estimated mortality	303.3	ND	ND	ND	ND	ND	ND	ND	303.3
	Upper 85% CL	444.5								444.5
	Lower 95% CL	198.1							198.1	
1988	Estimated mortality	88.0	ND	ND	ND	ND	ND	ND	ND	88.0
	Upper 95% CL	125.1								125.1
	Lower 95% CL	32.7								32.7
1989	Estimated mortality	11.9	13.4	0	1.5	36.5	0	3.0	0	66.4
	Upper 95% CL	23.5	25.5	-	8.3	63.8	-	17.0	-	94.2
	Lower 95% CL	5.1	8.1	-	0.04	18.9	-	0.08	45.1	
1990	Estimated mortality	2.1	7.4	0	1.1	39.2	1.1	0	0	50.9
	Upper 95% CL	7.7	15.3	-	5.9	54.1	5.9	-	-	67.5
	Lower 95% CL	0.3	3.0	-	0.03	27.6	0.03	-	-	37.6

Incidental catch positions

Fig. 3 shows the depths at which gillnets were set that entangled small cetaceans between 1988 and 1990. Reliable catch locations were available for 53 dolphins retrieved from fishermen. Most (47.5%) franciscanas were killed at depths between 2–10m, with an estimated 95% caught between 2–40m, suggesting that this depth interval is the preferred habitat for franciscanas (the 35m isobath is shown in Fig. 1). Burmeister's porpoises were caught at greater depths (range = 30–60m). The two dusky dolphins were caught at depths of 50–60m.

Fig. 4 shows the distance offshore that incidental captures were made. Almost all (87.8%) franciscana entanglements occurred between 0.2 and 5 n.miles of the coast. The equivalent values for Burmeister's porpoise were 0–25 n.miles. The two entanglements of dusky dolphins were between 15–20 n.miles offshore, where they appear to be frequently seen by purse-seine fishermen.

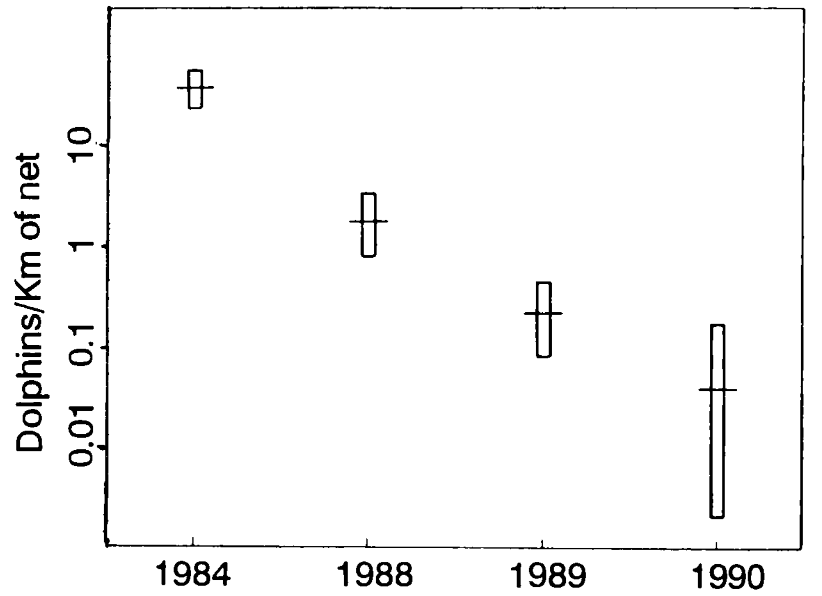

Fig. 2. Mean and 95% CI CPUE for franciscanas in Necochea gillnets (1984–1990). The estimate for 1984 is based on data in Pérez Macri and Crespo (1989). The Y axis is a logarithmic scale.

Biological data on the incidental catch

The sex and standard length of 47 individuals collected during the 1988–90 study were recorded (a female caught in 1986 is included) and the length distributions are given in Fig. 5.

Age data for 42 franciscanas (28 males and 14 females) are presented in Table 4 and Fig. 6. The maximum age recorded in our sample is 8–9 years for a 133.5cm male; the large (167cm) female caught in 1986 was not aged. The modes of the age-group frequencies are 0–2 years and 3–7 years for males and about 0–3 years and 6–7 years for females. The 0 to 1 age-group of both sexes seems to be over-represented. All the animals of this age-group were about to complete their first GLG. No newborns have been found in gillnets since the sampling started.

The sex ratio of the total sample of franciscanas caught is 1.61 males/female. The proportion of females is greater at body lengths >145cm, but males are more abundant in nearly all the smaller length groups.

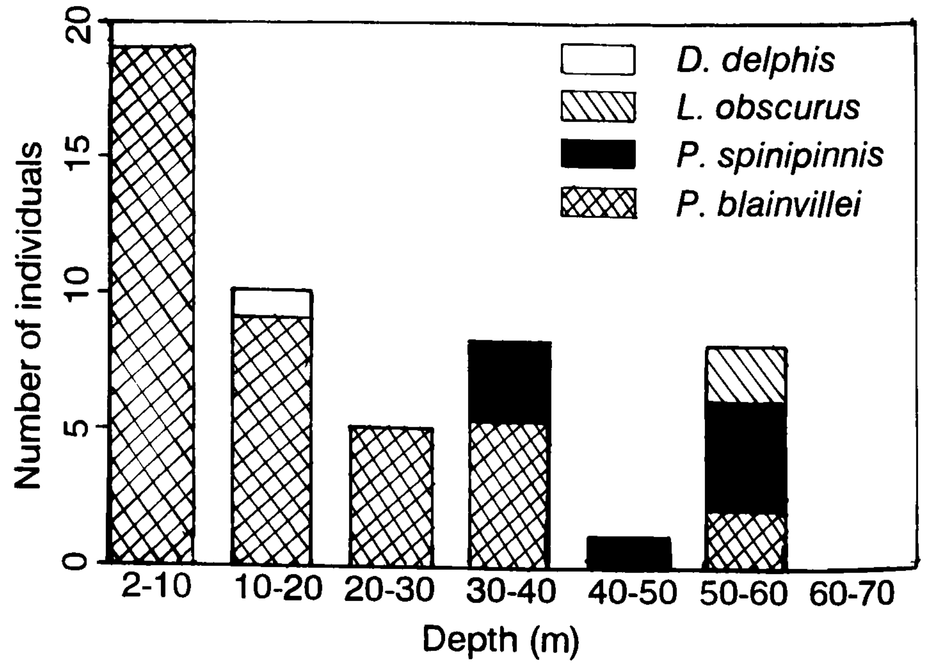

Fig. 3. Small cetacean (absolute) by-catches by depth in Necochea and Claromecó (1988–1990).

DISCUSSION

Distribution of the fleet

The fishermen say the offshore movement of gillnetting operations from Necochea is because the target sharks have now moved further away from the coast. A similar

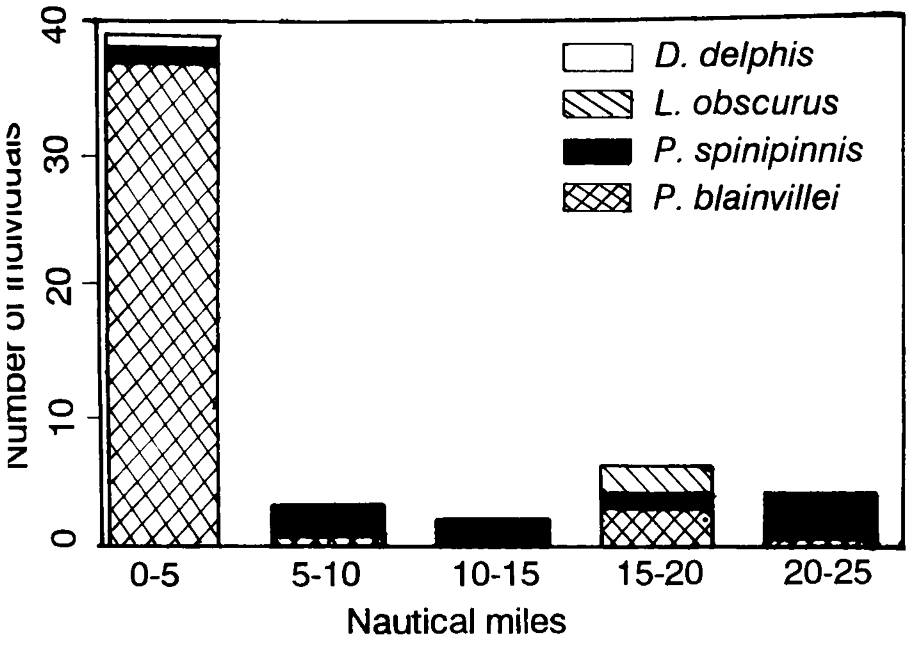

Fig. 4. Small cetacean (absolute) by-catches by distance from the coast in Necochea and Claromecó (1988–1990).

phenomenon and explanation has been described by Brownell (1981) for the Uruguayan gillnet fishery. Of course, an alternative explanation might be that inshore stocks of sharks have been overexploited but no data exist to confirm or deny this. In Necochea the high potential cruising radius of the boats suggests that fishing effort will not decrease for logistic reasons as it did in Uruguay. Fishing effort here will depend primarily on the shark market and the size of the catch.

Fishing effort

The increasing number of boats operating with gillnets in Necochea has resulted in an increase in total net-length fishing effort from around 17,000 to 65,000–80,000m used per year (Table 1). In addition, several boats are being constructed in Necochea at present. It is clear that gillnet fishing effort is growing in Necochea, whereas it has remained reasonably stable in Claramecó since the 1980s at between 5% and 14% (mean 10.8%) of that of Necochea.

Cetacean mortality

The absolute number of deaths of franciscanas for the Necochea fleet and the CPUE have decreased considerably in recent years (Table 3 and Fig. 2); this can be explained by the movement of the fleet to more off-shore grounds, away from the preferred habitat of the franciscana.

The estimated franciscana CPUE is considerably higher in Claramecó, with about 75% of the 1989 and 95% of the 1990 estimated captures in this locality. This is because the boats operating from Claromecó are smaller and have a shorter cruising radius, so they set their nets mostly within the 0–5 n.miles range, where franciscanas are more abundant (as shown by the analysis of the overall gillnet catch, Figs 3 and 4). The high CPUE value in Claromecó emphasizes the potential importance of small scale, inshore fishing along the coast of Buenos Aires province in causing franciscana mortality. The impact of other such fishing camps (some of them shown in Fig. 1) may be considerable. It should also be noted that in Claromecó, where more nets were used in 1990, the franciscana CPUE also decreased from 1989 to 1990, although the absolute number of deaths and the fishing areas remained similar.

There are a number of factors to be borne in mind when considering the available CPUE data. During 1988, only 25 of the (mean) 70 active fishing days (mid-September to mid-October) were monitored. This period, according to fishermen, usually has lower cetacean mortality than November-December. However, as our data did not allow us to confirm this pattern we assumed constant mortality throughout the season. Future studies will serve to determine the validity of this assumption, and thus our estimated CPUE series.

In addition, all our mortality (and thus CPUE) estimates were based on 'known' mortality, i.e. retrieved plus discarded dolphins. However, the number actually thrown away is probably larger than reported to us. For example, it seems that heavy, difficult-to-handle dolphins were brought back to port less frequently; obviously, fishermen preferred not to mention this selection. More directly the existence of national laws restricting cetacean catches may have led fishermen to have concealed some of the catches. The total estimated catch of small cetaceans, particularly that of larger animals (e.g. adult female franciscanas and adults of both sexes of Burmeister's porpoise) may have been underestimated. If there has been a change in under-reporting over time this will affect the validity of any conclusions from our estimated CPUE series.

It is thus not possible from the very limited CPUE data available to reach any firm conclusions. However, comparison of the two CPUE values of Claromecó with each other and with the 1984 Necochea value (when the number of boats was similar to the number operating at present from Claromecó) suggests that the CPUE (and thus abundance) of the franciscana preferred habitat might have diminished.

The mean CPUE value for Burmeister's porpoises at both locations remains low. An analysis of the catch

Table 3

Catch per unit of effort (CPUE) of franciscanas and Burmeister's porpoises in gillnets of the Necochea area, by year and locality. Catch numbers are the mortalities shown in Table 2. The effort unit is based on 1km of gillnet set for one day.

	Effort (1km of net)					CPUE: PBLA				CPUE: PSPI	
	1984	1988	1989	1990		1984	1988	1989	1990	1989	1990
Necochea	16.8	64.8	80.0	64.9	Mean CPUE =	18.11	1.05	0.15	0.03	0.17	0.11
					Upper 95% CL =	26.54	1.93	0.29	0.12	0.32	0.24
					Lower 95% CL =	11.83	0.50	0.06	0.00	0.08	0.05
Claromecó	?	?	4.4	9.1	Mean CPUE =	?	?	8.38	4.31	?	0.12
					Upper 95% CL =			14.64	5.94		0.65
					Lower 95% CL =			4.33	3.04		0.00

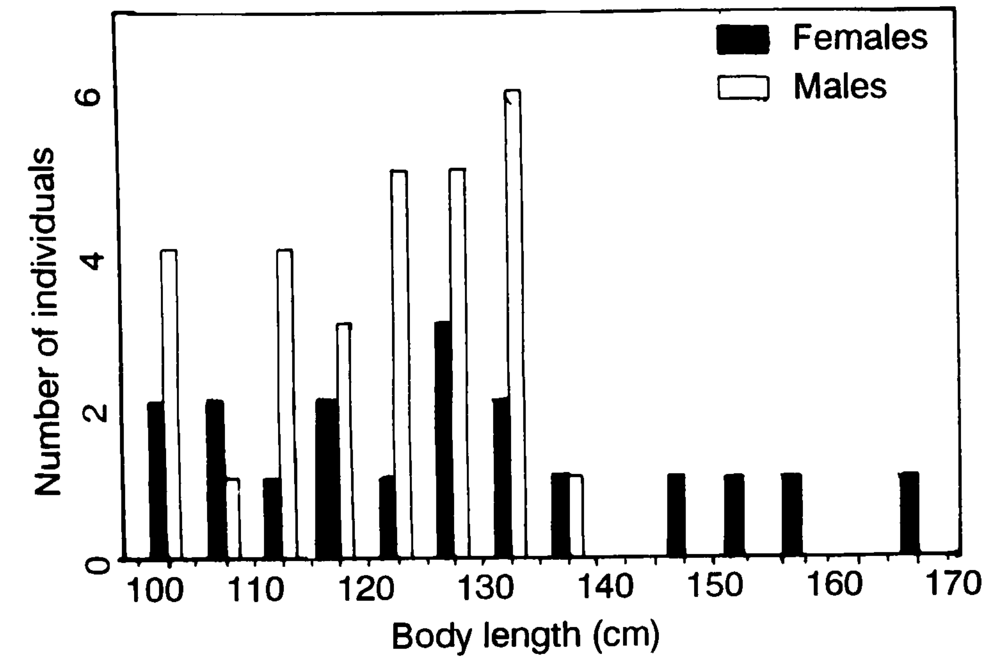

Fig. 5. Length distribution for the franciscana by-catch in the Necochea area (1988–1990). A large female (167cm) caught in 1986 is also included.

positions confirms the suggestion of Brownell and Praderi (1982) that this species is found at a wide range of water depths. It does not seem, therefore, that the species in this area is at risk at present, but the offshore movement of the fishery may change this situation in the future.

Larger cetaceans are rarely caught in gillnets in this area. On 8 October 1990, one killer whale was caught in a Necochea gillnet. It was heavily coiled and the net was lost. This is the first record of a killer whale incidentally killed by gillnets along the Argentine coast. Fishermen from Claromecó reported the entanglement of an adult sperm whale, *Physeter macrocephalus*, sometime between 1980–82. They described the animal accurately enough to differentiate it from a southern right whale; it breached with the gillnet coiled around its head and escaped with the net still entangled.

Analysis of biological data

An examination of the length and age frequency data for the franciscanas retrieved from gillnets reveals an apparent under-representation of large females. It seems likely that this may be due to the selective 'discarding' of difficult-to-handle animals discussed above. However, the lack of 3–6 year old females is difficult to explain solely in terms of the small sample size or any sampling bias.

Pérez Macri and Crespo (1989) described a lack of old, large individuals in their sample (mainly collected at San Clemente in 1984–86). One explanation is that this population structure reflects overexploitation of the stock in the Buenos Aires region. This may lead to a reduction in the reproductive capacity of females, as proposed by Read and Gaskin (1988) for the harbor porpoises in the Bay of Fundy. Further examination of the franciscana by-catch is required to test this hypothesis.

A preliminary comparison of reproductive parameters from the small Argentinian sample with those from Uruguay given by Kasuya and Brownell (1979), suggests that the male reproductive parameters are similar (Monzon and Corcuera, 1990). In contrast, the apparently high proportion of pregnant and simultaneously lactating females suggests that females in the Necochea area may not have the two-year breeding cycle (Corcuera and

Table 4

Body length, age (GLGs) and date of capture of the sample of franciscana dolphins caught in Necochea (NEC) and Claromecó (CLA) (1988-1990) by sex. A female caught in 1986 is included. NA = Teeth not available.

Females					Males				
Field no.	Body length (cm)	Age (GLG)	Date of capture	Loc.	Field no.	Body length (cm)	Age (GLG)	Date of capture	Loc.
N90-08	101.0	0.8	17/10/90	CLA	N90-07	100.2	0.8	17/10/90	CLA
N90-15	103.2	0.8	28/10/90	CLA	N88-05	101.0	0.8	01/10/88	NEC
N90-05	106.4	0.8	29/10/90	CLA	N89-18	101.0	1.2	18/12/89	CLA
N90-14	109.0	0.8	28/10/90	CLA	N88-04	102.0	0.8	30/09/88	NEC
N89-19	114.5	2.2	20/12/89	CLA	N90-25	105.0	1.8	18/10/90	CLA
N88-01	116.0	NA	18/09/88	NEC	N90-01	111.0	1.8	15/10/90	NEC
N90-04	116.3	1.8	17/10/90	CLA	N90-12	111.5	NA	17/10/90	CLA
N89-10	120.5	2.0	11/12/89	CLA	N90-19	113.4	0.8	28/10/90	CLA
N89-21	127.0	2.2	22/12/89	NEC	N90-26	113.5	0.8	22/10/90	CLA
N90-02	128.5	1.8	17/10/90	NEC	N89-15	115.0	1.0	13/12/89	CLA
N89-24	129.0	2.9	20/12/89	NEC	N89-16	115.0	2.0	13/12/89	CLA
N88-08	131.5	NA	07/10/88	NEC	N90-09	117.0	1.8	17/10/90	CLA
N88-06	132.5	NA	01/10/88	NEC	N89-22	120.0	1.0	23/12/89	NEC
N89-17	135.0	5.0	18/12/89	CLA	N90-21	122.0	1.8	17/10/90	CLA
N88-03	147.0	6.8	30/09/88	NEC	N90-16	122.7	5.0	15/11/90	CLA
N89-12	151.0	7.0	13/12/89	CLA	N90-10	123.0	4.8	17/10/90	CLA
N88-07	157.0	6.8	01/10/88	NEC	N89-23	124.0	6.0	23/12/89	NEC
N86-01	167.0	NA	22/09/86	NEC	N89-08	125.0	5.9	25/11/89	NEC
					N90-18	126.0	3.8	28/10/90	CLA
					N89-20	127.0	5.0	20/12/89	NEC
					N89-14	128.0	6.0	13/12/89	CLA
					N88-02	128.0	3.5	30/09/88	NEC
					N90-11	130.0	6.8	17/10/90	CLA
					N89-02	131.0	3.8	10/11/89	NEC
					N90-17	131.7	6.0	14/11/90	CLA
					N89-13	133.0	7.0	13/12/89	CLA
					N89-07	133.0	2.0	11/12/89	CLA
					N90-06	133.5	8.8	19/10/90	CLA
					N90-22	137.0	4.8	16/10/90	CLA

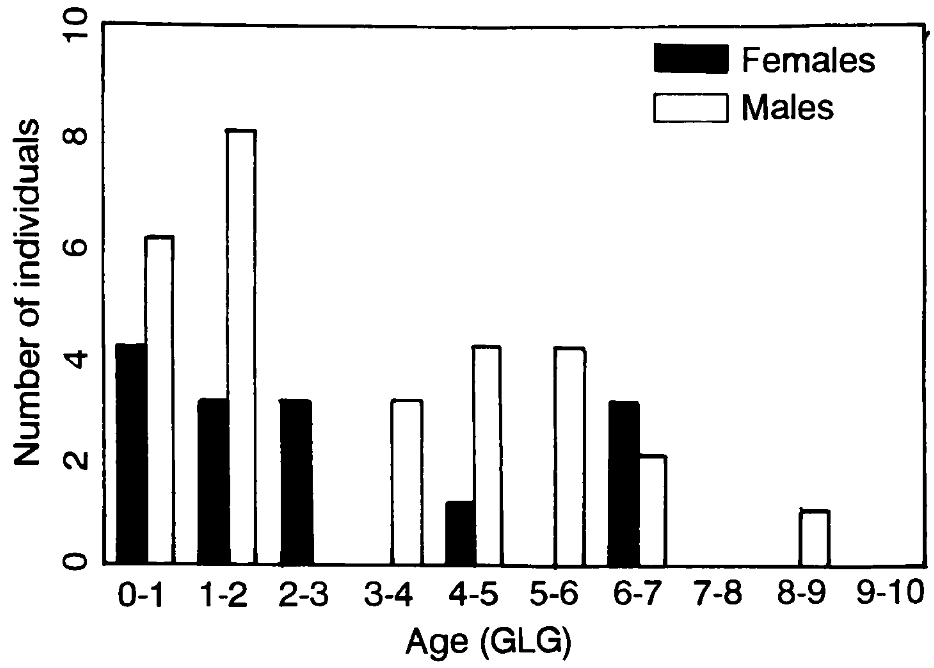

Fig. 6. Also distribution for the franciscana by-catch in the Necochea area (1988–1990).

Monzón, 1990) proposed by Kasuya and Brownell (1979) for Uruguayan animals. Corcuera *et al.* (1990) also found some apparent differences in attainment of physical maturity. In all cases, however, further data are required before firm conclusions can be reached.

Economic damage caused by marine mammals to gillnet operations

The carcass of an entangled dolphin causes damage to the nets when it is hauled up and so fishermen try to free the carcass while it is still in the water. Fishermen report that the cost of repairing nets damaged in this way or losses due to lost fishing days are less than caused by other factors producing gillnet damage (e.g. weather or shark bites).

Southern sea lions, *Otaria flavescens*, are known to prey on sharks caught in gillnets, but they do not get entangled. The sea lions always bite the sharks' belly, expose the viscera and eat only the liver. Such damaged sharks are often brought aboard in less fresh condition and then cannot be processed for export; fishermen are paid US$ 0.6–1.3/kg of shark for export but only US$ 0.2–0.8/kg for damaged sharks. During one 1989 fishing trip, around 60% of sharks recovered from one *posta* had been damaged by only one male sea lion.

However, fishermen agree that *Mustelus spp.* sharks are the main cause of damage to shark carcasses because they attack more frequently than pinnipeds and bite any part of the shark's body.

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Appendix 1

PURSE-SEINE OPERATIONS

Fishing effort

Although mortality of dusky and common dolphins in gillnets is sporadic, they are more frequently entangled during purse-seine operations. In 1989, 17 boats from Necochea operated with purse-seines but the number can vary widely depending on the demand for anchovies. The fishing season usually lasts between 2–3 weeks during the austral spring (mid-October to mid-November), although it can be much shorter (as little as 1 day) or even not occur in some years, depending on market demands.

Purse-seine nets (approx. 150m long) are operated by two co-operating vessels. The fishing distance from the coast ranges from 0.5–30 n.miles. Fishermen primarily locate anchovy schools visually or with sonar but when this is not possible they search for gulls, penguins or dolphins. Sometimes vessels will pursue dolphin schools for several hours. Fishermen report that dolphins move in tight schools distributed over a large area while searching for food. Once they find food, some individuals dive and herd the fish school to the surface by swimming around and under, in an ever-tightening formation. This behavior has been previously described by Würsig and Würsig (1980). Fishermen do not usually set the nets until dolphins drive the fish shoal to the surface.

Dolphins are usually killed when they get entangled in the sides of the net (where the mesh size varies from 30 to 60cm) while it is being retrieved.

Cetacean mortality

According to fishermen's logbooks and recollections, the percentage of trips with dolphin interactions was low (1–5%?) between 1960 and 1980, increased to approximately 5% between 1980–85 and reached 20–30% during 1988–89.

About 25–30 delphinids were caught per co-operating boat during each purse-seine trip with interactions in the 1960–70 period. This decreased to 10–15 in the next decade, except in 1972 when around 100 dolphins were caught by one vessel-pair. On one occasion in 1989, an encounter with 16 boats resulted in a by-catch of 4–8 dolphins per pair or a total kill of 32–64 dolphins. Two more encounters took place during that fishing season. In 1990, only one boat operated for a single day. At least five common dolphins were killed of which two were brought back to port.

Dolphin encounters can result in substantial economic losses to the vessels; a catch of more than 20–30 dolphins can destroy a purse-seine net. The main economic factor however, is the time wasted repairing damaged nets rather than the cost of the gear itself. In addition, bottlenose dolphins, *Tursiops truncatus*, have been reported to pierce the purse-seine nets to catch the fish contained inside, although no dolphin deaths have been recorded to date during such encounters.

It appears that overall dolphin mortality in purse-seine nets may be as high as that in gillnets. Most fishermen agree that dolphins get entangled in purse-seine nets at least once or twice per season, giving an estimated total kill of roughly 64–128 in 1989 and 4–8 in 1990. The high variability in purse-seine effort due to the fluctuating international demand for anchovy makes prediction of future fishing effort impossible.

Despite the short fishing season, small cetacean mortality in Argentine purse-seines may be large (the same fishing gear is also used in Mar del Plata harbour). The lack of information on stock identity and abundance of the affected dolphin species in these waters make it impossible to assess the impact of incidental catches at the population level.

SC/46/SM25

Incidental Mortality of Franciscanas in Argentine Waters: The Threat of Small Fishing Camps

Javier Corcuera

Museo Argentino de Ciencias Naturales 'B. Rivadavia' and Estación Hidrobiológica de Puerto Quequén-CONICET. Av. A. Gallardo 470, (1405) Buenos Aires, Argentina

ABSTRACT

Previous studies have shown that artisanal fishing camps along the Buenos Aires Province (BAP) are responsible for higher franciscana mortality than large fishing harbours. This paper presents a recent survey of the species' mortality along the southern BAP coast. The overall annual mortality estimate for this area is 230–250 individuals. Mortality and CPUE data suggest that higher mortality levels do not necessarily correspond to areas of higher dolphin densities. A five-year study of variation in mortality levels at one small fishing camp indicates that some difficult-to-control fishing variables (e.g. the preferred fishing ground of just one boat) may be the main factor in interannual mortality variation. A clarification of stock identity questions and estimates of franciscana population size are urgently required. If precautionary conservation measures are taken, they should allow for the particular situation of each fishery. A potential solution to the franciscana bycatch problem in a simple single target-species fishing camp is proposed and discussed.

KEYWORDS: SOUTH ATLANTIC; FRANCISCANAS; INCIDENTAL CAPTURE; MANAGEMENT

INTRODUCTION

The franciscana (*Pontoporia blainvillei*), an endemic small cetacean of the southwestern Atlantic coast, is the species most frequently caught by inshore gillnets along the Brazilian, Uruguayan and northern Argentine waters (Perez Macri and Crespo, 1989; Pinedo *et al.*, 1989; Praderi *et al.*, 1989; Crespo *et al.*, 1994). Previous studies have shown that in Argentina, artisanal fishing from camps situated along the Buenos Aires Province (BAP) pose more of a threat to cetaceans than operations from large fishing harbours (Corcuera *et al.*, 1994). This is primarily due to the fact that fishing is carried out in shallow waters close to the coast i.e. the preferred (inshore, 0–20m) habitat of the franciscana (Crespo *et al.*, 1994). This study presents recent data concerning franciscana mortality along the southern BAP coast.

MATERIALS AND METHODS

Monitoring

Between September 1988 and April 1994, a total of 299 days were spent monitoring commercial fishing harbours and fishing camps along the southern BAP coast (Fig. 1). During the 1988–92 period (Crespo *et al.*, 1994), studies concentrated on two localities: Puerto Quequén-Necochea (fishing location no.1) and Claromecó (no.2). In April 1994 we began a project to cover the whole BAP coast, starting with the southeastern area. Locations monitored were nos 1, 2, 3 (Monte Hermoso), 4 (Pehuencó), 5 (Puerto Rosales), 6 (Villa del Mar), 7 (Ingeniero White), 8 (San Blas) and 9 (Carmen de Patagones-Viedma). Locations 1 and 7 are considered fishing harbours, i.e. a dock is available to accomodate (usually) large vessels (>8m), the target species may be sold in regional, national and/or international markets and operations usually occur within 30 n.miles of the coast. Locations 2–6 and 8–9 are small fishing camps, with no dock, small (<8m) boats, a local market only for their target species and an operational area usually less than 10 n.miles from the coast.

Surveys performed until 1992 were based on interviews with fishermen and confirmed or corrected using the

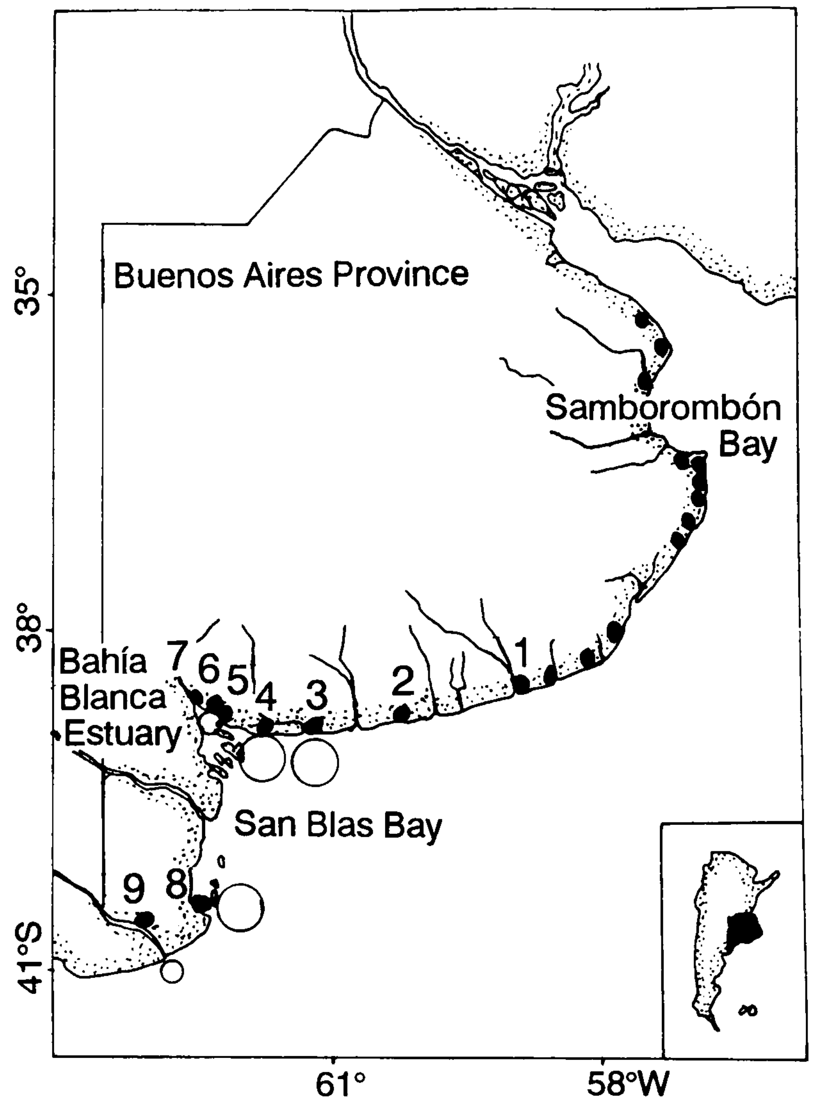

Fig. 1. Locations surveyed and CPUE relative levels (empty circles) of franciscanas caught.

number of dolphin carcasses retrieved (Crespo *et al.*, 1994). The 1993 data were obtained from 24 selected fishermen found in the nine surveyed locations. They were interviewed (two to five hours for each interview) and asked to describe their fishing operations in terms of target species and their correspondent economical benefits, costs of fishing, types of gear, mean length of fishing season, effective fishing days during 1993, mesh size, metres of net

Table 1

Mortality and CPUE (x1000) of franciscanas in the southern Buenos Aires Province (1993).

Loc. #	Mortality			No. of boats (*N*)	Effort (*NxDxK*)	CPUE		
	Mean	95% Max.	95% Min.			Mean	95% Max.	95% Min.
1	4.7	11.0	1.4	18	1215.0	3.9	9.0	1.1
2	34.0	47.5	23.5	11	724.5	46.9	65.6	32.5
3	91.5	112.3	73.7	26	178.4	512.9	629.4	413.2
4	6.0	13.1	2.2	2	12.8	468.8	1020.3	171.9
5	9.0	17.1	4.1	3	52.5	171.4	325.5	78.5
6	14.0	23.5	7.7	6	187.5	74.7	125.3	40.8
7	76.5	95.7	60.3	23	1986.0	38.5	48.2	30.4
8	0 (14.9)	(24.7)	(6.4)	2	0(34.1)	0(437.0)	(724.3)	(246.3)
9	1.0	5.6	0.0	1	4.2	238.1	1326.2	7.1
All	236.7 (251.6)	268.9	207.5	80	4360.9	54.3	61.7	47.6

( ) = Data from 1991 included.

used, preferred fishing depths and distance from the coast of the operations. They were then asked to describe dolphin sightings within their fishing area. At this phase of the interview they frequently informed us of any dolphin bycatch and the frequency of the entanglements. A total of 80 of 111 considered vessels were using gillnets of mesh sizes (range 7–36cm) associated with franciscana entanglements.

Annual mortality estimation by year and location

Annual mortality estimates of franciscanas were obtained for 1993 for the 9 locations. These estimates were compared with 1988–92 data gathered in locations 1 and 2 (Corcuera and Monzón, 1993). The estimation procedure assumed that mortality was constant throughout the fishing season. Initially I compared annual mortalities by estimating 95% confidence intervals (CI) of each estimate using the Poisson model which can be used to describe relatively rare events (Zar, 1984). However, as this model assumes that each entanglement is independent, some bias may arise out of the fact that pairs are occasionally caught in the same net (Crespo *et al.*, 1994). I thus used a chi-square test of goodness of fit for the 1988–92 data for the number of dolphins caught per day (n=115, 71 dolphins with date of capture and 44 days with no dolphins caught) using both Poisson's expected values and with a negative binomial distribution of expected values, using Green's index test (Ludwig and Reynolds, 1988). The index of dispersion (variance/mean ratio) of the data was 1.49 (the Poisson model assumes an index of dispersion = 1). The correspondent chi-square statistic showed that there was no significant difference if a Poisson series was used (total chi-square = 2.42, d.f. = 2) whilst the Green's index (0.0071) was not significantly different from zero, confirming that the franciscana bycatch does not follow a binomial model. It is thus appropriate to estimate the 95% CI following the formulae given by Corcuera *et al.* (1994) according to Pearson and Hartley (1976), as described by Zar (1984). As the data were in some cases obtained from partial surveys (a variable proportion of the operating boats were monitored during a variable proportion of the fishing season), each mean and CI was adjusted to account for both the number of boats and fishing season days not monitored. In order to account for the boats not surveyed and the active fishing days not monitored, I scaled up those figures under the assumption that the catch rate of the missing vessels and the missing fishing days was the same as those that were surveyed.

Effort units and CPUE

Catch per unit effort (CPUE) data by year and locality were calculated using the estimated annual mortalities. The fishing effort unit used was = No. of boats (N) per day of active fishing operations (D) per gillnet km (K). Confidence limits for each CPUE were obtained dividing the 95% CI of the mortality estimates by the fishing effort recorded for the respective year and locality.

RESULTS AND DISCUSSION

Mortality of franciscana dolphins

Table 1 presents the estimated franciscana mortalities, the number of boats, the effort and the CPUE along the southern BAP coast (locations 1–9 in Fig. 1) for 1993. The highest estimated mortalities were found in locations 3 and 7, followed by location 2.

Location 3 is Monte Hermoso, a small fishing camp where 3 of the 28 boats catch most of the dolphins (74%). These boats are approximately 7m long and set 0.8–1.4km of 21cm mesh size gillnets for soupfin sharks (*Galeorhinus galeus*) and related species. Due to the prevailing strong winds in this area, the boats operate close (<5 n.miles) to shore. The fishing ground extends up to the Bahía Blanca estuary and generally follows the 10m depth line. Fishermen state that franciscanas are more frequent within this depth. The shark fishing season is short (September to October). The other 25 boats are smaller and although they operate at the same depth, carry fewer gillnets and operate only occasionally under light wind conditions.

Location 7 is Ingeniero White, a fishing harbour deep inside the Bahía Blanca estuary. The water circulation of this large estuary is regulated by a complex of tidal flats; its mean depth is 10m (Piccolo and Perillo, 1990). The 23 vessels operating there use 10.5cm mesh size gillnets for small sharks and 7cm gillnet for sciaenids. Little information on incidental captures was available before this survey for this important fishing area (Perez Macri and Crespo, 1989; Crespo *et al.*, 1994; López Cazorla, unpublished). The 10.5cm mesh gillnets are responsible for about 70% of the franciscana bycatch and are usually set in deeper areas such as main channels and the outer estuary. The 7cm mesh gillnets are set to block the mouths of up to 200m wide tide channels and are called *tapaduras* or *tapacanals*. Each boat carries up to ten of these nets. Fishermen say that franciscanas are sometimes blocked in 1m depth waters with this gear but they are not usually entangled. The fishing ground covers almost the entire estuary. Two small fishing camps (nos 5 and 8) are also within the Bahía Blanca estuary, but they seem to have a low impact on franciscana dolphins.

Location 2 is Claromecó, the small fishing harbour previously studied by us (Corcuera *et al.*, 1994). Three to five relatively large boats (7–12m long) fish there with a high gillnet effort (mesh-size of 18–36cm) and a long fishing season (June to December). The fishing ground is typically around 6 n.miles from the coast in waters 12m deep.

Of approximately 237–252 franciscanas caught along the southern Buenos Aires coast, some 85% of the catches are due to these three fisheries.

There are some ten small-scale fishing locations from Puerto Quequén northwards to the La Plata estuary in Buenos Aires Province (black dots without numbers in Fig. 1) where mortality is known to occur but to an unknown extent. Some are located near or within the La Plata outer estuary in Samborombón Bay (a high density area of franciscanas) and we suspect their fishing operations may result in similar mortality levels to those in the Bahía Blanca estuary and its surroundings.

CPUE

In order to investigate whether locations 2, 3 and 7 simply coincide with higher densities of franciscanas, the CPUE at each location (Table 1) is presented as proportional circles in Fig. 1, on the assumption that CPUE is roughly proportional to density. The mean CPUE values are not consistent with the mortality levels previously discussed, apart from in location 3. Although there are several factors that may bias our 1993 CPUE estimations by locality, the CPUE data suggest estuarine, outer estuarine and near estuarine waters are areas of high franciscana abundance, i.e. around locations 3, 4 and probably 8 and 9. Outer estuaries are known to be highly productive ecotones and may allow opportunistic cetacean species to feed with a reduced risk of predation. The apparent high densities for locations 8 and 9, although based on only a few data, are consistent with recent knowledge of the franciscana's southern limit of distribution (Crespo and Harris, 1992).

The case of Claromecó

An examination of the available CPUE and mortality data for Claromecó (location 2) provides some information on the different mortality levels by location. The 1989–93 CPUE estimations of Claromecó suggest a decreasing trend (Fig. 2), although the 1990–93 period was relatively stable in terms of CPUE. However, the actual mortality in 1992 was about double the usual levels. This increase and the subsequent 1993 decrease was due to only one vessel which operated in a particular area for a long time during 1992. Franciscana sightings were frequent there, as opposed to other areas where the boat had fished (also for long fishing periods) in previous years. In 1993, however, this boat was active only for one month, after which it ceased operation for economic reasons. This vessel was responsible for the highest incidental captures during the 1989–93 period.

Franciscana mortality levels seem to be extremely sensitive to qualitative changes in coastal fishing effort, particularly: (1) the use of large mesh size gillnets and (2) the geographical position of the nets (therefore implying a patchy distribution with perhaps site-fidelity). Franciscanas are associated more frequently with waters of 1–20m depth (Crespo *et al.*, 1994). Just one inshore

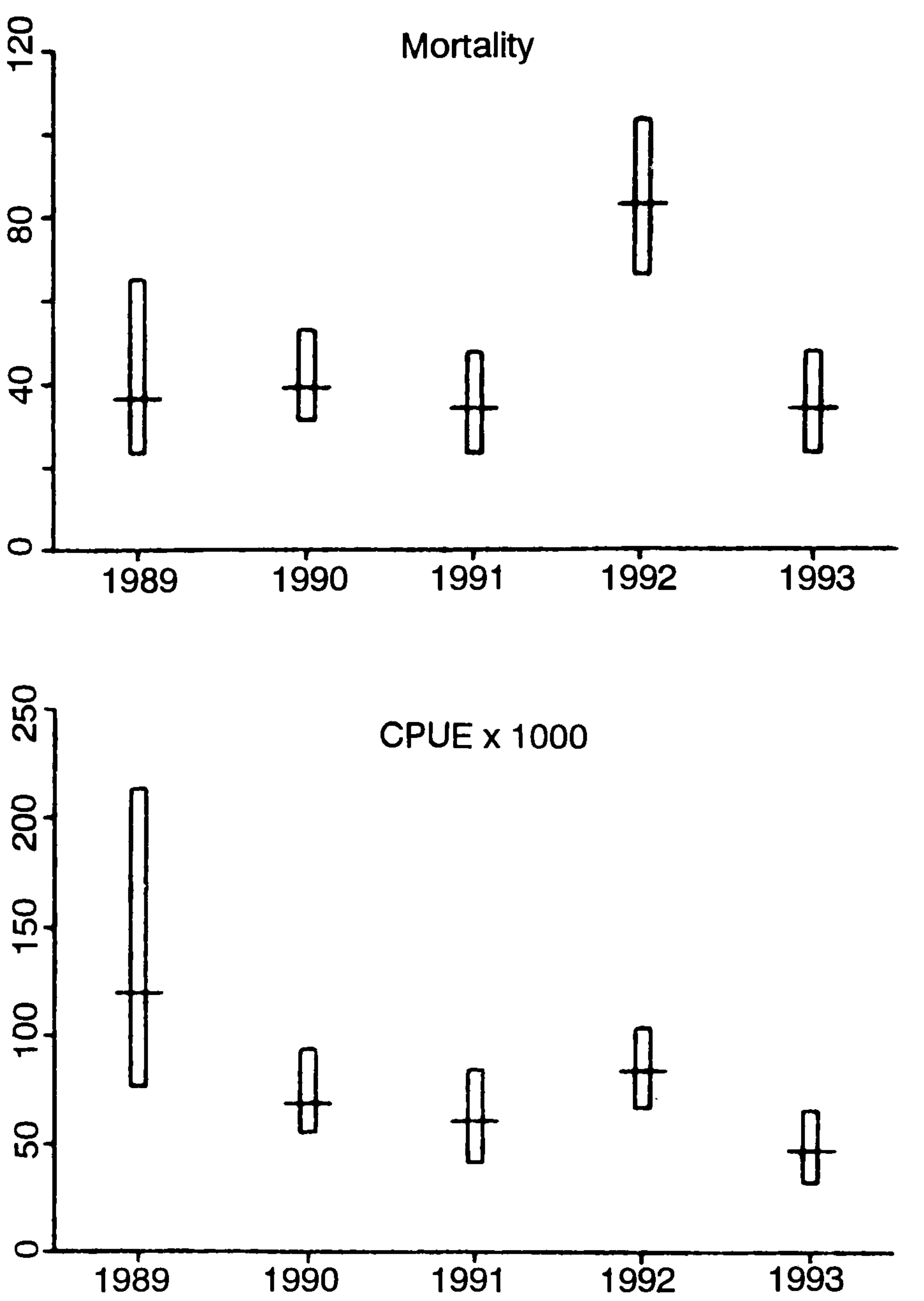

Fig. 2. Mortality and CPUE of franciscanas at Claromecó.

fisherman setting his nets at the 'right' place may result in a greater mortality than that of a large fishing harbour fleet, which usually operates outside that depth range.

Urgent research needs

Other factors related to human activity (e.g. industrial, agricultural and sound pollution) in the La Plata River and the Bahía Blanca mid and outer estuaries could also affect the franciscana stocks and/or the fish nurseries upon which they probably feed. The probable existence of at least two different stocks of franciscanas (Pinedo, 1991) stresses the importance of separating different mortality estimates by areas, until stock identity questions are resolved. The impact of the BAP mortality can only be correctly evaluated if stock identification is determined and abundance estimates for each stock obtained.

Precautionary conservation measures

The use of large mesh gillnets and the definition of fishing grounds at the local level are highly variable factors and are difficult to control. Under such circumstances artisanal fishermen must be offered alternative non dolphin-lethal ways to catch their target species. For these to be acceptable, they must, at least maintain the historical relationship between fishing costs and benefits, if not be completely able to sustain the level of fish catches.

This approach seems possible in the case of those fishing camps almost exclusively devoted to the shark gillnet fishery, such as Monte Hermoso. Longlines could successfully replace gillnets there if: (1) the longlines for soupfin and bigger shark species provide a better price/kg relationship than gillnets; (2) the longlines can be technically improved (e.g. an automated low coast baiting method is devised) to ensure their easy use; and (3) the artisanal fishermen can cooperate to fulfil foreign requirements in terms of levels of shark catches and quality of fish. Enhancing the acoustic reflectivity of gillnets by means of low-cost materials might provide another approach, although this perhaps is less promising as discussed elsewhere in this volume (e.g. IWC, 1994).

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Net Fisheries and Net Mortality of Small Cetaceans off Tierra del Fuego, Argentina

R. Natalie P. Goodall and Adrián C. M. Schiavini

Centro Austral de Investigaciones Científicas (CADIC), C.C. 92, 9410 Ushuaia, Tierra del Fuego, Argentina

Carlos Fermani

Museo del Fin del Mundo, 9410 Ushuaia, Tierra del Fuego, Argentina

ABSTRACT

There are five basic types of inshore fishing off Argentinian Tierra del Fuego: coastal fishing with gillnets or lines along the northeastern coasts; beach seining, use of wicker pots, and trapping for centolla (*Lithodes santolla*) in the Beagle Channel.

Northern coastal fishing uses three basic types of nets: (a) gillnets 25–100m in length with a mesh of 10–14cm for *róbalo* (*Eleginops maclovinus*), *merluza* (*Merluccius* sp.) and trout (although fishing for trout with nets is illegal); (b) finer-meshed (approximately 3cm) gillnets for *pejerrey* (Atherinidae) and small *róbalo*; and (c) trammel nets for all the above species. These nets are set perpendicular to the coast on stakes fixed in the tidal zone, where they lie exposed at low tide and are lifted by the sea at high tide. Occasionally small boats are used, especially near river mouths, either with one end of the net held on shore or with nets pulled between two boats. This fishery takes place between October and April; that for *pejerrey* extends into the winter.

We have monitored the mortality of small cetaceans in this fishery over the past 15 years. The species taken are, in order of quantity, Commerson's dolphin (*Cephalorhynchus commersonii*), spectacled porpoise (*Australophocaena dioptrica*), Peale's dolphin (*Lagenorhynchus australis*) and Burmeister's porpoise (*Phocoena spinipinnis*). Cetaceans are not trapped in the finer-meshed *pejerrey* nets. Pinnipeds are taken occasionally, but usually break through the nets. During 1989–1990, this fishery increased due to the economic situation of the country, but has since declined to former levels.

Fishing for *centolla* has lessened in the last few years, with only two companies with four boats (some 1,000 traps) working at present in the Argentine (northern) half of the Beagle Channel. Cetaceans are not caught in crab traps, but marine mammals may be harpooned for bait. Although illegal, there is some clandestine crabbing with nets in the Chilean section of Tierra del Fuego. Dolphins are entangled in these nets.

Offshore fishing is increasing; ten Argentine/foreign ships under Argentine permit and with mixed crews are based in Ushuaia at present. These fish with trawl nets or long-lines on the continental shelf off Patagonia, usually north of Tierra del Fuego, for squid, octopus, *merluza*, southern cod or *abadejo* (*Genypterus blacodes*) and others, producing tinned caviar and frozen fish. We have no information on possible cetacean exploitation in this fishery.

KEYWORDS: INCIDENTAL CAPTURE; COMMERSON'S DOLPHIN; SPECTACLED PORPOISE; PEALE'S DOLPHIN; BURMEISTER'S PORPOISE; PINNIPEDS

INTRODUCTION

Harpooning of dolphins for food in Tierra del Fuego began some 6,500 years ago with the arrival of the indigenous canoe peoples via the western channels. Direct exploitation probably reached its height during the early part of this century (Weber, 1920; Goodall *et al.*, 1988a and b), and now occurs only occasionally in Argentine waters, for bait for southern king crab *centolla* (*Lithodes santolla*) and false king crab or *centollón (Paralomis granulosa)* (Goodall and Cameron, 1980).

Incidental capture of the smaller cetaceans with nets in inshore waters during other fishing activities probably began in this century and has greatly increased in recent years. This type of fishing has been described for Tierra del Fuego and estimates given for numbers of dolphins taken (Goodall, 1978; Goodall and Cameron, 1980; Goodall *et al.*, 1988a and b; Goodall, 1990). It entails two types: (a) bottom netting for *centolla*, now illegal; and (b) netting for fish with fixed shore nets or nets used from boats near shore.

Cetaceans may also be captured in several kinds of fishing activities in offshore waters (the continental shelf off Argentina) by ships based in Ushuaia. This is a new fishery of which little is known.

The purpose of this paper is to describe the types and size of nets used and to review and update information on incidental and directed kills of cetaceans.

METHODS

Information on net fishing and cetacean takes in this area was obtained from review of the literature and from colleagues, fishermen and ship captains. In addition, much information was supplied by the Dirección de Recursos Naturales (DRN) of the Government of Tierra del Fuego.

We have carried out an on-going biological study of stranded and incidentally captured cetaceans along the coasts of Tierra del Fuego since 1975. We re-examined our collections and notes in order to re-estimate the number of cetaceans possibly taken in shore-based nets.

For comparative purposes, the Argentine coastline where netting occurs was divided into four sections (Fig. 1): (A) from Cabo Espíritu Santo to Cabo San Sebastián, the southeast end of Bahía San Sebastián; (B) from Cabo San Sebastián to Río Grande; (C) from Río Grande to Kaitush; and (D) the coast southeastwards from Kaitush. The latter coast has more cliffs and rocky shores, so shore fishing can be carried out only near river mouths; fewer expeditions were made to this area and it is under-represented in the sample. The crab and other fishing areas of the Beagle Channel are marked (E).

During 1990, we measured nets encountered on the beach and those confiscated by DRN because of illegal use. We also queried fishermen on net sizes and types.

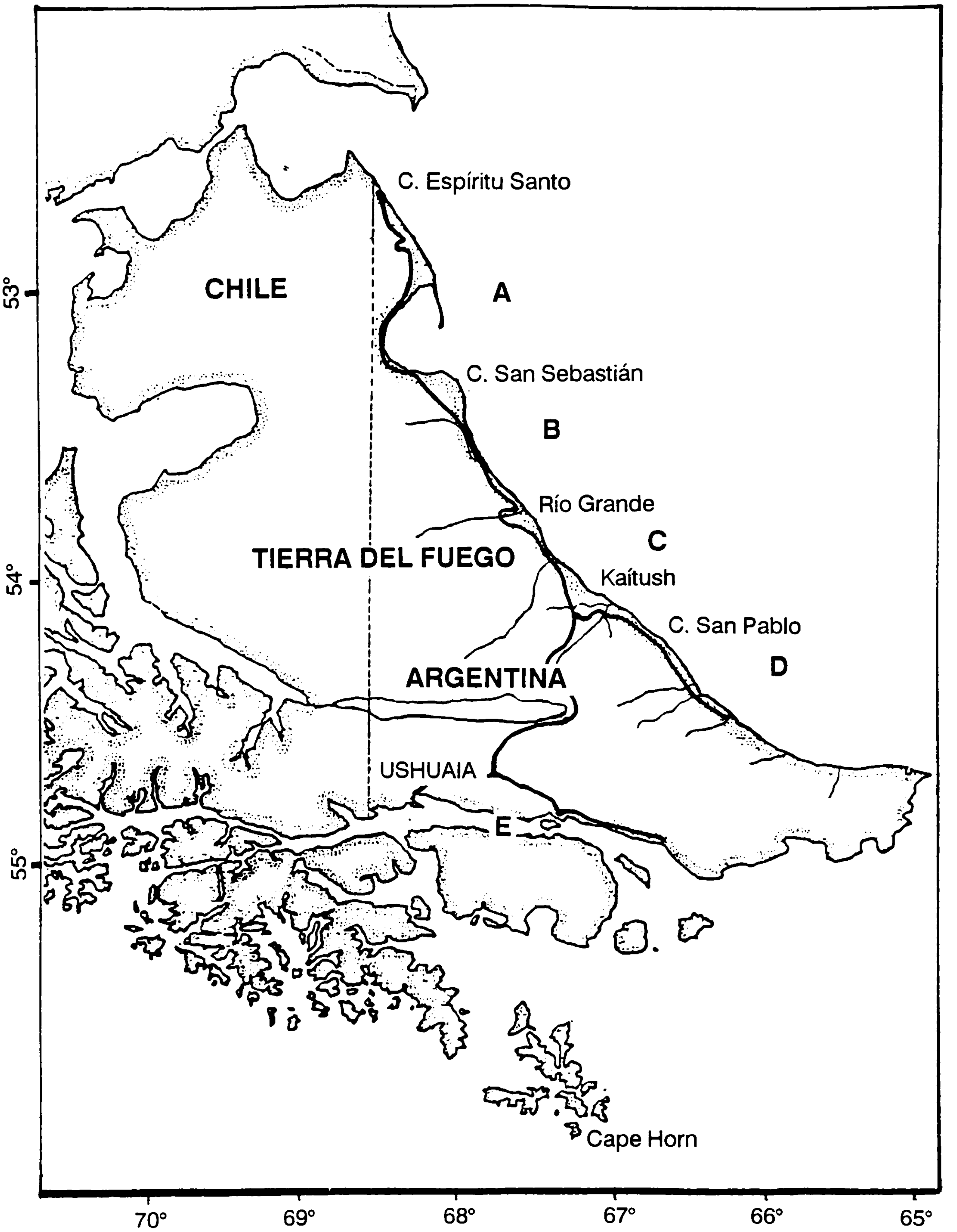

Fig. 1. Areas of Argentinian Tierra del Fuego where shore-based *róbalo* (A-D) and *centolla* fishing (E) take place.

TYPES OF FISHING

Nets set for centolla

Centolla occur in deep waters during most of the year but migrate to shallow waters near shore in late spring to moult. Females generally reach coastal moulting areas in November and males in December and January (J. Vinuesa, pers. comm.). From at least the 1950s until 1976, crabs were fished from October to about March while migrating (and a few in deeper waters in winter) with nets weighted to rest on the channel floor; the crabs would become entangled walking up the nets (illustrated in Goodall, 1975). The nets were usually 1.3m high, with sections joined to a length of 1,000m, marked on the surface with floats. They were checked once a day, weather permitting (Goodall, 1978). The mesh was usually 12cm square (stretched diagonally approx. 20cm). The nets were not baited.

This fishing usually took place in the Beagle Channel in Argentine waters and in many parts of Chilean Tierra del Fuego. On the northeastern coast of Tierra del Fuego, nets set on the mud flats could catch crabs only between late November and early December, when the crabs reached the tidal zone (they can be picked up by hand in tide pools on the lowest November tide). Small cetaceans were often trapped in both types of crab netting.

Since netting took female and young crabs, it was outlawed in Argentina in 1976 and in Chile in 1977.

However, some clandestine artisanal netting still occurs in the Chilean Strait of Magellan area and southern Santa Cruz, Argentina. As far as we know, netting for crabs does not take place at present in Argentinian Tierra del Fuego.

Crab fishery with traps

Since 1976 in Argentina and 1977 in Chile, *centolla* have been fished with traps. Since this resource is overexploited, fishing in recent years in both countries has turned to the *centollón*. In Argentine Tierra del Fuego, the king crab fishery is regulated under Resolución 132 of the Secretaría de Intereses Marítimos as administered by the local DRN. The area covered includes the northern (Argentinian) half of the Beagle Channel from Bahía Lapataia (68°34′W) to the western cliffs of Isla Gable (67°33′W), about 344 n.miles^2, with a limit of 1,000 traps (Boschi *et al.*, 1984). Crabbing also occurs from Isla Gable eastward to Islas Becasses (66°39′W) (Fig. 2). False king crabs have no legal regulation at present.

As of 1990, only two companies, *Mar Frío* and *Pesquera del Beagle*, operate from Ushuaia (54°49′S, 68°13′W), using Almanza (54°42′S, 67°33′W) as an alternate port. Each company operates two 15–17m wooden ships with the wheelhouse on deck near the stern and a winch for lifting and lowering the traps (illustrated in Goodall *et al.*, 1988a). The boats are operated by a captain and two crew members, normally Argentine but sometimes including Chileans. A fishing expert sometimes accompanies the boats. Crab holding capacity for the two *Pesquera del Beagle* boats is 2,000kg each; that for *Mar Frío* boats is 3,000kg each.

The operational unit can be defined as the 'line'. Each line consists of a series of ten traps, spaced 20m apart on a cable with one or two buoys at one end. The trap is a truncated cone of 70–115mm mesh net over an iron frame composed of three rings joined by bars. The trap is 130cm high with a base diameter of 150–180cm and a 40cm opening in the top protected by a plastic ring which impedes the escape of the captured crabs. Each boat carries about 25 lines of traps for a total of approximately 1,000 traps in the area. Two additional fishermen occasionally take crabs by license, while a few people may dive for crabs or take them from others' traps.

Crab traps are baited with animal flesh, skin or bone placed in fine-meshed plastic bags (approximately 12 by 25cm) tied inside the traps and changed each time the trap is lifted. The companies sell bait (fish) to the fishermen, but they often prefer to get their bait free (see Directed catches for crab bait below).

Except for adverse weather conditions, trap checking trips are daily from either Ushuaia or Almanza. On the basis of 1990 data (10–31 May, July, August and 1–15 September), we calculate an average of 202 (±24) working days per year. All 25 lines are continually in the water and are checked every 2–3 days at a rate of 8-10 lines per day. The crabs are unloaded alive and processed at the plants in Ushuaia, where they are canned or frozen.

Crabbing is permitted eight months per year (January to August), but fishermen may take up to two months to lift and store the traps, effectively extending the season to ten months. The fishermen receive about US$1.00 per kg for *centolla* and US$0.50 for *centollón*. The market for crabs is locally in Tierra del Fuego and in Buenos Aires, Europe and Japan.

The catch of *centolla* has declined recently, from 130,544kg in 1988 to 84,239kg in 1990. That of the *centollón* has also declined, from 182,168 kg to 131,495kg. The tendencies in this over-exploited fishery are fewer males of legal size (carapace of over 12cm) and a larger proportion of juveniles in the catches. The present legislation does not effectively protect females (Bertuche *et al.*, 1989). However, catch per unit effort (CPUE), measured as individuals per trap, has not varied between 1975 and 1989.

According to the fishermen, there is a great loss of gear through loss of buoys by theft or weather. The lines thus lost continue to attract crabs which eat the dead ones in the trap and eventually die, forming a continuing cycle. The plastic mesh of the traps may endure indefinitely and these ghost traps, estimated to be some 500 lines since 1976, probably greatly deplete the resource. Only occasionally can a line be hauled from the channel floor and the traps retrieved. Crabs have been greatly over-fished for years and the industry is in decline; one company has now incorporated ships for offshore fishing.

***Nasa* fishing**

The *Mar Frío* Company has recently begun using *nasas* (wicker basket traps) to fish for *brótola* (*Salilota australis*) and southern cod or *abadejo* (*Genypterus blacodes*) in a deep section of the Beagle Channel east of Ushuaia. The fish thus obtained are used for crab bait or sold locally.

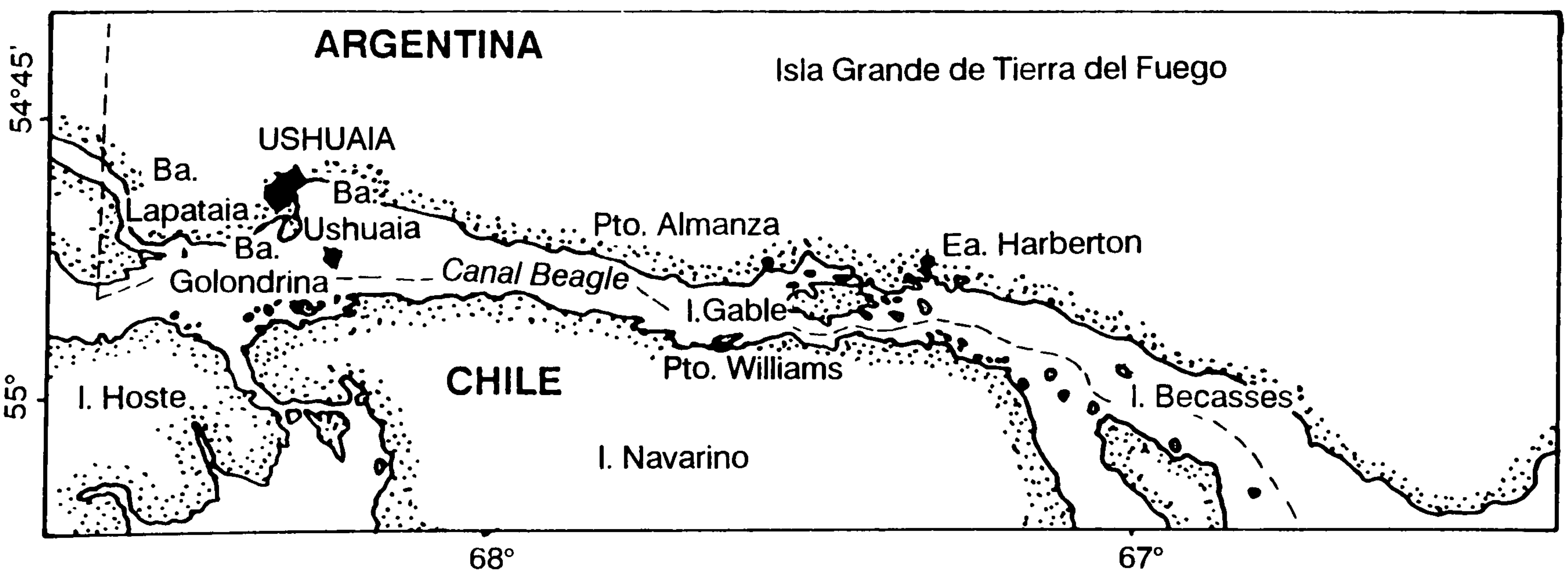

Fig. 2. Map of the Canal Beagle where *centolla* and scientific fishing is carried out, showing location of ports and the division of the channel between Argentina and Chile. Ba. = bahía, bay. I. = isla, island. Pto. = puerto, port. Ea. = estancia, farm.

Artisanal shore fishing

Shore-based fisheries which affect marine mammals are carried out on the northeastern coasts of Tierra del Fuego. These fisheries are controlled by DRN, which since 1987 has required licenses and has collected information, albeit many times partial, on catches. DRN has formed a group of volunteer wildlife inspectors in order to help control indiscriminant fishing, especially of the introduced trout, a major tourist attraction.

The species involved are those which normally swim near shore: Patagonian blenny or *róbalo* (*Eleginops maclovinus*), smelt or *pejerrey* (*Austroatherina nigrans*), and to a lesser extent southern hake or *merluza austral* (*Merluccius australis*), *abadejo*, *congrio* (*Pseudoxenomystax albescens*) and *palometa* (*Parona signata*) (nomenclature of Menni *et al.*, 1983). The latter two species are only rarely found in the nets.

These fisheries are carried out in three ways: by shore-based fixed nets, by a boat taking out a net hand-held on shore, and by operation of a net between two boats.

Shore-based set nets

This fishing is site-specific, limited to sand or clay beaches, bays or river mouths on the NE coast with gently sloping shores, a large tidal range (up to 10m at Bahía San Sebastián and about seven meters at San Pablo) and easy access by road.

Stakes are planted perpendicular to the beach in the intertidal area and nets are attached. Nets can vary from 20 to 100m in length and 140 to 200cm in height (Table 1). The nets are active only when the tide is in. This has been described as the world's laziest fishing; one must only wait for the tide to rise and fall again, then take the fish out of the net left exposed in the tidal zone. The nets are checked every low tide, both day and night, as the fish are quickly eaten by birds.

The nets are of three types: (a) *agalleras* (gillnets) for *róbalo* are set as far from the beach as tidal exposure permits and have a mesh size of 100-140mm; (b) gillnets for the smaller *pejerrey* or young *róbalo*, with a mesh of 20–40mm; and (c) *trasmallos* (trammel nets) (Table 1, Fig. 3). A simple 100m gillnet can cost US$1,000, if one buys the mesh, lines, floats and leads and puts it together oneself. The trammel nets are more expensive and seldom used. In some trammel nets, the center, finer-meshed panel is two to three times the height of the two outer nets, so that fish caught in its billows push through the larger meshes and become thoroughly entangled.

These three types of nets may be used in various combinations, with one or two *pejerrey* nets nearer shore and two or more *róbalo* nets attached to them or set separately further seaward (Fig. 4), depending on the site, the tides and the number of nets the fisherman has. Each fisherman may operate from one to four lines of nets, each set 50 to 200m apart, but many new fishermen have only one net. Trammel nets may be used as a last alternative when the gillnets fail.

Small groups of one to three men camped in shacks near the nets may fish all season (about October to April) and sell their catch to a buyer who comes every two to three days by truck. The fish are sold in Río Grande or Ushuaia and the excess or that which spoils is sold to the *centolla* packing plants in Ushuaia for bait for the crab traps. The more stable campsites are usually distant from towns.

Table 1

Types of nets used in shore-based fishing in Tierra del Fuego. Codes: r = róbalo nets; p = pejerrey nets; PE = polyethylene lines; PA = polyamide line, twisted (*hilo, sedal*).

No. nets joined	Net height cm	Length meters	Diameter twine, mm	Mesh size	Material: Mesh	Material: Floatline	Material: Leadline	Source or reference
Róbalo - gillnets (*agalleras*)								
2	140	25 each	0.24	140	-	-	-	Fernando Ravlik to RNP
1	140-150	25	0.24	140	-	-	-	F. Ravlik to RNP
2	140-150	25	0.24	120	-	-	-	F. Ravlik to RNP
1	±150	50	thicker	-	-	-	-	RNP obs.
1	±250	25	1.0	140	PA, white	-	-	RNP obs. dry on beach, floats yellow
2	±150	25-30	1.0	120	PA, white	-	-	RNP obs., floats yellow, floats gray
4	Observed three sets of nets with four 25m '*robaleras*' in each set							RNP obs.
1	180-200	100	1.0	120	PA, white	-	-	J. Varela to RNP, homemade
1	150-200	100	1.0	120	PA, white	-	-	J. Varela; most common net
1	200	70	1.0	120	PA 1mm	PE 6mm	PE 6mm	P. González to ACMS
Pejerrey - *agalleras*								
2	140-150	25	0.06	30	-	-	-	F. Ravlik to RNP
1	140+	25	0.06	30	-	-	-	F. Ravlik to RNP
1	200	12	0.18	30	PA	-	-	F. Ravlik to RNP
Róbalo and Pejerrey Agalleras *set in a row*:								
3(p,p,r)	-	120 total	-	p ±50	-	-	-	L. Benegas obs. to RNP
				p 'bolsa de hilo'	-	-		
				r ±90		-	-	
4 (p,p,r,r)	-	25 each	-	Similar to above		-	-	RNP obs.
Trammel nets (*trasmallos*):								
	150+	to 100m	1.0	120	PA	-	-	J. Varela to RNP
	450		1.0	20	PA	-	-	
	150	47	1.0	440	PA	PE 6mm	PE 6mm	CADIC 'Trammel 11'
			0.5	50	PA			
	240	60	1.0	440	PA	PE 6mm	PE 6mm	CADIC 'Trammel 3'
			0.5	40	PA			

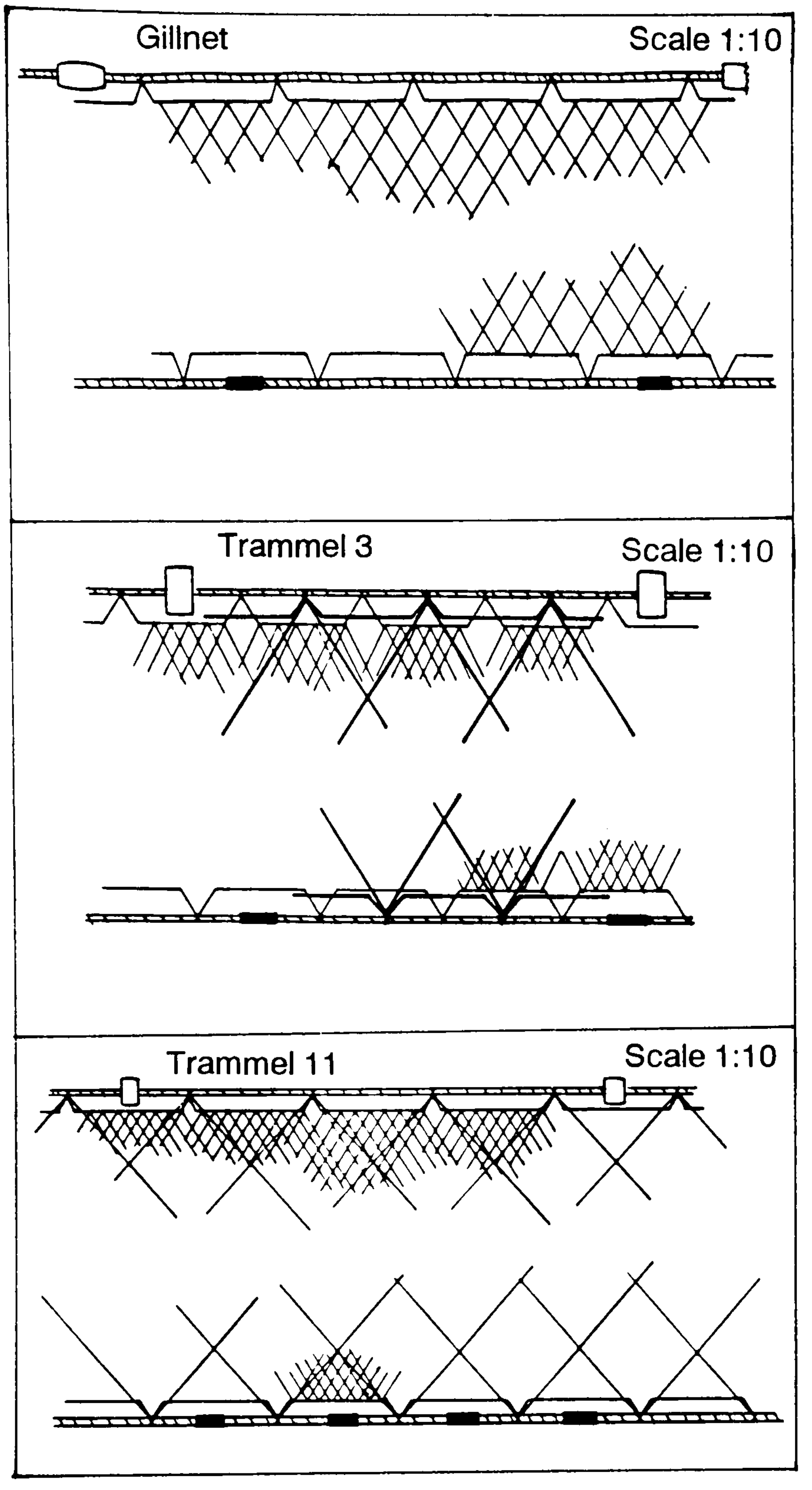

Fig. 3. Schematic drawings of the type of gillnets used in Tierra del Fuego and the trammel nets used by scientists at CADIC.

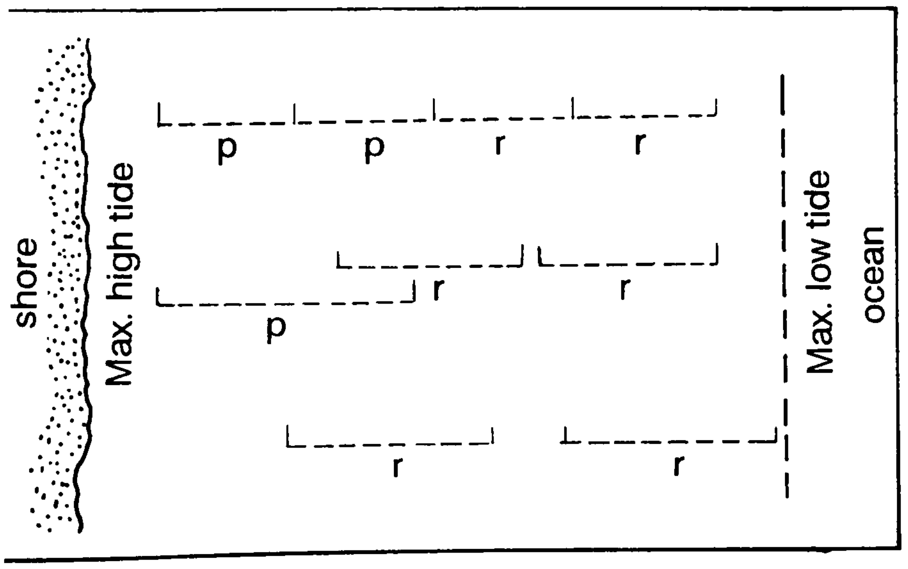

Fig. 4. Examples of net placement in shore-based fixed-net fishing on the NE coasts of Tierra del Fuego (*r* = *róbalo* nets, *p* = *pejerrey* nets).

Sporadic fishing is more common near Río Grande, with men fishing overnight or on weekends, bringing their nets and attaching them to permanently installed stakes.

The locality emphasis of this fishing changes from year to year, as fishermen claim that *róbalo* tend not to return to areas which are heavily fished. In the 1970s and early 1980s, most fishing was in the northern part of the zone (Bahía San Sebastián), but in 1988–89 most of it concentrated north of Río Grande (Fig. 5).

Boat-shore method

The exposed northeastern coasts of Tierra del Fuego, where *róbalo* fishing is also carried out, are extremely dangerous for boats due to the shallow shores, strong winds and waves. Boats are used by only a few fishermen and are normally kept on shore inside river mouths to be used on exceptionally calm days. The usual method is for one or two people in the boat to take one end of the net out in a large circle while another person(s) on shore holds the other end.

Boat fishing

One or two rowboats or inflatable boats may be used to drag the net out to encircle a school of fish. Both this and the former method require several people (as opposed to one man with his shore nets), good weather conditions and a river or other easy launching site. Most boat fishing is done in or near river mouths. Legally, no net fishing of any type is permitted in rivers or within 300m on either side of river mouths to protect introduced Atlantic land-locked salmon (*Salmo salar*) which have returned to the sea. However, clandestine fishermen find river mouths an excellent place to net large numbers of both *róbalo* and trout.

The information available on the coastal net fisheries is too incomplete to permit an estimate of effort. There are no official data on types of nets used, length of time each fishes, or the exact amount of landings. On the basis of fishing licenses given by DRN, we determined the number of licenses in use on the 15th of each month from September 1987 to September 1990 (Fig. 6). Until February 1989, the licenses were for three months, but since then are for six months.

The licenses given for the south coast (Beagle Channel and adjacent waters) are for *róbalo* (see below), mussels and other shellfish. Due to the severe economic situation of the country from 1989–1990 and the difficulty in finding work, more families resorted to fishing, as shown by the increase in licenses.

The catch may be as much as 400kg of fish per tide or as little as one or two fish. It is difficult to obtain more than two fish per m^2 of net even with large schools, because each captured fish tangles up at least 50cm of net. The *róbalo* begin to arrive in coastal waters in October, are most numerous in December to February and are gone by April or early May. *Pejerrey* are caught throughout the *róbalo* season. Only recently have fishermen discovered that *pejerrey* can also be caught in winter.

A fisherman may obtain about $US 0.50 per kilo of *róbalo* and $US 3.00 to 3.50 per kg of *pejerrey*, since these are usually sold directly instead of through a company like the *centolla*. We have no information on the price of *merluza*, the third most abundant fish caught. The fish are sold fresh to local homes, hotels, restaurants and markets.

On the basis of DRN data, we analyzed reported catch by species and area (Fig. 7). The area with most catch was

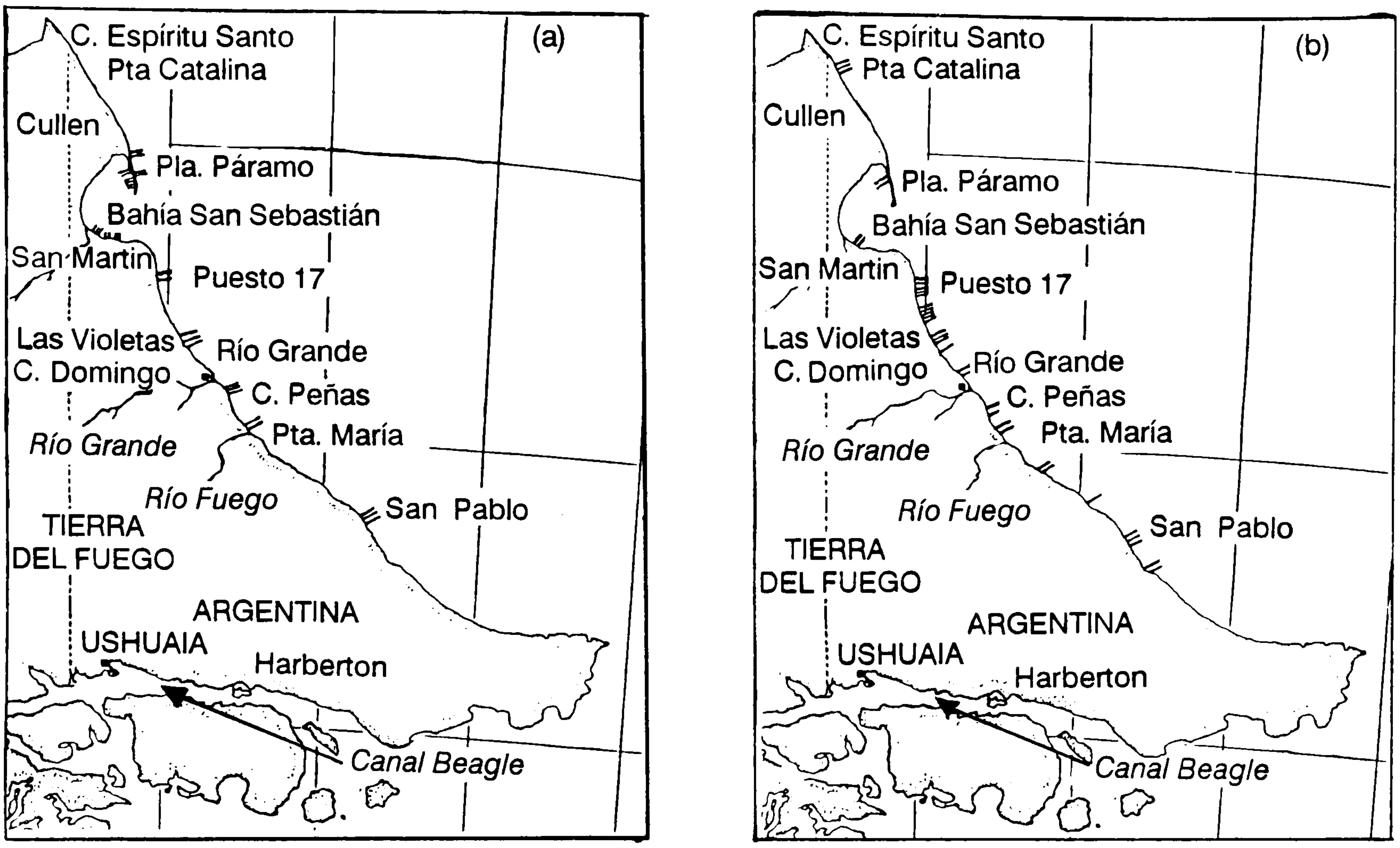

Fig. 5. Principal areas where shore-based nets were set (a: 1976–86; b: 1987–90). Each line represents 1–2 nets.

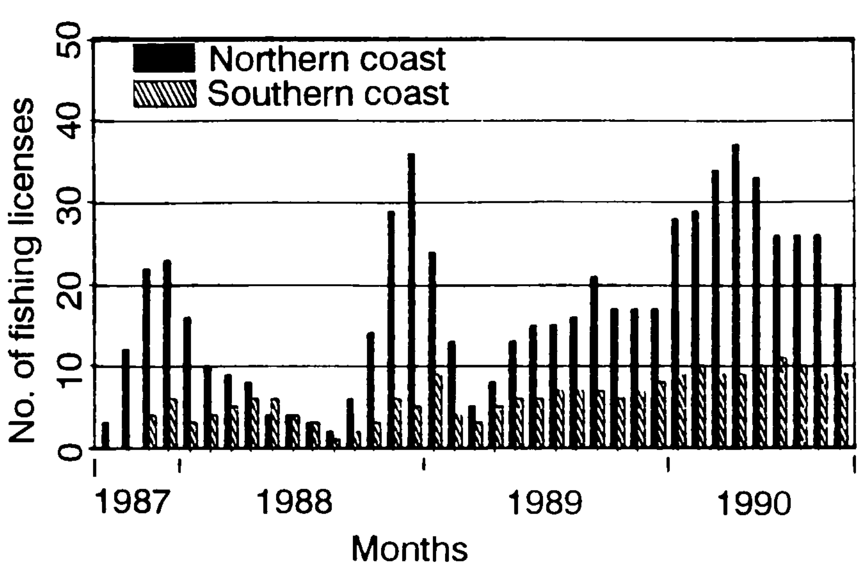

Fig. 6. The number of fishing licenses in use at mid-month for the NE and southern coasts of Argentinian Tierra del Fuego, since the licensing began in September 1987. These include licenses for mussels and other shellfish (mainly south coast).

B, the area with easiest access from Río Grande and for which most fishermen (58%) requested licenses.

This fishing requires a big investment in nets and produces a good return only one or two months a year. Extensive damage to nets is common through bad weather on the exposed coasts or from pinnipeds. The seals and sea lions go for the fish's head, ripping the nets. Nets are not often lost completely so as to become ghost nets at sea, but they may be damaged by waves, moving shingle or debris.

Beagle Channel net fishing

Róbalo enter the Channel mainly in summer but occasionally in spring. Waters in the channel are somewhat more protected than off the north coast, and *róbalo* are fished from inflated boats using a beach seine (*red de cerco*). A typical net is about 70m long, 150cm high, has approximately 30mm mesh and a 250 by 250 by 70cm bag in the center. Fish are located visually before setting the net around them with the boat. Up to 500kg may be taken in one set (J. Varela, pers. comm.).

Line fishing

From November to February some fishermen leave their nets and fish for *róbalo* with lines, either along the coast or more frequently at river mouths and up to 500m up the rivers, where the fish may remain at low tide. Four to five kg fish can be taken with rod and spoon (unbaited), or using a line wrapped around an empty tin can with a block of wood wedged inside for a handle. Some fishermen dig worms from the beach for use as bait.

Scientific fishing

A research program entitled 'Bioecology of Fish Resources of the Beagle Channel', sponsored by the Centro Austral de Investigaciones Científicas (CADIC) in Ushuaia, has been underway since February 1987. The researchers obtain the fish for their study through the use of trammel nets in Ushuaia, Golondrina and Lapataia Bays (all within 30km of Ushuaia) and occasionally in other areas, such as Bahía Aguirre and Río Irigoyen. The nets are set using 5m inflatable boats with 35 HP engines. The nets used (Table 1, Fig. 3) are usually set at depths of up to 20m in the zone near the coastal border of kelp (*Macrocystis pyrifera*). Most remain only one day in the water (96% of the sets, n = 291). Assuming the various types of nets as equal and that each net in the water one day represents one net/day, the fishing effort of the program to date is approximately 8 net/days per month (Fig. 8).

Offshore fishing

Seven ships (Argentine/Russian and Argentine/Japanese) based in Ushuaia since 1989 fish in Fuegian waters. Three others fish off Argentina beyond the 12 mile limit, over the wide continental shelf between Tierra del Fuego and the Malvinas Islands (about 55–53°S) and from there

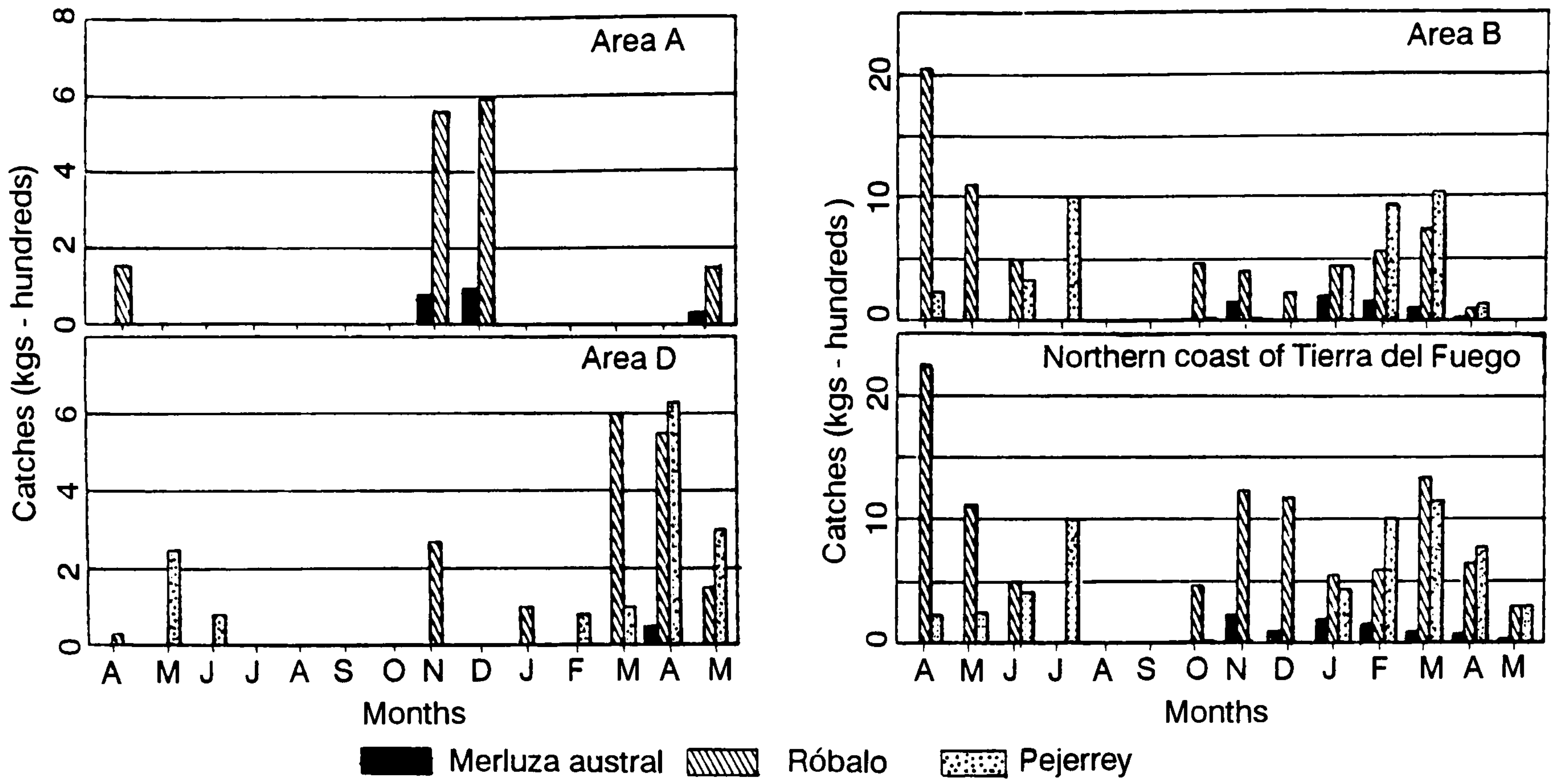

Fig. 7. Tentative data on catches of fish from Cabo Espiritu Santo to San Pablo. Data collection began in April 1989, but many fishermen did not report their catches.

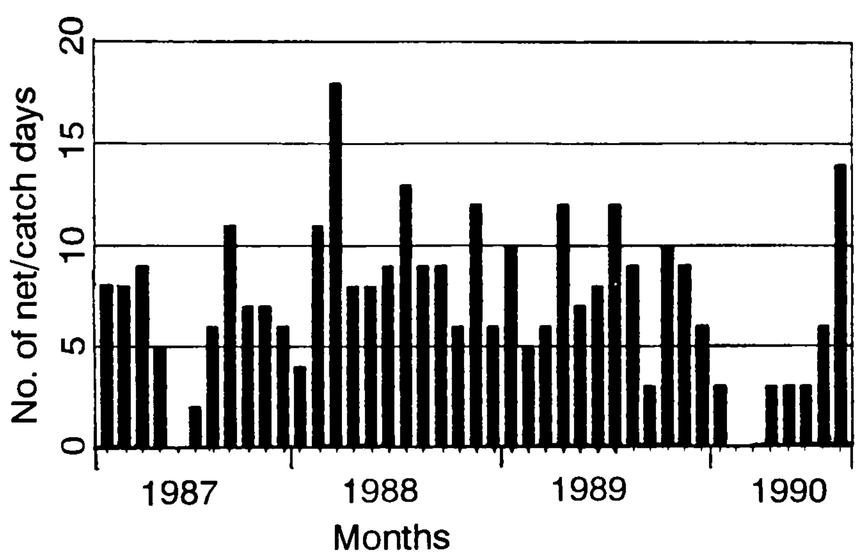

Fig. 8. The number of net/days of scientific fishing carried out per month in the Canal Beagle.

northward to about 45°S. The crews are part Argentine and part foreign. They fish for squid with long-lines (one squid ship was lost SE of Bahía Aguirre in August 1990) or for octopus, *merluza, abadejo* and other fish using trawls. The fish are trans-shipped to a freezer boat at Ushuaia; few fish are sold locally.

Some ships based at Río Gallegos and Puerto Deseado fish waters as far south as Tierra del Fuego, while others, especially foreign vessels based in Punta Arenas, Chile, may fish Fuegian offshore waters (J. Jordan, pers. comm.).

Some of these vessels buy fishing licenses from the UK as well as Argentina, so they have two quotas in the same ecosystem, increasing the fishing effort applied to the SW South Atlantic Ocean.

INCIDENTAL TAKES OF CETACEANS

Small cetaceans, seals and birds, as well as fish, are taken incidentally in the various types of nets, especially those set perpendicular to the shore. Marine mammals are unaffected by *nasa* or line fishing and are seldom if ever taken in beach seines, although one Commerson's dolphin, *Cephalorhynchus commersonii*, which had evidently been taken in such a net, was found on the north shore of the Beagle Channel in 1983. A summary of previously published information on cetacean mortality is given in Table 2.

Centolla nets

Incidental death of dolphins, porpoises and seals was probably extensive during the years when these nets were permitted. This was before our program was in operation, so we have no reliable information on this catch. One Burmeister's porpoise (*Phocoena spinipinnis*) trapped in 1974 was sent to the Museo Argentino de Ciencias Naturales in Buenos Aires, and four trapped in one week in December 1975 were reported to our program (Goodall and Cameron, 1980; Goodall *et al.*, 1990a). We examined a very young Commerson's dolphin taken in crab nets in 1972.

Crab netting continued for several years in Chilean waters after it became illegal; we picked up at least ten Commerson's dolphins which died in this manner along the shores of Bahía Inútil in two days in 1978. Fishermen there told us that 20–30 dolphins died per season in the nets set from two boats (Goodall *et al.*, 1988a).

Róbalo fishing

Marine mammals, especially small cetaceans, are often taken incidentally in shore-based *róbalo* nets (Goodall, 1978; 1989; Goodall and Cameron, 1980; Goodall *et al.*, 1988b).

The species most often taken in the nets is the Commerson's dolphin, which seems to follow the *róbalo* and *pejerrey* in their near-shore movements from October to April (although some fish may remain in the area year round) and have their young near shore in mid-summer (December to January) (Goodall *et al.*, 1988a). Of the coastal fishes, only *pejerrey* has been cited in a study of stomach contents of this species (Bastida *et al.*, 1988); the dolphins evidently follow the fish along the shore into the nets. They have often been observed feeding or playing in the breakers (Goodall *et al.*, 1988a). Fishermen consider

Table 2

Published references on cetacean mammal mortality through shore-based net fishing in Tierra del Fuego. Codes: N = specimens in our collection which were caught in nets; N? = specimens in our collection which were most probably caught in nets; R = incidental take reported by fishermen or others.

C. commersonii			*L. australis*			*A. dioptrica*				
N	N?	R	N	N?	R	N	N?	R	Notes	References
28	-	15	1	-	-	1	-	-	Number much higher	Goodall, 1978
69	-	-	1	-	-	2	-	-	= 72 animals 1975-1979	Goodall & Cameron, 1980 Goodall *et al.*, 1988a
71	75	21	2	19	1	1	-	-	Jan. 1979 - May 1986	Goodall *et al.*, 1988b
Total 167			Total 22			Total 3				Goodall *et al.*, 1988b
Min. 70 - Max. 167			Total 22			Total 3			Jan. 1979 - May 1986	Lichter & Goodall, 1988
236			23			5				

the Commerson's dolphins stupid, as they become immobilized when caught in the net and make no attempt to get loose. Hence more die, but there is less damage to nets. Some dolphins are still alive when the tide recedes and are released.

Fishermen claim that the dolphins are not taken in the *pejerrey* nets because of their fine mesh and because they are set closer inshore.

The second species in numbers taken is probably the spectacled porpoise (*Australophocaena dioptrica*). At first we assumed that the many specimens of this species had stranded, but on mapping the specimens, almost all coincide with spots where nets are set (see map in Goodall, 1990).

Peale's dolphins may be in the area most of the year but they are more numerous in summer. According to the fishermen, when caught in a net Peale's dolphins usually struggle and get out, leaving large holes. Nevertheless, some die (Tables 3 and 4). One live dolphin was returned to the sea, a difficult task on the mud flats.

Burmeister's porpoises also get caught in the nets; other potentially-caught animals are the southern right whale dolphin *Lissodelphis peronii*, fur seals, leopard seals, elephant seals and southern sea lions (Tables 3 and 4).

Previous publications by our program reported about 236 Commerson's dolphins, 23 Peale's dolphins and 5 spectacled porpoises taken in nets from 1975 to 1986 (Table 3). In the present study we reviewed our field notes by year and area. We counted specimens that we know died in nets, specimens that we are fairly sure died in nets, and others reported by fishermen (for which we have no specimens). We arrived at a total of 313 Commerson's dolphins, 34 spectacled porpoises and 20 Peale's dolphins for the period 1975–1990 (Table 4). The area where most dolphins were caught was Bahía San Sebastián (Table 3). This is a minimum estimate; actual catches must have been much greater, perhaps three times as high, because as many animals are washed away by the tide or stripped of flesh by birds (we did not count skeletons unless they were obviously associated with a net) and because there were large gaps in our visits to the fishing areas. Spectacled porpoises especially may have a higher rate of incidental mortality; their carcasses tend to break up quickly and float inland. The mortality of the Commerson's dolphin may be at a dangerous level for a stretch of coast approximately 150nm long.

The cetaceans taken in nets are not used for food in Argentina. Generally they are left on the mud beside the nets, to be scavenged by birds or taken away by the tide. From 1976 to about 1986, fishermen often saved the dolphins for our study, but some were sent to the crab factories for bait. Since DRN has recently been issuing licenses and attempting to control catches, the fishermen now suddenly know nothing at all about dolphins and pretend that they just appear on the beach for unknown reasons.

Table 3

Total number of marine mammals taken by area in passive shore-based set nets in Tierro del Fuego between 1975 and March 1990. Key as Table 2.

	Cephalorhynchus commersonii			*Lagenorhynchus australis*			*Australophocaena dioptrica*			*Phocoena spinipinnis*		*Lissodelphis peronii*	*Arctocephalus australis*		*Hydrunga leptonyx*	*Mirounga leonina*	*Otaria flavescens*	
	N	N?	R	N	N?	R	N	N?	R	N	N?	N?	N?	R	N?	N?	N?	Total
(A) Cabo Espíritu Santo to San Sebastián																		
Total	61	18	40	6	1	3	3	11	1	-	1	4	3	-	-	-	-	152
(B) Cabo San Sebastián to Río Grande																		
Total	57	16	4	1	6	-	1	10	-	1	1	1	-	1	1	1	3	104
(C) Río Grande to Kaitush																		
Total	51	20	24	-	1	-	-	7	-	-	-	-	-	-	3	-	-	106
(D) Kaitush and Southeast[1]																		
Total	10	4	8	1	1	-	-	1	-	-	1	1	-	-	-	-	-	27
Total	179	58	76	8	9	3	4	29	1	1	3	5	3	1	4	1	3	388

[1] This area is greatly under-represented in the collection, as there are fewer suitable beaches for fishing and we made fewer expeditions.

Table 4

Total numbers of marine mammals taken in passive shore-based set nets in Tierra del Fuego. The year indicates the year found, not necessarily date of death. Key as Table 2.

	Cephalorhynchus commersonii			*Lagenorhynchus australis*			*Australophocaena dioptrica*			*Phocoena spinipinnis*		*Lissodelphis peronii*	*Arctocephalus australis*		*Hydrunga leptonyx*	*Mirounga leonina*	*Otaria flavescens*
	N	N?	R	N	N?	R	N	N?	R	N	N?	N?	N?	R	N?	N?	N?
1975[1]	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
1976[1]	1	-	15	-	1	-	-	-	-	-	-	-	-	-	-	-	-
1977	15	2	6	-	-	-	3	2	1	-	-	-	1	-	-	-	-
1978[2]	10	5	13	1	-	-	-	3	-	-	-	3	-	-	1	-	-
1979[2]	6	-	5	2	-	1	-	-	-	-	-	-	-	-	-	-	-
1980	15	3	16	-	2	-	-	3	-	-	1	-	-	-	-	-	-
1981	14	3	3	-	1	-	-	1	-	-	-	-	-	-	1	-	-
1982	29	2	-	1	-	1	-	6	-	-	-	-	-	-	-	1	-
1983	18	6	2	-	2	1	-	1	-	-	-	-	-	-	-	-	-
1984	11	7	3	1	1	-	-	2	-	-	1	-	-	-	-	-	-
1985	3	1	-	-	2	-	-	1	-	-	-	1	-	1	1	-	-
1986	6	7	-	1	-	-	-	1	-	-	1	2	-	-	-	-	-
1987	1	1	6	-	-	-	-	2	-	-	-	-	1	-	-	-	-
1988	23	9	3	-	-	-	-	3	-	1	-	-	1	-	-	-	3
1989	11	2	-	2	-	-	1	3	-	-	-	-	-	-	1	-	-
1990[3]	16	9	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	179	58	76	8	9	3	4	29	1	1	3	6	3	1	4	1	3
Total per species			313			20			34		4	6		4	4	1	3

[1] Record incomplete - only one expedition to area; [2] Fishing and our expeditions curtailed due to near war with Chile; [3] Data to March only.

Scientific fishing

In three years of weekly sets of nets, only one cetacean has been captured during scientific fishing, a juvenile Burmeister's porpoise whose mother swam nearby until the calf was released unharmed, on 14 April 1988 (Sobral, pers. comm.; Goodall *et al.*, 1990b). This low figure of incidental take may reflect depletion of the dolphin populations in the area, mainly Peale's dolphins, by capture of dolphins for crab bait (described below).

Offshore commercial fishing

There are no laws in Argentina requiring reporting of cetaceans taken incidentally at sea, and we have no information on possible mortality in this new and expanding fishery. However, there have been a number of reports of dolphins being taken by similar ships off the Province of Chubut (E. Crespo, pers. comm.; A. Scolaro, pers. comm.; Goodall *et al.*, 1988b).

DIRECTED CATCHES FOR CRAB BAIT

Marine mammals are not taken incidentally in the traps used for *centolla*, but they are often used as the preferred bait for the traps. There is little information on deliberate exploitation in Argentinian waters, limited to the northern half of the Beagle Channel and waters immediately to the east. Any shooting or harpooning of marine mammals is clandestine, but we obtained information and some specimens of at least 23 Peale's dolphins harpooned for bait in July 1979 (Goodall and Cameron, 1980). Obviously the take has been high in past years; Peale's dolphins are no longer seen in the parts of the Beagle Channel where centolla fishing occurs (Goodall, 1978; Goodall and Cameron, 1980; pers. obs.). This is compounded by the fact that half the channel belongs to Chile, where fishermen are more experienced in harpooning dolphins.

In 1987, up to 60–70 sea lions from islets near Isla Gable were killed for bait and a newly established colony was eliminated. About the same time, we were informed of killing of sea lions on islets east of Gable Island on the Chilean side of the channel. There have been recent slaughters of Magellanic penguins and cormorants. The government of Tierra del Fuego, Argentina, enacted in 1989 a decree protecting all birds in the Territory.

Other animals killed and used for bait are sheep, cattle, horses, other sea birds and fish (Goodall and Jordan, 1986). The domestic animals are sometimes bought but often stolen. In 1990 crab companies bought fat, spoiled meat and beef bones from the slaughter house or meat markets for use as bait since the sale of beef has increased with the increase in population. Bones of cattle seem to make an acceptable, longer lasting bait than most of the others.

CONCLUSIONS

All types of fishing activities, except crab trapping, increased in Tierra del Fuego in 1989–90 due to the economic problems of the country as a whole, the lack of work on the island due to closure of factories, and the 'opening' of the Argentine economy. Control by DRN is limited because of understaffing and lack of funds. Offshore fisheries are under very little control, and there are no observers or reporting of captures of fish or incidental take of cetaceans.

In the *centolla* fishery, information on the current levels of capture of marine mammals as bait is needed for both Argentina and Chile. It is imperative to find an alternate type of bait. Methods need to be developed for recovery of ghost traps and for avoiding future loss of traps, or to assure the rapid degradation of lost lines.

The *róbalo* shore fishery takes a large number of coastal dolphins and porpoises. Better relations with the fishermen could result in more accurate data and recovery of carcasses for biological study. Plans are under way for better methods of obtaining data on catches and nets.

Studies are needed to develop methods of protecting coastal cetaceans.

The offshore fishery should be monitored for fishery effort assessment and incidental cetacean catches.

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Africa and Indian Ocean

Marine Mammals and Fisheries Along the West African Coast

Jacques Maigret

Museum National d'histoire naturelle, Cellule de préfiguration de la Galerie de l'Evolution, 36 rue Goeffroy St Hilaire, 75005 Paris, France

ABSTRACT

There are no studies of the relationship between cetaceans and fisheries for West Africa. The widely dispersed unloading centres along the coast make such study difficult. The artisanal fisheries which use a wide variety of gear, do not appear to have any major impact on cetacean populations. This report provides a preliminary review of West African fisheries with particular attention to the problem of catches of marine mammals. The five identified artisanal gillnet fisheries do not often catch cetaceans. Foreign industrial fisheries are more likely to have an impact on cetacean populations.

KEYWORDS: INCIDENTAL CAPTURE; FISHERIES; NORTH ATLANTIC; SOUTH ATLANTIC; BOTTLENOSE DOLPHIN; COMMON DOLPHIN; HARBOUR PORPOISE; HUMP-BACKED DOLPHIN; KILLER WHALE; PYGMY SPERM WHALE; DWARF SPERM WHALE; PYGMY KILLER WHALE; MELON-HEADED WHALE; STRIPED DOLPHIN; SPOTTED DOLPHIN; CLYMENE DOLPHIN; SPERM WHALE; LARGE WHALES-GENERAL

INTRODUCTION

Little information on West African fisheries, marine mammals or interactions between them is available. For this review I contacted people who are working in fishery laboratories, directly or through the relevant departments of international organisations (CECAF/FAO). I received answers from three countries (Mauritania, Senegal and Ivory Coast) where I have personal contacts and from two others (Sierra Leone and Nigeria). This report is the result of bibliographical research and personal experience of the area. It should be considered preliminary.

The data on the fishery activities in each country have been taken from reports, generally unpublished, by the French ministry for co-operation (Moal and Woitellier, 1984), ORSTOM (Fontana *et al.*, 1989) and FAO/CECAF. Little information on cetaceans is available in the literature apart from Cadenat's work in Senegal between 1945 and 1963 and Maigret's from 1970 until 1982. Some data have been published by IFAN (Institut Fondamental d'Afrique Noire, Dakar).

GEOGRAPHICAL AND ECONOMIC FRAMEWORK

West Africa, considered to represent the large region between Morocco and Angola, is characterised by its border with the Atlantic Ocean. The marine mammal populations there have been little studied. They can be divided into three categories:

(1) 'coastal' populations including bottlenose dolphins (*Tursiops truncatus*), common dolphins (*Delphinus delphis*), harbour porpoises (*Phocoena phocoena*), monk seals (*Monachus monachus*) in the North and hump-backed dolphins (*Sousa teuzsii*) and manatees (*Trichechus senegalensis*) in the Gulf of Guinea;
(2) 'migrating' populations including killer whales (*Orcinus orca*), pygmy and dwarf sperm whales (*Kogia breviceps, K. simus*), pygmy killer whales (*Feresa attenuata*), melon-headed whales (*Peponocephala electra*) and several balaenopterid species;
(3) 'pelagic' populations including striped dolphins (*Stenella coeruleoalba*), spotted dolphins (*S. attenuata, S. frontalis*), clymene dolphins (*S. clymene*), spinner dolphins (*S. longirostris*), sperm whales (*Physeter macrocephalus*) and several balaenopterid species.

The eastern Atlantic Ocean near Africa includes two quite different environments: subtropical and tropical. The subtropical zones along the desert coasts in both the Northern and Southern Hemisphere are subject to the regime of the trade winds which leads to the phenomenon of 'upwelling'. These areas, with relatively cold waters, are very productive (e.g. off Mauritania and Angola) with an enormous biomass of phyto- and zooplankton. The tropical zone, by contrast, on both sides of the Equator is characterised by warm water, with low salinity. Productivity is low and is associated with river estuaries. The icthyological fauna is limited.

Although coastal West Africa is largely non-industrial, a few industries are developing. Populations are concentrated in a few large towns such as Casablanca (Morocco), Dakar (Senegal), Lagos (Nigeria) and Abidjan (Ivory Coast), often without technical infrastructures. Although pollution is not thought to be a problem in the region, monitoring is non-existent in some areas.

The exploitation of marine resources is irregular but is increasing with the growth of the population and the economic crisis that is enveloping most African countries; as more food is needed, people are looking to the sea to supply their needs. Current fisheries off West Africa can be divided into three main types: artisanal; local commercial; and foreign.

Artisanal fisheries use small boats (pirogues and canoes) and a variety of gear: lines; purse seines; beach seines; traps and nets. The catches are primarily for local consumption.

Local commercial fisheries involve small boats (often in poor condition), operating under West African national flags and include trawlers, shrimp-trawlers, pilchard-seiners and tuna-liners. Catches may be for local consumption or export (shrimps, cephalopods or tuna).

In addition there have been commercial fishing fleets from foreign countries operating, generally using much larger vessels:

(1) bottom trawlers from Japan, Korea, USSR (now the Russian Federation), Spain and Portugal that take cephalopods, shrimp and seabream;

(2) mid-water trawlers from USSR (now the Russian Federation), Poland and Romania that take small pelagic fishes, mainly pilchard, horse mackerel and mackerel (a fleet of seiners working with factory ships for fish meal disappeared from the area between 1978 and 1980);
(3) oceanic tuna-clippers from France, Spain and the USA using large purse-seines;
(4) tuna bait-boats from Spain, France, Taiwan, Korea and Japan; and
(5) tuna long-liners from Korea and Taiwan (some use also driftnets).

These international commercial fleets do not unload in African ports and work within the framework of fishing agreements with each state. They are difficult to control and their catches are only known from the declarations of the country of origin. Although they are largely outside the scope of this report, some may have cetacean bycatches.

COMMERCIAL FISHERIES

It might be argued that all fisheries have some impact on cetacean populations in that they reduce the fish stocks. Small pelagic fishes and cephalopods are the main prey of cetaceans; FAO (1982) estimated their biomass in the area at approximately 3–4,000,000 tonnes and they have been overexploited in some areas. This factor must be borne in mind in any consideration of the relationship between marine mammals and fisheries.

Demersal fisheries probably have little direct interference with cetaceans, but others, including pelagic trawling and purse seining, do include cetacean bycatches.

It has sometimes been reported that the catches of dolphins (e.g. common dolphins and *Stenella* spp.) occur mainly at night, perhaps because at that time the animals are moving slowly near the surface and are less alert. We observed such catches on board Romanian trawlers. One night in May 1980, the trawler '*Otlet*' caught six common dolphins in its first haul and 22 in the second; all were dead when brought on board. The fleet working in the same area included 12 trawlers; all caught dolphins, but we could not determine the exact number. It is difficult to determine the exact numbers of pelagic trawlers from eastern Europe that operate in these waters and it is not possible to extrapolate these numbers to the total pelagic trawler fleet because catches are not made all year round and are dependent on fishing gear and, of course, on the presence of dolphins with the concentrations of pelagic fish.

The tuna fisheries in the area use several different techniques, as described below.

(1) *Pole and line boats with rods and living bait*. Boats from African coastal countries as well as Spain and France use this method. It does not appear to affect cetaceans. Dolphins are often used as a cue for detecting tuna as the two often coincide (although the relationship is not as strong as in the eastern Tropical Pacific).
(2) *Long-liners*. Vessels from Japan, Korea and Taiwan operate from the Canary Islands and Tema (Ghana). I have no information on the activities of these boats. That some of them use driftnets has been confirmed by observations in Mauritania (M. Ba, pers. comm.). Two large cetaceans were observed caught in nets in March and September 1989 by N.O. '*N'Diago*' off Cape Timiris (19°40'N, 16°30'W). The larger measured about 25m and the smaller 10m, but the species were not identified.
(3) '*Purse seiners*'. Vessels from the FIS fleet (France, Ivory Coast and Senegal), from Spain and sometimes clippers from the USA operate. Levenez *et al.* (1979) and Maigret (1981) have reported on the relationship between the Atlantic tuna fishery and marine mammals. The fishing techniques are different to those used in the eastern tropical Pacific and the captains do not use the dolphins to locate concentrations of tuna schools. Consequently, the catches in seines are less dramatic. After 1980, the FIS fleet was greatly reduced by the transfer of some vessels to the Indian Ocean.

COUNTRY ACCOUNTS

Morocco

The fish stocks of Morocco can really be considered as being 'European' and of the temperate Atlantic rather than African. Little information on Moroccan fisheries can be found in 'West African' literature and in spite of contacts in the Fishery Institute I did not obtain any additional information to that published.

There are several types of fisheries in the Moroccan zone.

Bottom-trawl fishery

Vessels from Spain and Portugal take seabream and shrimp and in the south vessels from Japan take cephalopods.

Pelagic fishery

The Soviet fleet sometimes caught pelagic fish species in the south, off western Sahara.

National fishery

A well-developed fishery exists that uses small bottom-trawlers, seines (pilchard) and some gillnets – although no quantitative information is available it is likely that a few cetaceans are caught.

TUNA FISHERY

In the northern ports of Morocco some small boats operate with driftnets. The fishery is also developing quickly in the south, where fishermen are replacing purse seines with driftnets. The total catches (including longlines and seines) are about 3,000 tonnes per year. No information on cetacean bycatches is available.

LOBSTER FISHERY

A coastal set net fishery for lobsters (*Panulirus regius*) in the south of Morocco (Western Sahara) with nets deployed in the evening (between 0 and 10m deep) was operated by France and Spain until 1975. It stopped between 1975 and 1980 because of the Polisario conflict, giving the lobster population time to recover. Exploitation started again in 1981 in the south (La Güera and Nouadhibou), this time using Senegalese pirogues and more recently has included larger vessels from Moroccan ports. The fishery takes place in the area of the most important monk seal colony. According to the fishermen, they do not catch seals in their nets but they sometimes do catch porpoises and dolphins (about ten per year between 1980/82 in Nouadhibou).

Mauritania (Table 1)

As noted earlier, common dolphins and *Stenella* spp. are caught by eastern European pelagic trawlers (42 trawlers in 1988). An estimated minimum of about 500 to 1,000 dolphins per year are caught. Harbour porpoises and other dolphins are taken by the artisanal lobster fishery in the

Table 1

Fleets operating and catches in Mauritania (1988). Coastline = 700km.

Vessel type	No.	Vessel type	No.
National		*Foreign*	
Artisanal	750	Lobster boats	18
Trawlers	133	Bottom trawlers	116
		Pelagic trawlers	42
		Seiners	2
		Tuna clippers	20
		Liners	5

Catches:	Pelagic fish	Demersal fish	Tuna
Tonnes:	443,000	108,000	6,100

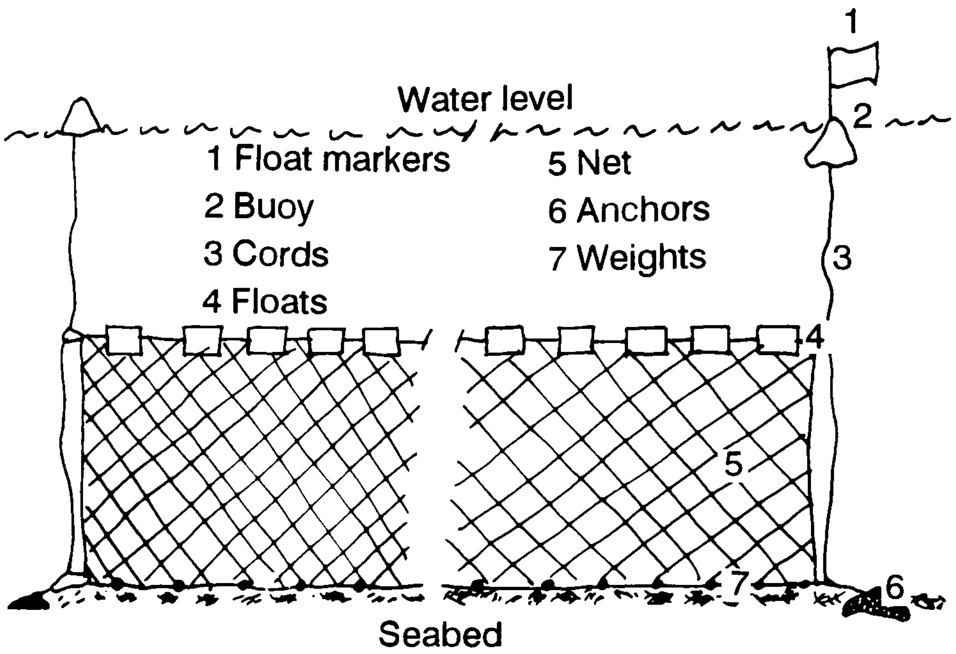

Fig. 2. Setnet used by the artisanal fishery in Mauritania and in other countries of Guinean Gulf (Diop and Mohammed, 1990).

border area between Morocco and Mauritania (estimated at less than 20 per year, but the population is thought to be small along the northwestern African coasts).

In the 1980s, the artisanal fishery (Fig. 1) numbered about 600 boats (it recently decreased from 770 boats in March to 450 in August 1989 – Diop and Mohammed, 1990) using different gear: lines, palangres, traps, pots for octopus and gillnets (Fig. 2). Since 1980, new gillnets (set nets) made with nylon monofilament have been given to the fishermen as part of a Japanese aid programme to Mauritanian fisheries. The nets, although very efficient for fishes, also entangle marine animals. Between 1980 and 1982 I observed the catches of ten dolphins (bottlenose and common dolphins), one monk seal, one female killer whale (perhaps not killed by nets but by a boat's propellers) and several turtles (*Caretta caretta* and *Dermochelys coriacea*).

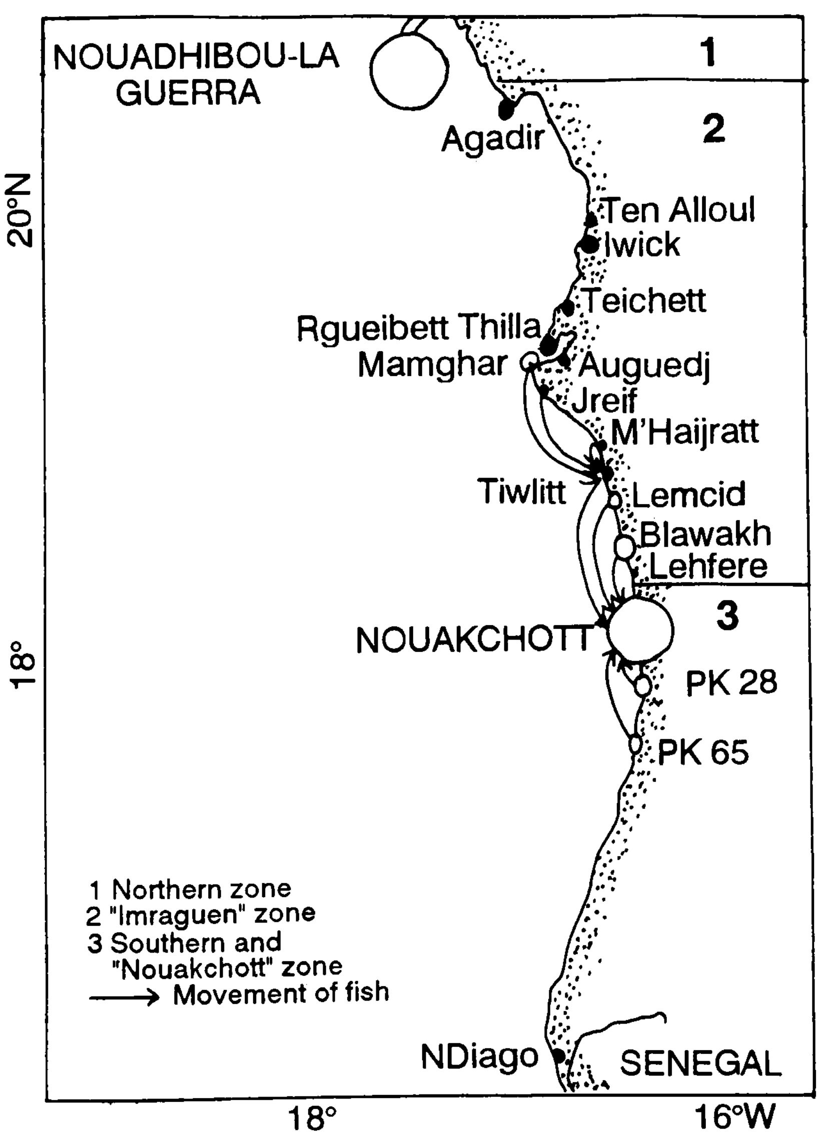

Fig. 1. Coast of Mauritania with the unloading centres for artisanal fishery (Diop and Mohammed, 1990).

The Imraguen fishery on the Banc d'Arguin uses the help of bottlenose dolphins to guide the mullet shoals to their nets. Around about 1980, they changed from their traditional fishery to the use of gillnets which increased the risk of catching dolphins. Although no captures have been reported, the Atlantic hump-backed dolphin is found in this area.

Senegal (Table 2)

The artisanal fishery comprises some 4,500 small boats (8 to 12m), in addition to the pirogues without engines which work in the estuaries and involves some 35,000 fishermen. There are more than 180 points of unloading along the coast. Catches of dolphins are prohibited in Senegal and are not declared; officially there is no catch of marine mammals (CRO Dakar-Thiaroye, pers. comm.). However, Maigret (1981) reported average catches of 2–3 dolphins each month in purse seines in M'Bour in 1977, the most important unloading point on the south coast. The animals are immediately cut up and eaten by the fishermen. About 30–50 dolphins (bottlenose dolphins, common dolphins and sometimes *Stenella* spp.) are caught each year in this part of Senegal. In the north, around Kayar, I found many marine mammal carcasses and skeletons, some of them probably relating to fishery activities far from the shore, but this area is a zone of mass stranding (Maigret, 1979). Despite the paucity of information, I believe that the total catches of the artisanal fishery in Senegal do not exceed 100 cetaceans per year.

Table 2

Fleets in operation and catches in Senegal (1988). Coastline = 700km.

Vessel type	No.	Vessel type	No.
National		*Foreign*	
Artisanal	4,500	Trawlers	41
Trawlers	750	Palangres	4
Seiners	5	Tuna seiners	39
Tuna seiners	3	Tuna liners	16
Tuna liners	2		

Catches:	Pelagic fish	Demersal fish	Tuna
Tonnes:	182,000	83,000	17,200

Manatees (*Trichechus senegalensis*) are also caught on the estuaries of the rivers Senegal, Saloum and Casamance. Again, although their capture is officially prohibited, a few years ago I found manatee meat on the market in towns in the Saloum Delta.

Cape Verde Islands (Table 3)

About 4,000 fishermen work in Cape Verde; 60% use lines while the remainder use traps and set nets for lobsters or use beach purse seines. The continental shelf is too narrow to allow much development of an artisanal fishery. The industrial fishery is mainly for tuna with lines and purse seines but some driftnets (mesh 160mm) may be used off the coast to catch tuna and bonito (Prado and Smith, 1994). There is no information on bycatches of cetaceans but the Cape Verde Island area includes concentrations of sperm whales (*Physeter macrocephalus*) and possibly humpback whales (*Megaptera novaeangliae*) in winter.

Table 3

Fleets operating and catches in Cape Verde Islands (1988).

Vessel type	No.	Vessel type	No.
National		*Foreign*	
Artisanal	536 [1]	Tuna boats	4
Liners	59		
Tuna boats	10		
Catches:	Pelagic fish	Demersal fish	Tuna
Tonnes:	3,800	920	6,200

[1] 120 without engine.

Gambia (Table 4)

The artisanal fishery includes 400 pirogues, 300 working in the open sea and the remainder in the estuary of the Gambia river, employing about 1,800 fishermen. There are 11 points of unloading on the coast. The number of coastal purse seiners decreased from seven in 1982 to three in 1988. These are Ghanaian vessels, as are all those operating in the Gulf of Guinea. There is no information on fishery/marine mammal interactions, although the situation is probably similar to that in Senegal.

Table 4

Fleets operating and catches in the Gambia (1988). Coastline = 100km.

Vessel type	No.	Vessel type	No.
National		*Foreign*	
Artisanal	400	Tuna seiners	37
Trawlers	3	Tuna liners	11
		Palangres	6
		Trawlers	33
		Seiners	3
Catches:	Pelagic fish	Demersal fish	Tuna
Tonnes:	10,500	10,000	280

Guinea – Bissau (Table 5)

Although the number of vessels in the foreign fleet appears large, the vessels do not work in Guinea-Bissau waters all year round. The artisanal fishery includes 400–750 pirogues, dispersed in the mangrove channels along the coasts; it is essentially a subsistence fishery for shrimps and pilchards. Nothing is known about interactions with marine mammals.

Table 5

Fleets operating and catches in Guinea-Bissau (1988). Coastline = 350km.

Vessel type	No.	Vessel type	No.
National		*Foreign*	
Artisanal	400	Trawlers	135
		Tuna seiners	11
		Tuna liners	45
Catches:	Pelagic fish	Demersal fish	Tuna
Tonnes:	91,300	36,000	2,600

Guinea (Table 6)

The bottom trawler fleet (there were 11 vessels in 1982) from east European countries is not controlled. Trawlers from the European Economic Community also operate, and often unload in Conakry. The artisanal fishery employs 8,000 fishermen, most of whom are foreigners (Sierra Leone, Ghana). Gear includes lines, palangres, set nets and dams in the mangrove channels. Driftnets may be used (Prado and Smith, 1994) to catch sharks (mesh 570mm) and barracuda (mesh 150mm). There are 80 unloading points along the coast. There is no information on fishery/marine mammal interactions.

Table 6

Fleets operating and catches in Guinea (1988). Coastline = 510km.

Vessel type	No.	Vessel type	No.
National		*Foreign*	
Artisanal	1,700 [1]	Trawlers	99
Trawlers	3	Palangres	8
		Tuna liners	11
		Tuna seiners	45
Catches:	Pelagic fish	Demersal fish	Tuna
Tonnes:52,500	143,000	3,800	

[1] 400 with engine.

Sierra Leone (Table 7)

The number of pirogues appears to have decreased considerably during the 1980s (7,000 in 1982, only 700 in 1988). Over the same period, the number of Soviet mid-water trawlers decreased from 83 to 45. There are numerous unloading centres, especially for catches of the Madeiran sardinella (*Sardinella maderensis*) and the African ethmalosa (*Ethmalosa fimbriata*). I received some information from Tombo, one of the artisanal purse-seine fishery centres where a German fishery pilot project is operating (A.C.V. Forbe, pers. comm.). The fishery uses two kinds of pirogues: traditional pirogues, 13–15m long with an outboard engine (of the Ghanaian type) and a larger type, 15–20m long with a diesel engine. About 70 pirogues operate from the village. The fishermen (12–21

Table 7

Fleets operating and catches in Sierra-Leone (1988). Coastline = 510km

Vessel type	No.	Vessel type	No.
National		*Foreign*	
Artisanal	700	Trawlers	39
Trawlers	24	Pelagic trawlers	45
Catches:	Pelagic fish	Demersal fish	Tuna
Tonnes:	140,000	22,500	2,400

per boat) use polyamide ring-nets (mesh 35 to 45mm). Fishing effort consists of about 10,500 fishing trips per year of 4 to 8 hrs each. They catch about 8,000 tonnes, mainly *Sardinella maderensis* (47%) and *Ethmalosa fimbriata* (43%). Very infrequently (once or twice per year) 'porpoises' and manatees are entangled in the centre of the net; they are dead before being disentangled and are consumed locally.

Liberia (Table 8)
Almost nothing is known about the fishery activities in this country.

Table 8

Fleets operating and catches in Liberia. Coastline = 550 km.

Vessel type	No.	Vessel type	No.
National		*Foreign*	
Artisanal	Hundreds	Unknown	-
Commercial	18		
Catches:	Pelagic fish	Demersal fish	Tuna
Tonnes:	2,000	5,700	4,300

Ivory Coast (Table 9)
The artisanal fishery (Fig. 3) employs 36,000 fishermen, of which almost 31,000 are foreigners. It includes some 400 pirogues and the use of 3,350 gillnets, 240 purse seines and 50 beach seines. The artisinal fishery appears to involve few interactions with marine mammals (cf. Senegal). A driftnet fishery for tunas, swordfish and sharks was introduced in 1983 (F.X. Bard, pers. comm.). It developed in two ports, San Pedro and Abidjan, with respectively 10 and 20 pirogues (Fig. 4) from Ghana each fitted with 40HP outboard engines and a crew of eight. In the evening the nets are put out at the surface, in water deeper than 1,000m and retrieved during the same night. There are about 1,500 fishery trips per year and the catches (about 200 tonnes) are sold on the local market. Dolphins are caught incidentally but as catches of marine mammals are prohibited in the Ivory Coast, they are not declared but are consumed by fishermen or buried on the beach. The number of marine mammals caught is not known. Many coastal populations of the Gulf of Guinea worship marine mammals and they do not like catches of dolphins. When they find an animal dead on the beach, they bury it ceremonially.

Table 9

Fleets operating and catches in the Ivory Coast (1988). Coastline = 700km.

Vessel type	No.	Vessel type	No.
National		*Foreign*	
Artisanal	700	Tuna seiners	?
Trawlers	9		
Shrimp trawlers	3		
Seiners	19		
Catches:	Pelagic fish	Demersal fish	Tuna
Tonnes:	66,000	10,600	7,000

Ghana (Table 10)
In contrast with other African countries, Ghana, like Senegal, has a strong maritime tradition and fishermen from Ghana have colonised the coast from Mauritania to the Congo, bringing their fishing techniques with them.

The pelagic fishery is well developed with pirogues and purse seiners, both of which probably cause some marine mammal mortality.

The origin of the swordfish fishery (cf. Ivory Coast) is Cape Three Points. F.X. Bard (pers. comm.) reports that he saw one dolphin caught in Dixcove (Western Ghana) in May 1988. There is no information on the number of marine mammals killed.

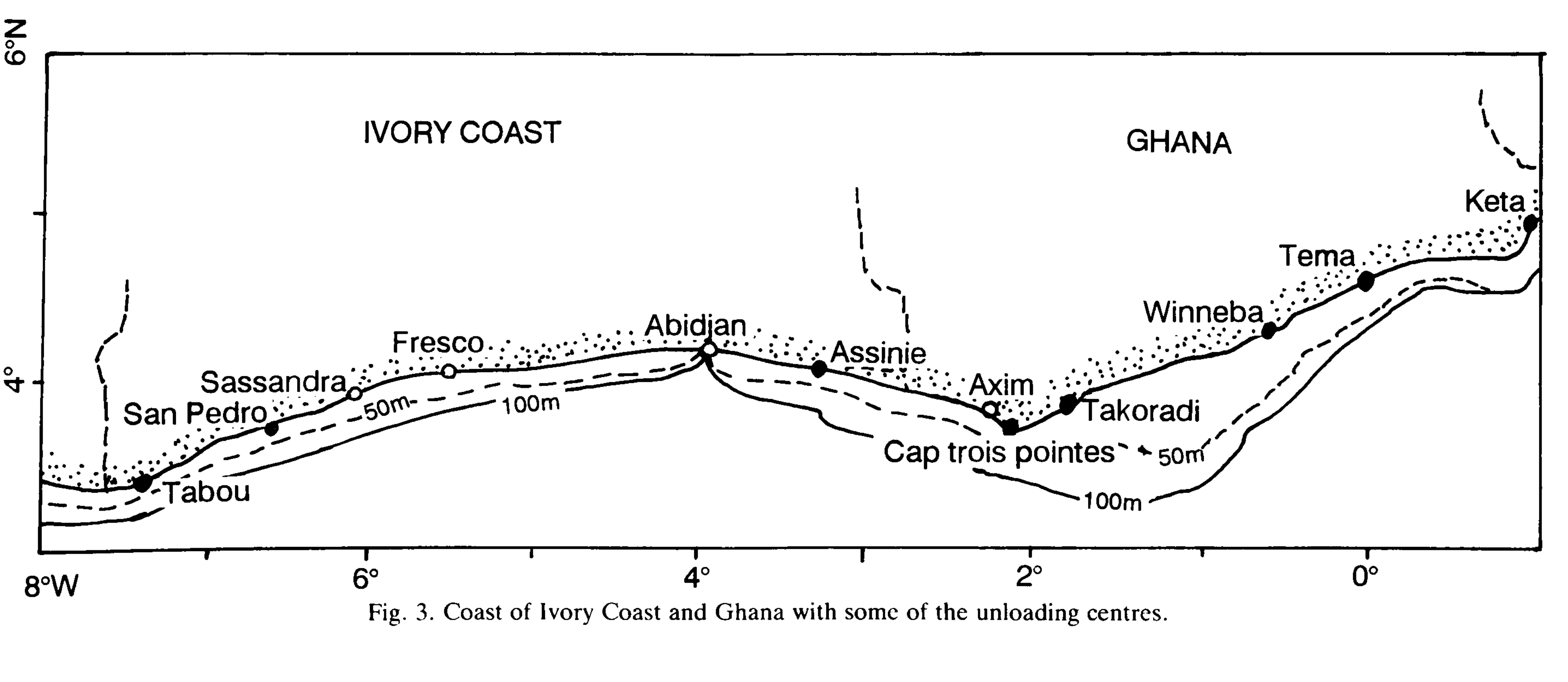

Fig. 3. Coast of Ivory Coast and Ghana with some of the unloading centres.

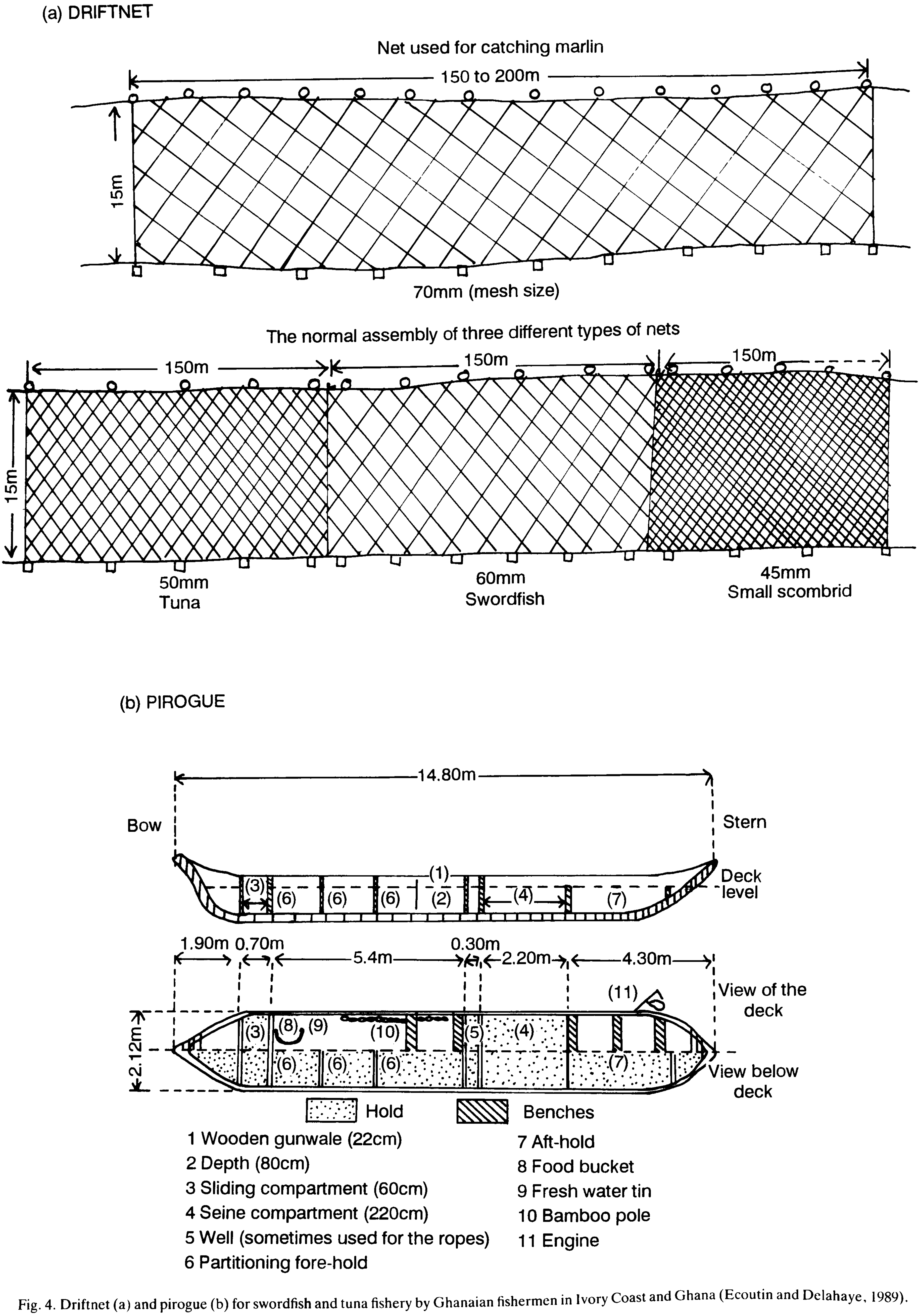

Fig. 4. Driftnet (a) and pirogue (b) for swordfish and tuna fishery by Ghanaian fishermen in Ivory Coast and Ghana (Ecoutin and Delahaye, 1989).

Table 10

Fleets operating and catches in Ghana (1988). Coastline = 500km.

Vessel type	No.	Vessel type	No.
National		*Foreign*	0
Artisanal	8,000		
Trawlers/seiners	230		
Trawlers	17		
Tuna seiners	27		
Tuna liners	6		
Catches:	Pelagic fish	Demersal fish	Tuna
Tonnes:	236,000	61,000	7,900

Table 11

Fleets operating and catches in Togo (1988). Coastline = 100km.

Vessel type	No.	Vessel type	No.
National		*Foreign*	0
Artisanal	320		
Commercial	1		
Catches:	Pelagic fish	Demersal fish	Tuna
Tonnes:	10,000	330	1,000

Table 12

Fleets operating and catches in Benin (1986-1988). Coastline = 900km.

Vessel type	No.	Vessel type	No.
National		*Foreign*	0
Artisanal	300		
Trawlers	6		
Catches:	Pelagic fish	Demersal fish	Tuna
Tonnes:	4,200	3,600	700

Togo (Table 11)

Togo fisheries (Fig. 5) are not large due to the narrow continental shelf. The artisanal fishery is concentrated around the main town, Lome. About 80% of the fishermen are Ghanaian. The pirogues use two types of nets (Weigel, 1984):

(1) *awli* nets that resemble a ring-net without rope and are 400–1,000m long by 30–50m deep, with 25mm mesh; and

(2) gillnets or *tonga*, made with 2–5 panels of about 3m in length with mesh sizes varying from 25mm at the top to 100mm at the bottom.

Benin (Table 12)

Fishermen from Benin fish in several other neighbouring countries. The fishery in Benin itself is limited to lagoons because the continental shelf is too narrow for the development of artisanal activities. The gear types used are the same as in other countries: lines, palangres, seines and gillnets. A small fishery for *Sardinella* with driftnets (mesh 40mm), similar to those described for Nigeria below, was reported by Prado and Smith (1990).

Nigeria (Table 13)

Given that Nigeria is the largest and most heavily populated (over 100,000,000) country in West Africa, its marine fisheries are not well developed. The artisanal fishery operates principally in the estuaries and lagoons. Of

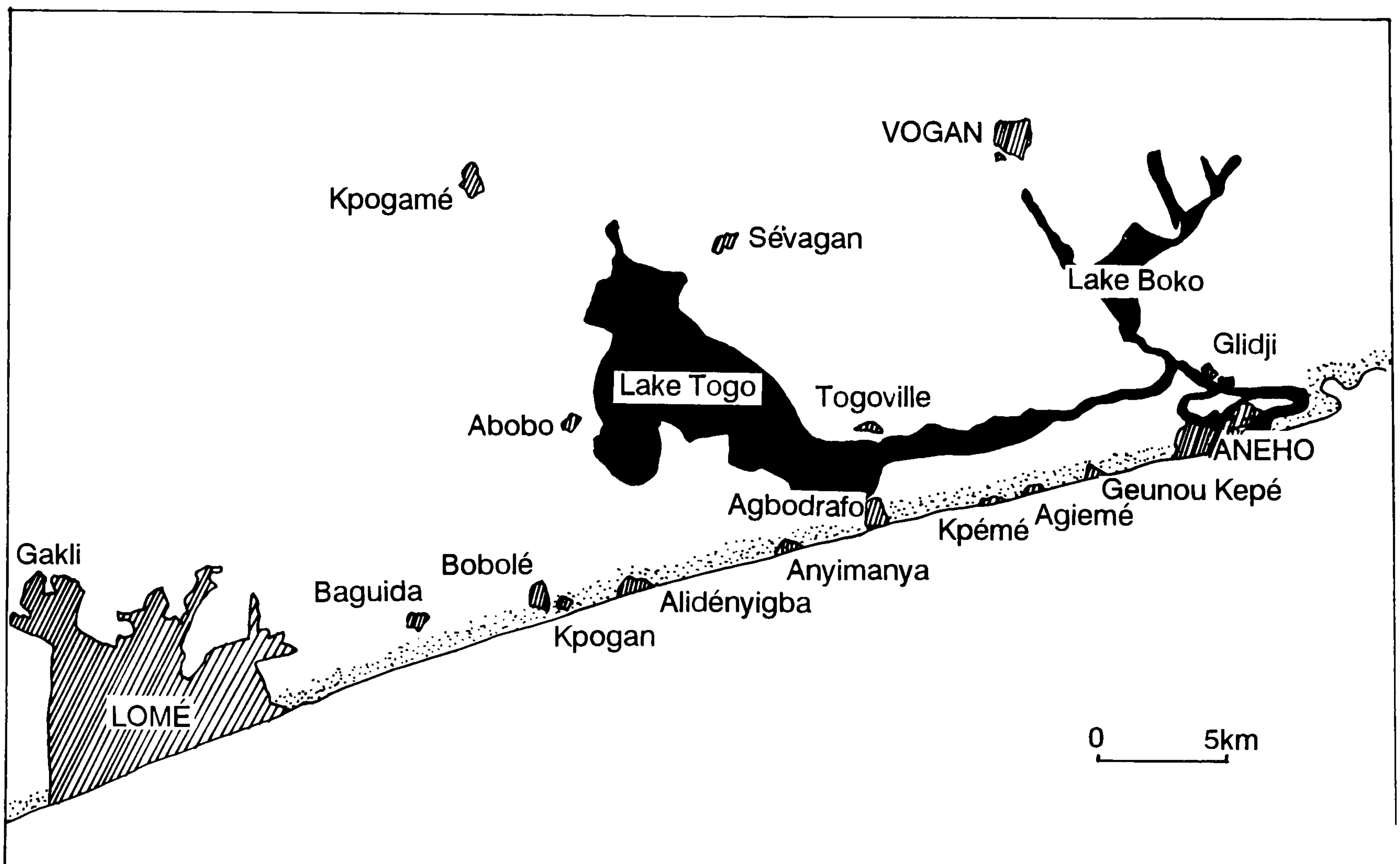

Fig. 5. Coast of Togo and artisanal fishery centres (Weigel, 1984).

Table 13

Fleets operating and catches in Nigeria (estimated 1988). Coastline = 900km.

Vessel type	No.	Vessel type	No.
National		*Foreign*	A few
Artisanal	110,000		
Trawlers	70		
Shrimp trawlers	40		
Catches:	Pelagic fish	Demersal fish	Tuna
Tonnes:	48,300	135,000	700

the 110,000 pirogues, only 20,000 are fitted with outboard engines. A mixed driftnet/surrounding-net fishery exists along the coast of Nigeria (P.E.K. Udolisa, pers. comm.). The pirogues are 7–11m and use monofilament nets 45–75m long, 10–17m deep and with mesh sizes of 50–63mm. The target species are small pelagic fish (*Sardinella* and *Ethmalosa*) for the domestic market. Little is known of the activities of this fleet which is widely spread along the coast. Although some cetaceans are incidentally caught, the number is not known.

Fishing occurs in the area where both the hump-backed dolphin and the manatee live and both are probably caught in the nets. Manatee meat is highly prized and manatees might be hunted in the mangrove channels to be sold on the market as in several other West African countries (cf. Senegal).

Cameroon (Table 14)

Typically for this part of the Gulf of Guinea, Cameroon's continental shelf fishery is small and the productivity of the waters is limited. The artisanal fishery exploits the richer estuaries and lagoons. Fishing is a domestic activity and the catches are unloaded at more than 120 centres along the coast, particularly around the capital Douala.

Table 14

Fleets operating and catches in the Cameroons (1988). Coastline = 360km.

Vessel type	No.	Vessel type	No.
National		*Foreign*	0
Artisanal	2,000		
Trawlers	15		
Shrimp trawlers	16		
Catches:	Pelagic fish	Demersal fish	Tuna
Tonnes:	1,800	700	10,400

Equatorial Guinea (Table 15)

The artisanal fishery uses principally lines, palangres (on the rocks of the continental shelf) and also some setnets and beach-seines on the shore. No additional information is available.

Sao Tome and Principe (Table 16)

Five fishery centres employ 3,000 fishermen, but only 1,000 of these work full time. In addition to the three main ports (Sao Tome, Principe and Neves) there are many small centres which are used for unloading the fish. The artisanal fishery uses gillnets and sweepnets to catch small pelagic fish, and lines and palangres for bottom fish. Tuna is caught with driftnets. The fisheries are potentially dangerous for cetaceans, but it is not known if any are incidentally caught.

Table 15

Fleets operating and catches in Equatorial Guinea (1988). Coastline = 200km.

Vessel type	No.	Vessel type	No.
National		*Foreign*	
Artisanal	700	Trawlers	10
Liners	Some	Tuna seiners	48
Catches:	Pelagic fish	Demersal fish	Tuna
Tonnes:	1,800	700	10,400

Table 16

Fleets operating in Sao Tome and Principe Islands (1988).

Vessel type	No.	Vessel type	No.
National		*Foreign*	
Artisanal	1,500 [1]	Tuna seiners	48/50
Liners	6		
Trawlers	2		
Traps	1		

[1] Only 300 with engines.

Gabon (Table 17)

The artisanal fishery comprises only foreign fishermen (from Ghana, Nigeria and Benin) and operates in estuaries and lagoons. There is a small driftnet fishery on the continental shelf taking bottom species and small pelagic fishes (mesh size 60mm) and as in Nigeria (Prado and Smith, 1990) it is developing rapidly. The industrial fishery exploits bottom fishes with lines and palangres, and shrimps with trawls. There is no information on fishery/marine mammal interactions.

Table 17

Fleets operating and catches in Gabon (1988). Coastline = 800km.

Vessel type	No.	Vessel type	No.
National		*Foreign*	
Artisanal	700/800	Trawlers	3
Trawlers	9	Tuna seiners	No agreements
Shrimp trawlers	18		
Liners	7		
Catches:	Pelagic fish	Demersal fish	Tuna
Tonnes:	3,000	7,200	13,800

Congo (Table 18)

The artisanal fishery comprises 200 pirogues (Fig. 6) and some 16 unloading centres. Lines and gillnets are both used. There is no maritime tradition in the Congo and the fishermen principally come from Benin.

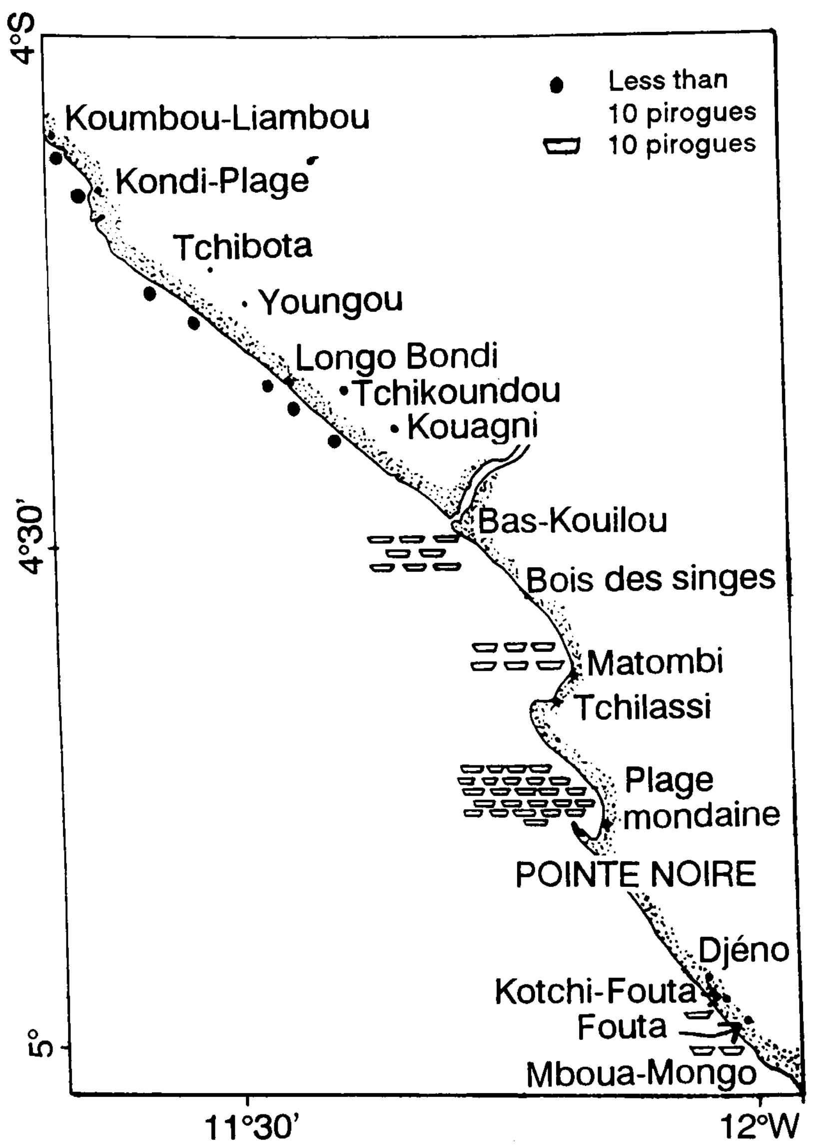

Fig. 6. Coast of Congo and distribution of pirogues in the fishery centres (Fontana, 1981).

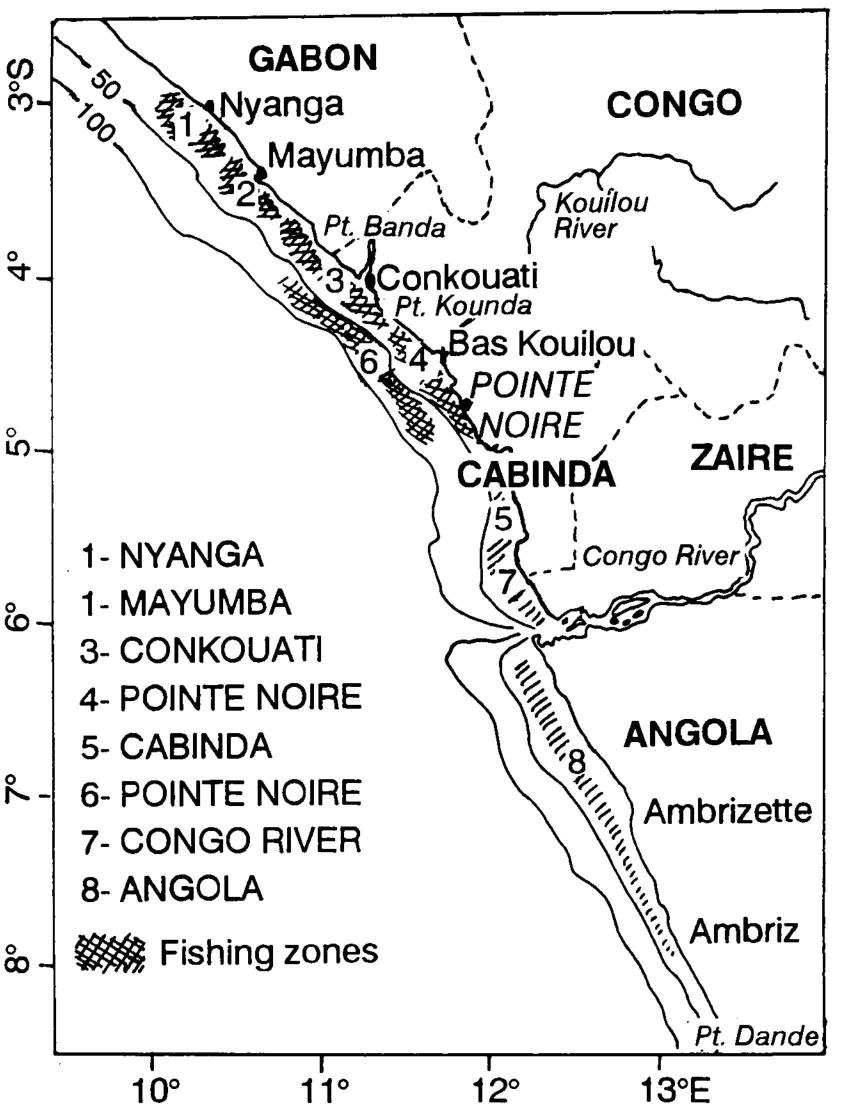

Fig. 7. Coast of Congo, Cabinda, Zaire and north of Angola (Fontana, 1981).

Table 18

Fleets operating and catches in the Congo (1988). Coastline = 180km.

Vessel type	No.	Vessel type	No.
National		*Foreign*	
Artisanal	150/200	Shrimp trawlers	-
Seiners	5	Tuna seiners	-
Trawlers	13		
Tuna seiners	3		
Catches:	Pelagic fish	Demersal fish	Tuna
Tonnes:	8,500	5,200	300

Table 19

Fleets operating and catches in Angola (estimated 1988). The fleet of East European countries is not included in this Table. Coastline = 1,600km.

Vessel type	No.	Vessel type	No.
National		*Foreign*	
Artisanal	Unknown	Shrimp trawlers	37
Seiners	120	Tuna seiners	23
Trawlers	33		
Tuna liners	43		
Nets	12		
Liners	7		
Catches:	Pelagic fish	Demersal fish	Tuna
Tonnes:	565,000	65,000	7,000

Cabinda and Zaire

I was unable to obtain information on fisheries in either of these countries.

Angola (Table 19)

Angola (Fig. 7) is in a similar situation to Mauritania, with high fish production and a strong foreign fleet, particularly from east European countries (USSR, Poland and Romania). There is little information on these fisheries but the problems for marine mammals are probably similar to those for Mauritania.

I have no information on artisanal fisheries but, as there is no maritime tradition, fishing activity is probably slight.

CONCLUSIONS

There is no traditional fishery for marine mammals in West Africa. Incidental catches appear to be rare in local fisheries. Catching cetaceans will often result in the loss or destruction of the net and a heavy financial loss for the fishermen, who are often poor. Some coastal populations have a high regard for marine mammals and in some cases their religious belief prohibits their capture (e.g. the Imraguen of Mauritania).

Similar fishing techniques are used throughout the region and are often employed by the same people (Oualofs of Senegal, Beninois and Ghanaians) who migrate temporarily or permanently to other coastal areas bringing their techniques and fishing gear. Pirogues, lines and palangres, sweepnets and setnets probably have no effect on marine mammals. Seines and gillnets may result in entanglement of cetaceans but such catches are rare; the former are used to catch small pelagic fish such as *Sardinella* and *Ethmalosa*. The mesh sizes (between 30 and

100mm) can entangle dolphins but the fishing technique used allows them to swim out of the net before the net is closed. Cetacean catches are so destructive to the nets that the fishermen prefer to catch nothing at all.

Dolphins are occasionally entangled in set nets used to catch bottom fish while anchored in rocks and channels (e.g. South Moroccan lobster fishery). The panels are made up of several pieces of net, none longer than 100m. With the introduction of nylon monofilament nets in the 1980s there has been an increase in the catches of marine mammals in such nets. I was unable to determine the extent to which this kind of net is used. They are more difficult to maintain and repair and under the conditions of African fisheries they do not last long. Their use should be monitored and discouraged given their more harmful effect on marine mammals.

It seems that only the new tuna fishery in Morocco and the driftnet swordfish fishery by Ghanaians are likely to catch large numbers of cetaceans. Although I did not obtain information on the use of driftnets in other countries, they are probably employed elsewhere.

I obtained little information on direct hunting for manatees and there is little information on its status. Where information does exist (e.g. Senegal), manatees appear to be rapidly decreasing.

It appears from this survey that the artisanal fisheries of West Africa are in general not sophisticated or intense enough to have a large direct effect on marine mammals. However, foreign industrial fisheries are more likely to be able to deplete cetacean populations (e.g. mid-water trawlers from eastern Europe and the tuna-clippers from east Asia). Monitoring of such fleets is necessary but their mode of operation makes this difficult.

RECOMMENDATIONS

Fundamental research (distribution, ecology and status) on marine mammal populations along the West African coast is required, particularly on endemic and possibly endangered species such as the Atlantic hump-backed dolphin, the manatee and the monk seal.

Although it is necessary to determine the structure of the fisheries along the African coast, in the long term, such studies are only useful if the countries and their fishermen understand why they should protect marine mammals, despite the apparent increasing demand for food for their populations. Consequently, a training programme for scientists should be implemented in order to facilitate the formation of a local network to study the problem of incidental catches in this area.

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Passive Gear Fisheries of the Southwestern Indian and Southeastern Atlantic Oceans: An Assessment of their Possible Impact on Cetaceans

V.G. Cockcroft and R. Krohn[1]

Centre for Dolphin Studies, Port Elizabeth Museum, P.O. Box 13147, Humewood 6013, South Africa

ABSTRACT

The majority of coastal states in the southwestern Indian and southeastern Atlantic oceans are under-developed, with poor infrastructure and limited harbour facilities. Consequently, there are few data on the extent and distribution of passive gear fisheries in this area. Nevertheless, there is evidence of substantial use of drift or set gillnets in some areas, which may result in the depletion of local stocks of coastal cetaceans. Because most passive gear fisheries are artisanal and probably for subsistence, they are difficult to monitor and regulate. High seas fisheries in the southern African region of the Atlantic and Indian Oceans have traditionally used either trawls, long lines or purse-seines. The incidental entrapment of cetaceans during these operations is unknown, but seems minimal. However, there is a growing driftnet fishery in both the Indian and Atlantic Oceans and the few data available suggest that there is probably an extensive cetacean bycatch. Recommendations for the monitoring and regulation of both artisanal and industrial passive gear fisheries of this region are presented, with particular recognition of the developmental status of the nations in this area.

KEYWORDS: INCIDENTAL CAPTURE; SOUTH ATLANTIC; INDIAN OCEAN; BOTTLENOSE DOLPHIN; COMMON DOLPHIN; HUMP-BACKED DOLPHIN; SPOTTED DOLPHIN; SPINNER DOLPHIN; KILLER WHALE; RISSO'S DOLPHIN; HUMPBACK WHALE; MINKE WHALE; BEAKED WHALE; PINNIPEDS; FISHERIES

INTRODUCTION

The islands of the southern Atlantic are British territory and consist of St. Helena and its dependencies. All are either sparsely or unpopulated, with little development and few harbour facilities. Although the islands of the southern Indian Ocean are well populated, their infrastructure and harbour facilities are generally poor and, in many instances, primitive. Similarly, after decades of political instability and war, the infrastructure and harbour facilities of Mozambique are basic. Almost 90% of all domestic fish catches in this region are made by fleets from Namibia and South Africa, the tonnage landed by the latter country accounting for almost 70% of all catches.

South Africa, with the most robust economy in the region, has a fishing industry more than double the tonnage of that of all the other countries and territories combined. The South African harbour and industrial infrastructure is the most modern in the area and a significant amount of trans-shipping of catches from both the southern Indian and Atlantic Oceans occurs.

Consequent to the economic development status of most of these states, little is known of the extent of passive fishing gear use within either their exclusive economic zones (EEZ), or the oceanic waters surrounding them. In general, domestic harvesting of the major fish resources has used trawls, purse-seines, small-scale gillnets and baited lines, with foreign fleets participating in many of these activities, particularly the harvesting of pelagic tuna resources through long lines and purse-seines. Interaction between these latter fisheries and marine mammals has not been recorded, because of difficulties in accurate monitoring.

There is evidence that Japanese, Taiwanese and Korean driftnetting vessels, some probably displaced from the Pacific Ocean, are relocating to the southern areas of the Indian and Atlantic Oceans. Many of the vessels which hitherto used long lines may now also use driftnets to supplement catches. This expansion in the use of driftnets is likely to increase fisheries/marine mammal interactions.

Unfortunately, the occurrence and distribution of cetaceans in this area are also little known, although Northridge (1984) has provided a comprehensive list of those that may be present in the southern areas of the western Indian and eastern Atlantic Oceans. A number of papers review the available information on cetaceans found in the International Whaling Commission's Indian Ocean Sanctuary (Chantrapornsyl *et al.*, 1991; Kasuya and Wada, 1991; Kruse *et al.*, 1991; Leatherwood *et al.*, 1991).

Coastal passive net fisheries in this area are described on a regional basis. Subsequently, the expanding pelagic driftnet fishery in the southern portions of the western Indian and eastern Atlantic Oceans is examined. The area covered by this report includes the southeastern Atlantic Ocean eastwards of 0° and the southwestern Indian Ocean westwards of 80°, between the equator and 45° south (Fig. 1). Since this report was completed, large-scale pelagic driftnet fishing has been prohibited by UN Resolution 46/215 (e.g. Nagao, 1994).

LITERATURE REVIEW

A review of the possible interactions of marine mammals and fisheries on a regional basis is furnished by Northridge (1984). An overview of the geographic, political and economic structure of all states, including domestic fish tonnages landed, is provided by Europa Yearbook (Anonymous, 1990a). More specific and detailed summaries of the fisheries of each of the Indian Ocean nations within this region, except South Africa, are given in Sanders *et al.* (1988). Information on the domestic fisheries of South Africa and Namibia were obtained from the relevant fisheries departments and individuals involved within the industry. Details of the number, type and gear of vessels fishing in the southern Atlantic and Indian Oceans were garnered from various FAO Fisheries Reports and

[1] *Zoology Department, University of Cape Town, P. Bag Rondebosch 7700, South Africa*

data kept by the Port Captain in Cape Town. Incidental information from organisations such as the Dolphin Action and Protection Society, concerned scientists and press cuttings provided alternative details of the likely expansion of driftnetting activities in this area.

SYNOPSIS BY COUNTRY

South Africa (Fig. 2)

The total recorded marine fish catch by South African registered vessels in 1989 was in excess of 700,000 tonnes. Almost all of the fishing within South Africa's EEZ uses active fishing gear. Nevertheless, there are several small artisanal fisheries using set gillnets, for which little or no information is available. Also, nets set off the southern half of Natal, to catch and deplete the population of sharks and reduce shark and bather interaction, are a special case and are discussed as a fishery. The characteristics of this latter fishery and its incidental take of dolphins has been reviewed by Cockcroft (1990) and Cockcroft and Ross (1991).

South Africa has comprehensive legal protection for cetaceans and the harassment, killing or capture of these animals is expressly prohibited.

(A) Natal anti-shark net fishery

LOCATION OF PORTS

The nets are shore based and cover the southern half of the Natal coast, centred on Durban (Cockcroft, 1990).

TARGET SPECIES

Sharks are the target species.

AREA OF OPERATION

The affected area in the southern half of Natal stretches from Mzamba to Richards Bay (Cockcroft, 1990).

VESSELS AND CREW

Surf launched small boats with outboard motors are used to check and clear the nets.

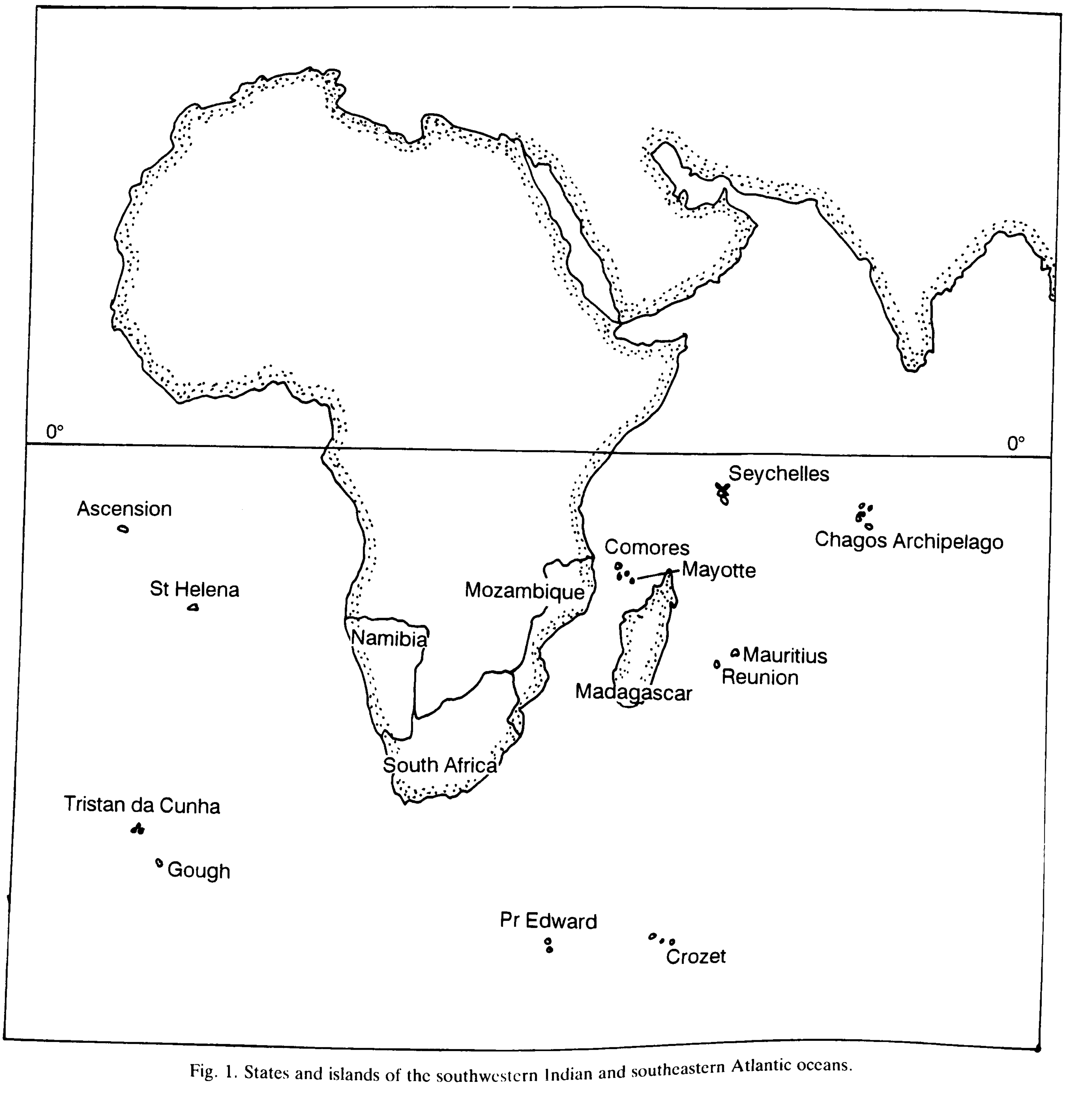

Fig. 1. States and islands of the southwestern Indian and southeastern Atlantic oceans.

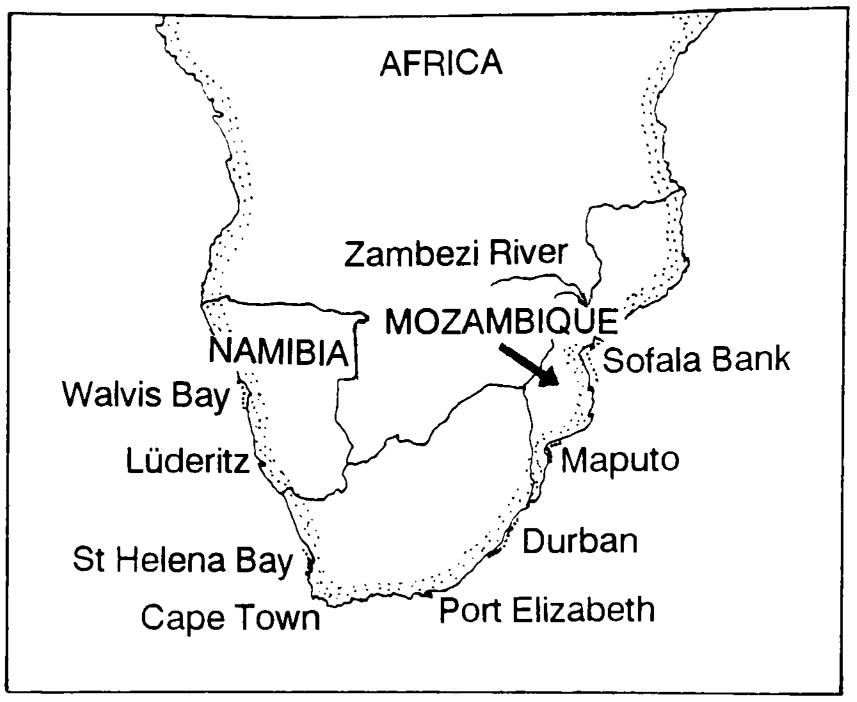

Fig. 2. The three southern African coastal states (cf. Fig. 1), their major ports and principal areas of passive gear fishing (....).

GEAR

Braided nylon (3.5mm diameter) multifilament nets, with a 25cm mesh size are used. Single nets are 110m in length by 10m in depth, with elliptical floats every 3m. Nets are set in a constant, fixed position and all operations are carried out by hand. If multiple nets are set, they are set discontinuously, in a staggered fashion, some 500m offshore. The number of nets set at any beach is dependant upon the extent of its use by bathers. A total of 416 nets (46km) are set at irregular intervals along 270km of coastline (Cockcroft, 1990).

OPERATIONS

Other than during periods of storm seas, nets are always in place and are hung from the surface, in water less than 20m in depth. Nets are examined daily, excluding weekends or during bad weather (an average of 18 days per month). Any catch is returned to shore bases for freezing.

ECONOMICS AND HISTORY

Nets were first set off Durban in 1952, subsequent to a number of horrendous and well publicised shark attacks on local and tourist bathers. Following several shark attacks at other beaches along the coast, with disastrous consequences for the tourist industry, other cities and towns followed Durban's successful lead in setting gillnets, the number of nets set reaching its present extent by 1981. Currently, the tourist industry along the Natal coast is worth several tens of millions of dollars annually and relies on the apparent safety provided by shark nets. Other than this, the fishery has little commercial value and all catches are used primarily for research purposes. In view of the apparent effect of these nets on the inshore ecology of this region, it is unlikely that any expansion will be contemplated and it is possible that the number of nets in certain areas may be reduced.

TOTAL LANDINGS

An average of about 1,400 sharks, some 90 tonnes, of various species are captured annually (Cliff *et al.*, 1988). Incidental captures include batoids, teleost fish and marine mammals. The latter includes an average of 31 bottlenose (*Tursiops truncatus*), 34 common (*Delphinus delphis*) and eight hump-backed dolphins (*Sousa chinensis*) annually (Cockcroft, 1990).

EFFORT DATA

In general, most nets are set for 360 days per year.

INTERACTIONS WITH CETACEANS

Although the capture or harassment of cetaceans in South African waters is illegal, this fishery is run by a state funded organisation and the incidental take of cetaceans in these nets is therefore permitted. The catch of small cetaceans in these nets between 1980 and 1988 is reviewed by Cockcroft (1990). Less than 1% of small cetaceans captured are released alive. In addition, minke and southern right whales (*Balaenoptera acutorostrata* and *Eubalaena glacialis*) are captured on occasion, although most escape.

PINNIPED BYCATCHES

No incidental catches of pinnipeds occur.

DISCUSSION

The effects and consequences of this fishery on the inshore ecology of Natal are controversial and are subject to ongoing research. The continued mortality of inshore bottlenose and hump-backed dolphins in these nets is of concern and the majority of evidence suggests that the Natal stocks of these two species may be unable to sustain this depletion (Cockcroft, 1990).

(B) St. Helena mullet and elephant fish fishery

LOCATION OF PORTS

This is an artisanal fishery on the South African west coast, primarily in St. Helena Bay and Lamberts Bay.

TARGET SPECIES

Although mullet (*Mugilidae*) and elephant fish (*Callorhinchus capensis*) are the main target species, the entire catch is apparently utilised.

AREA OF OPERATION

The fishery is localised to St. Helena Bay and Lamberts Bay.

VESSELS AND CREW

Because this fishery is shore based and mostly at a subsistence level, only small, 1–2 person vessels are used.

GEAR

Although the specifications of the nets used are highly variable, the primary type is nylon monofilament with a 5–10cm mesh.

OPERATIONS

Fishing occurs in shallow water, close to shore. Nets for mullet are set at the surface, while those for elephant fish are set on the bottom.

ECONOMICS AND HISTORY

There is little historical information on this fishery and it appears to be mainly at a subsistence level. Consequently, no rapid expansion is envisaged.

TOTAL LANDINGS AND EFFORT DATA

There is no system of data collection for this fishery.

INTERACTIONS WITH CETACEANS

Only two catches, both of dusky dolphins (*Lagenorhynchus obscurus*), are known from this fishery (P. Best, pers. comm., 6 June 1990). All fishermen require licences to set these nets, which may not be left unattended.

PINNIPED BYCATCHES

There is no information on pinniped interaction with this fishery, although given the large numbers of Cape fur seals resident on the west coast, a considerable interaction seems highly likely.

DISCUSSION

This is a small artisanal fishery and although all cetacean bycatches are supposedly reported to local officials, this is not well monitored and records are unreliable. Despite this, it is unlikely that this fishery poses any serious problem to local cetacean populations, although better recording of catch and bycatch would be beneficial.

There are other small, artisanal set net fisheries off the South African coast for which no information is available.

A new development (March 1991) is the industrial exploitation of inshore reef resources between Port Elizabeth and Durban. Nets, 300m in length and with a mesh between 15 and 30cm, are set in shallow water above inshore reefs to exploit resident fish stocks. Timely action by the South African authorities resulted in the prosecution of the Master of the *Captain George* (registered in Panama) and has probably excluded this fishing method from further use in the South African EEZ. However, it is possible that this or other fleets may use or attempt to use this method to exploit reef resources within the EEZs of other southwestern Indian Ocean states.

The impact of 'ghost nets' (portions of netting lost from vessels trawling within the EEZ) on cetacean populations in this area is unknown, but given the number of vessels in the trawl fleet, there is a possibility of some interaction.

Namibia (Fig. 2)

Although Namibia has potentially one of the richest fisheries in the world, the Namibian-registered fleet landed only 17% (>200,000 tonnes) of the estimated total catch within its EEZ in 1986. As far as is known, almost all of the fish resource exploitation within the EEZ involves the use of active gear, either by locally registered, South African or foreign vessels. Despite sporadic reports of stranded dolphins displaying apparent net marks (Rice, F.H. and Saayman, 1984), little is known of Namibian passive gear fisheries which may impact on cetaceans. Best and Abernathy (1994) provide some details of the incidental capture of Heaviside's dolphin (*Cephalorhynchus heavisidii*) in a set net fishery for inshore line fish near Walvis Bay. Although this fishery has apparently been terminated, rumours suggest that it may be either still in operation or about to be reintroduced. In either instance, any incidental catch of Heaviside's dolphin is of concern. Other inshore cetaceans which may entangle in these nets include bottlenose dolphins and southern right whales.

Apparently, a set net fishery for mullet was recently initiated off the southern Namibian coast. Although no data are available for this fishery, it is likely that some cetacean bycatch occurs, as it does for other set net mullet fisheries in South African waters.

As for South Africa, the incidence of gear loss from trawlers, resulting in 'ghostnetting', and the impact on cetaceans is unknown.

Mozambique (Fig. 2)

Recorded Mozambique fisheries catch landings for 1986 totalled 79,212 tonnes. As with South Africa and Namibia, most known passive gear fisheries off Mozambique are artisanal and most are probably only at subsistence level (Silva and Sousa, 1988). Mozambique does not have a system of statistical data collection for all its fisheries, particularly artisanal fisheries for which few data are available. However, a number of fisheries use passive gear which may impact on cetaceans.

(A) Mozambique shallow water shrimp fishery

LOCATION OF PORTS

The fishery is shore based throughout the coastal waters of Mozambique, particularly in shallow bays and estuaries. The main centres are the Sofala Bank at the mouth of the Zambezi River and Maputo Bay.

TARGET SPECIES

The target species is the shrimp *Panaeus* sp.

VESSELS AND CREW

Various types of small boat are used in this fishery. The number and specification of the boats used along most of the coast are unknown. In 1986, 196 boats were operating in Maputo Bay.

GEAR

The standard way of fishing for shrimp is the use of small hand drawn bottom trawls or beach seines. However, fine mesh 'mosquito' nets are also used and are normally drawn through the water, but may be left to drift and entangle the shrimp. The proportion of boats using 'mosquito' net and the drift method is unknown.

OPERATIONS

Operations are normally carried out in waters less than 10m in depth.

FISHERY DETAILS

There is no information on the economics and history of the fishery. Annual catches are probably over 5,000 tonnes. No effort data are available.

INTERACTIONS WITH CETACEANS

There are no reported interactions with cetaceans.

DISCUSSION

The likelihood of the incidental catch of cetaceans is small, given the small mesh of this gear. However, in view of the extensive fisheries elsewhere on the Mozambique coast, any additional incidental catches may be significant. Although little is known of the occurrence and distribution of cetaceans in Mozambique, this shallow water fishery is likely only to affect bottlenose (*Tursiops truncatus*), hump-backed (*Sousa chinensis*) and perhaps spotted (*Stenella attenuata*) dolphins.

(B) Maputo Bay kelee shad fishery

GENERAL

This fishery operates out of Maputo and targets kelee shad (*Hilsa kelee*) in Maputo Bay (682km²).

VESSELS AND CREW

The exact type and construction of vessels used in this fishery are unknown. However,[2] four motorised boats (6.5–8.5m in length) and 434 sailing boats (3 – 7m long), some of which have auxiliary motors, are used throughout the bay. The catch is stored on ice, probably in the open on the smaller sailing boats and within holds on the motorised boats.

GEAR

The net material is nylon monofilament. Both the industrial and artisanal fleets use nets of 5cm mesh, of variable length up to 200m and 5m deep. Between three and five panels are carried per vessel and these are deployed and retrieved by hand.

OPERATIONS

Vessels apparently deploy and retrieve nets daily (early morning and late evening, respectively), although this is presumably restricted by bad weather. Between three and five nets are set, at the surface, to drift in water less than 20m deep, but mostly less than 10m in depth.

ECONOMICS AND HISTORY

The catch is sold fresh and dried to the domestic (Maputo) market. Because of the lack of data collection, the history of this fishery is unknown, although some data are available from 1972. The stock appears over-exploited, although the number of artisanal boats fishing per year seems to be increasing. Fisheries biologists recommend an increase in mesh size (Silva and Sousa, 1988). Total landings and effort for the years 1984–6 are given in Table 1.

Table 1

Landings and effort for the Maputo Bay kelee shad fishery.

	Semi-industrial fishery		Artisanal fishery	
Year	Catch (t)	Effort (boats)	Catch (t)	Effort (boats)
1984	407	21	2,600	303
1985	128	6	3,730	434
1986	43	2	3,015	449

INTERACTIONS WITH MARINE

Bycatches are not monitored or reported and there is no known bycatch of marine mammals. It is illegal to catch or kill marine mammals in Mozambique waters.

DISCUSSION

Bottlenose and hump-backed dolphins inhabit Maputo Bay (VGC, pers. obs.), as they do other coastal areas of Mozambique (P. Dutton, pers. comm., 8 November 1990). Presently, however, both species appear only to occur on the seaward edge of the Bay, where fishing operations are absent or much reduced. These observations and the fact that both species are known to prey on kelee shad further south in Natal waters (Cockcroft and Ross, 1990), imply that some interaction with this fishery is probable. With the deployment of some 300km of driftnets daily in an area of almost 700km^2, it seems highly likely that captures of these two species occur and that there is or has been a substantial impact on local stocks.

[2] Semi-industrial fishery.

Dugongs were also once apparently commonly sighted in the outer reaches of the Bay, particularly in the Saco da Inhaca (Bay of Inhaca Island), where there are extensive tidally exposed mud flats and sea grass beds and small outcrops of coral reef. For several years, however, there have been no sightings of these animals. The mud flats and sea grass beds are extensively fished with short (30m), small-mesh (8cm) gillnets, which are anchored either to mangrove trees or stakes and left to drift with the tides. Although the capture of dugongs is illegal, fishermen like the taste and are known to eat any dugongs incidentally captured. There is some evidence that this has resulted in a directed fishery for dugongs in Maputo Bay (R. de Paula E Silva, pers. comm., 29 March 1991).

Other cetacean species which may interact with this fishery, especially just outside Maputo Bay, include humpback whales (*Megaptera novaeangliae*) during the austral spring and summer and spinner (*Stenella longirostris*) and common dolphins, both of which occur close inshore (VGC, pers. obs.). In view of the extensive use of gillnets in and around Maputo Bay and the mortality of bottlenose and hump-backed dolphins in shark nets off Natal (400km south), monitoring of the catch and bycatch in Maputo Bay and environs is imperative. An increase in the mesh size used in this fishery should be discouraged, as this would almost certainly increase marine mammal mortality.

There is little information on other passive gear fisheries in Mozambique waters. The recent establishment of a fish canning factory in Maputo (R. de Paula E Silva, pers. comm., 29 March 1991) suggests that fisheries within the area are set for expansion. A set gillnet fishery for sharks, in which some dolphin and dugong catches were made, operated north of Maputo until the mid 1980s. Although this fishery has apparently ceased (R. van der Elst, pers. comm., 29 March 1990), an industrial fishery for sharks was recently established within Maputo Bay and environs, but there is no information on marine mammal interactions with this operation (R. de Paula E Silva, pers. comm., 29 March 1991). There is a shark net fishery in the region of Vilankulos (central Mozambique), with sporadic reports of dugong catches in these nets (P. Dutton, pers. comm., 8 November 1990). In view of the scale of these and other coastal fisheries operations in the waters of Mozambique, some form of assessment and monitoring of cetacean bycatches is imperative.

Madagascar (Fig. 3)

Although there is great potential for the development of marine fisheries within Madagascar's EEZ, estimated existing total catches are relatively small, less than 20,000 tonnes in 1986. Of this total, artisanal fisheries contribute some 13,000 tonnes, most, possibly, on a subsistence basis. Fishery statistics are poor and little is known of fishing extent, distribution or target species. Consequently, there are no data for specific artisanal fisheries.

In 1981 it was estimated that some 10,651 full and part-time fishermen, using about 7,000 dugout canoes, were engaged in the artisanal fishery along the entire 4,500km of coast out to the 100m isobath (117,000 km^2) (Ralison, 1988). The most common gear of these fishermen is either hand line or gillnet, the latter suggesting that cetacean incidental capture is highly likely.

Although no accurate data are available, there are reports of incidental entanglements. Entanglement of bottlenose and hump-backed dolphins, and dugongs is reported for Antongil Bay, near Maroantsetra and

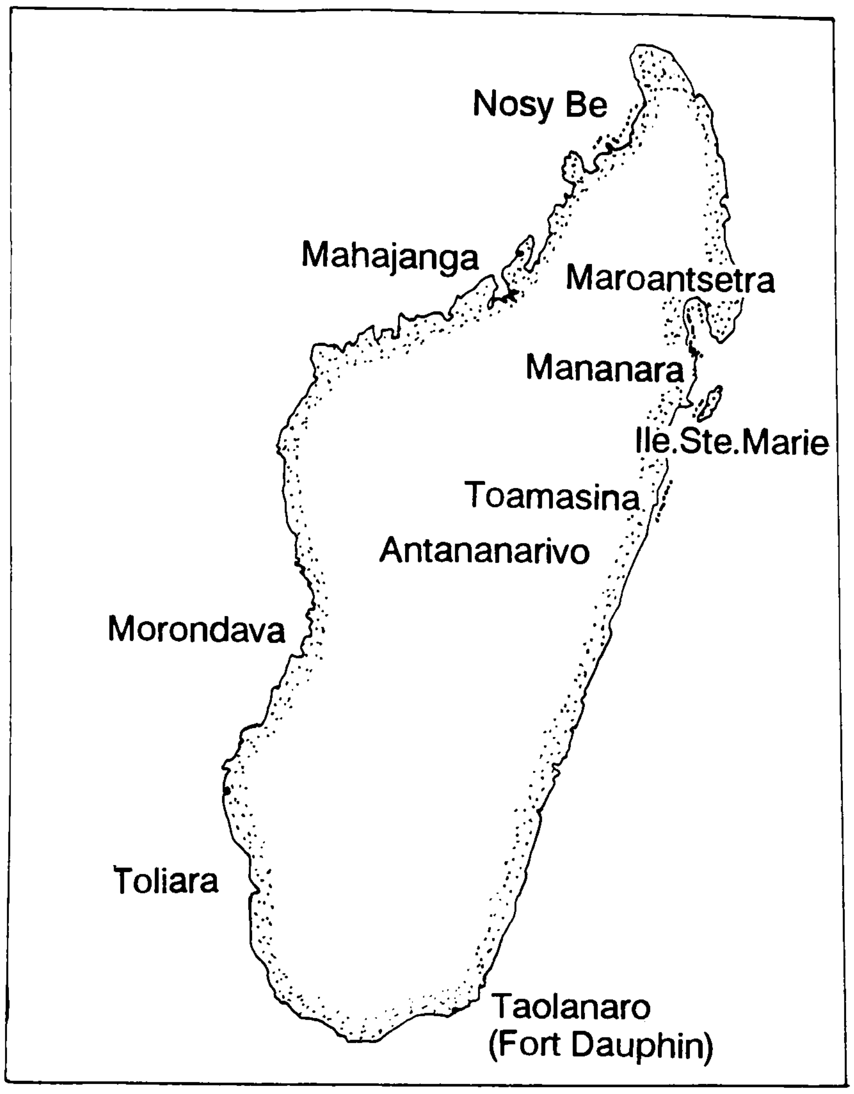

Fig. 3. Madagascar, off the southeast coast of southern Africa, its major coastal cities and towns and known principal areas of passive gear fishing (....).

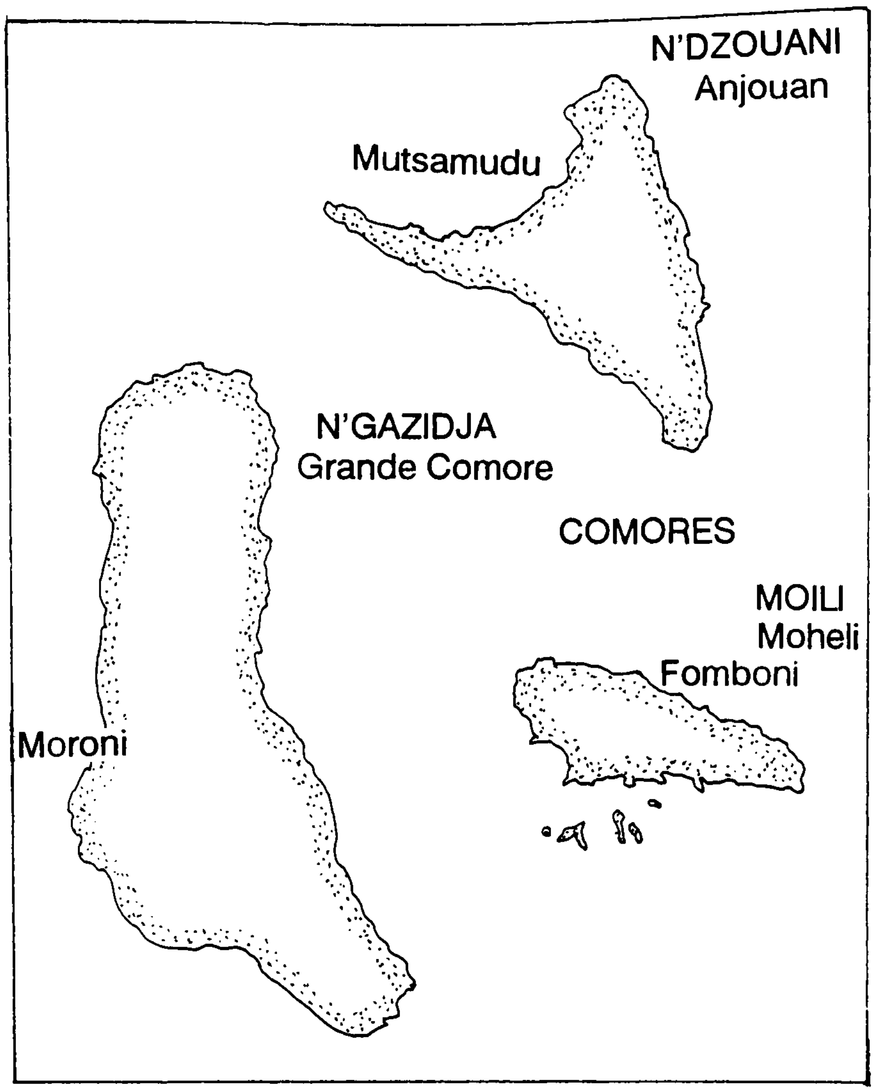

Fig. 4. The Comores Islands situated in the Indian Ocean between Africa (Mozambique) and Madagascar.

Mananara, at the south end of Ile. Ste. Marie and near Nosey Be (P. Folkens, pers. comm., 5 May 1990). Humpback whales in shallow bays during the austral spring may also be at risk in these nets. For the past five years, killer whales (*Orcinus orca*) have been netted in the nearshore waters north of Toamasina (P. Folkens, pers. comm., 5 May 1990). Some monitoring of and data for these fisheries is required, especially in view of the possible capture of bottlenose and hump-backed dolphins, which are probably subject to capture throughout this region.

The recent signing of a general fisheries agreement between Japan and Madagascar indicates that fishing effort, possibly in the nearshore zone, may be substantially increased in the near future. Although it is unknown what form this may take, in view of the impact of coastal gillnetting on marine mammals in other areas, this development should be closely monitored.

Comores Islands (Fig. 4)

There has been no collection of systematic statistical fisheries data in the Comores and documentation of fisheries and catches is non-existent. Estimated total catch for 1986 was 5,300 tonnes, the major portion of which was in artisanal fisheries. Fishing occurs around all three of the major islands, principally using 'Pirogues', which are either 4m in length with two outriggers (1,500 boats based mainly on Grande Comore), or 7m in length with one outrigger (1,200 boats based at Anjouan and a further 300 at Moheli) (William James, 1988). Although hand lines are the primary gear, gillnets are also used. These include, 15 locally manufactured gillnets (100m x 1.5m, mesh size 14cm and probably monofilament) and 100 nets, provided through Japanese aid, which are probably of similar size to the locally made nets. All three major islands have relatively narrow shallow water areas (<100m in depth; Moheli = 721km^2, Anjouan = 64km^2 and Grande Comore = 300km^2) suggesting that most fishing occurs close inshore.

The incidence of interactions between these artisanal fisheries and cetaceans is unknown, although the use of gillnets, whether set or drift, suggests that some cetacean mortality is likely, particularly for coastal species. Any increased aid involving gillnets would exacerbate this interaction. However, the neritic fish resources of the Comores appear to be at maximum exploitation levels (William James, 1988) and any expansion of artisanal fishing effort within existing fishing grounds seems unlikely.

Mauritius and Chagos Archipelago (Fig. 5)

With foreign aid to set up harbours and fish canning factories the fish catch in Mauritian waters almost doubled from an estimated 7,000 tonnes in 1981 to 13,000 tonnes in 1986. Of this total, artisanal fisheries account for some 28%, while industrial (oceanic tuna) and semi-industrial fisheries (hand lines for reef species on the Malha Bank and the bank surrounding the Chagos Archipelago) constitute the remainder (Samboo and Mauree, 1988). Statistics are only kept for the Mauritius Island fishery, although some information for the two other islands is available.

(A) Mauritian shallow water artisanal fishery

LOCATION OF PORTS

This fishery is shore based and does not require port facilities.

TARGET SPECIES

Various species are targeted by this fishery; these include Serranidae, Siganidae, Lethrinidae, Scaridae, Mullidae, percoids and octopus.

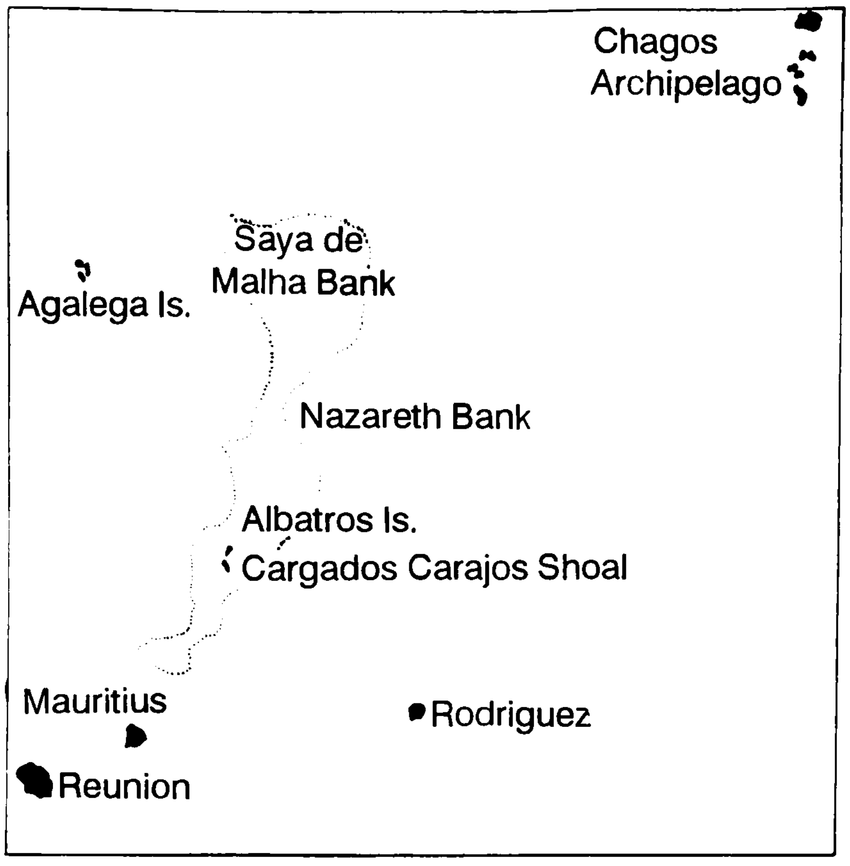

Fig. 5. The major islands of Mauritius and the Chagos Archipelago (shaded) in the southwestern Indian Ocean.

AREA OF OPERATION

The areas fished are primarily the lagoon areas of all three main islands, Mauritius, Rodrigues and Agalega, and the off-lagoon areas of the former two islands (Mauritius Island lagoon = 376 km^2; Mauritius Island off-lagoon = 832 km^2; Rodrigues Island = 1688 km^2 ; Agalega Island = 15 km^2; all areas to 100m depth).

VESSELS AND CREW

The specifications of the fishing craft used are unknown but all are between 7 and 10m in length. One thousand and nineteen (1,019) boats are based on Mauritius Island, with a further 215 on Rodrigues Island. The catch is apparently either landed and sold fresh or is dried before sale.

GEAR

Various gears are used, including seines and gillnets. A total of 201 fishermen use gillnets of unknown specification (69 in Mauritius Island lagoon and 132 off Rodrigues) and all gillnets are deployed primarily within lagoons.

OPERATIONS

Fishing is probably carried out on a daily basis, weather permitting, and in shallow water, because most is within lagoons.

ECONOMICS AND HISTORY

This type of fishing activity possibly began with the first settlements of the three main islands (c. mid 19th Century) as a food supply, fresh or dried fish, for domestic consumption. The total catches of the artisanal fishery are believed to be at or near maximum sustainable yield (MSY) levels and, consequently, no further expansion is envisaged.

TOTAL LANDINGS

The artisanal fishery is believed to catch about 3,500 tonnes annually. Some 65,000 part-time (subsistence) fishermen are also believed to fish the lagoons using hand lines and each is believed to take an average of 0.5kg of fish per day (almost 12,000 tonnes annually). About 15kg of fish per set are landed.

INTERACTION WITH CETACEANS

There is little information on any interaction with cetaceans, with only one known instance of incidental capture (sei whale – P. La Hausse de Lelouviere, pers. comm. 10 May 1991). However, with the regular use of gillnets by about 200 fishermen, it seems likely that more incidental cetacean mortality occurs. Species of at least two of the fish families targeted are known prey of bottlenose dolphins off Natal. Recently Corbett (1994) reported on a survey to assess the occurrence of cetaceans off the west coast of Mauritius. The most common species encountered were sperm whales (*Physeter macrocephalus*) and spinner dolphins. Other species seen included spotted, bottlenose and Risso's dolphins, two unidentified beaked whales (one probably *Mesoplodon layardii*) short-finned pilot whales (*Globicephalus macrorhynchus*) and humpback whales during the austral summer. Several of these species may be at risk of capture. Depletion of fish resources by part-time fisherman could also have an impact on local cetaceans. Mauritian law specifically protects marine mammals, but in common with all countries of the region, the authorities have little ability to enforce or implement these regulations.

PINNIPED BYCATCHES

Unknown, but unlikely.

DISCUSSION

With so little information on the fisheries or marine mammals of this area it seems prudent to attempt to promote, through the relevant authorities, a monitoring programme on the use of gillnets and any incidental bycatch.

Seychelles (Fig. 6)

Apart from the industrial tuna fishery in Seychelloise waters, some 4,630 tonnes of fish were taken by between 1,100 and 1,200 artisanal fishermen in 1986. Most artisanal fishing effort is centred on the three main islands of Mahé, Praslin and La Digue, although the Seychelles consists of a total of about 100 islands (Lablache *et al.*, 1988).

(A) Artisanal net fisheries (encircling gillnet and bottom shark gillnet fisheries)

LOCATION OF PORTS

This fishery is shore based and does not require port facilities.

TARGET SPECIES

For the encircling gillnet fishery, the main target species are Indian mackerel (*Rastrelliger kanagurta*) and big eye scad (*Selar crumenophthalmus*), while the bottom set shark gillnet fishery targets sharks of several species.

AREA OF OPERATION

This fishery operates in the nearshore region of the three main islands, an area of some 200km^2.

VESSELS AND CREW

Some 36 vessels, 28 motorised and 8 hand propelled, are in use by this fishery. These (Pirogues) are of unknown specification, but are probably similar to the small open boats used by Mauritian fishermen.

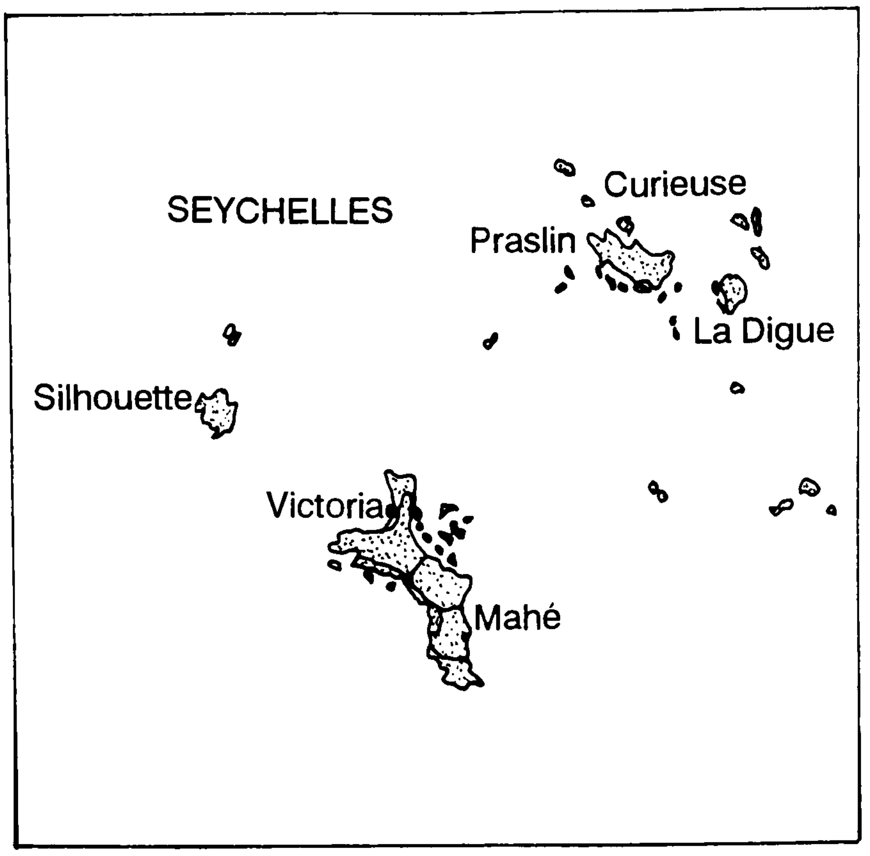

Fig. 6. The Seychelles group of islands in the south western Indian Ocean.

GEAR

Nets used in the encircling gillnet fishery are manufactured from polyester/cotton and have a mesh of about 6cm. Net panels are approximately 50m in length, but of unknown depth. Lengths of net are commonly strung together up to a maximum length of about 300m. Nets used in the bottom shark set gillnet fishery have a mesh of 15cm and range in length from 100 to 200m and a depth of between 4 and 5m.

OPERATIONS

Nothing is known of the operations of this fishery, although it is likely that it operates daily, weather permitting.

ECONOMICS AND HISTORY

The history of this fishery is unknown, but presumably it grew from local demand for either fresh or dried fish. The total landings in the fishery for 1985 and 1986 are given in Table 2.

Table 2

Catches for 1985 and 1986 for Seychelles artisanal net fisheries.

	Catch (t)			Catch (t)	
	1985	1986		1985	1986
Species			**Fishery**		
Jacks	1.9	2.4	Encircling gillnets	241	145
Mackerels	206	159	Set gillnets	31	50
Barracudas	7	5			
Trap fish	1	6	Total landings	375	272
Sharks/rays	38	27			
Others	124	71			

EFFORT DATA

In 1985 there were 4,900 sets of encircling gillnets and 600 sets of shark gillnets. The respective values for 1986 were 2,400 and 1,500.

INTERACTIONS WITH CETACEANS

There are no reported interactions between cetacean or indeed any marine mammals and the fisheries of Seychelles, including the offshore industrial tuna purse-seine and long line fisheries. Nevertheless, it is possible that some interaction occurs, probably involving the same species implicated in Mauritius. Marine mammals are comprehensively protected under Seychelles law.

DISCUSSION

Catches appear to fluctuate annually and the resource appears under-exploited (Lablache *et al.*, 1988), consequently fishing effort may have expanded since 1986, particularly that using bottom set nets, as these may be part of aid packages from industrialised nations.

Mayotte and La Reunion (Fig. I)

These two islands sustain small artisanal fisheries of which little is known. Fisheries statistics are not collected on Mayotte, but are routinely collected for La Reunion. On both islands, the most common gear used is various types of hand line, although both set and drift gillnets are used occasionally (Biais, 1988b; Biais, 1988a). No information is available on the number of these nets deployed, the number of fishermen using these nets, or any cetacean involvement. Given the fairly extensive shallow water banks in the vicinity of both islands, however, it seems probable that some cetacean and fisheries interaction takes place and is likely to increase if fishing expands.

Kerguelen

The only known fisheries within Kerguelen's EEZ are commercial bottom and mid-water trawling operations by French and Russian vessels. No cetacean bycatch has been reported for either these or other fisheries in the area (G. Duhamel, pers. comm., 1 August 1990).

St. Helena and Dependencies (Fig. 1)

With only some 6,500 people resident on St Helena and its dependencies of Ascension and Tristan da Cunha, there appears to be little or no artisanal fishery. Total fish landings for 1987 approached 335 tonnes, mostly from tuna long lines.

The industrial fisheries of the southwestern Indian and southeastern Atlantic Oceans (Figs. 1 and 7)*

There is increasing evidence of an expansion of industrial fishing effort in the southwestern Indian and southeastern Atlantic oceans. Specifically, there has been a recent significant increase in the industrial and artisanal catch of tuna in the Indian Ocean (Anonymous, 1989a). Traditionally, tuna fisheries in the western Indian Ocean (Fig. 7) have used either long line or purse-seine methods. There is conflicting evidence of tuna and dolphin association for this area and although fishing authorities throughout the region deny any cetacean interaction with tuna purse-seining, there is circumstantial evidence of incidental captures. The extent of this interaction is unknown and is not reviewed in this paper.

In 1990 there were apparently only 44 driftnet vessels (20 Japanese and 24 Taiwanese) in operation in the South Pacific, whereas the Taiwanese fleet consisted of more than

* Since completion of this report, the following developments occurred (Nagao, 1994): (1) Japan banned large-mesh driftnet fishing from 15 August 1990 in all waters outside the Pacific Ocean; (2) UN Resolution 46/215 banning such fisheries came into effect on 1 January 1993.

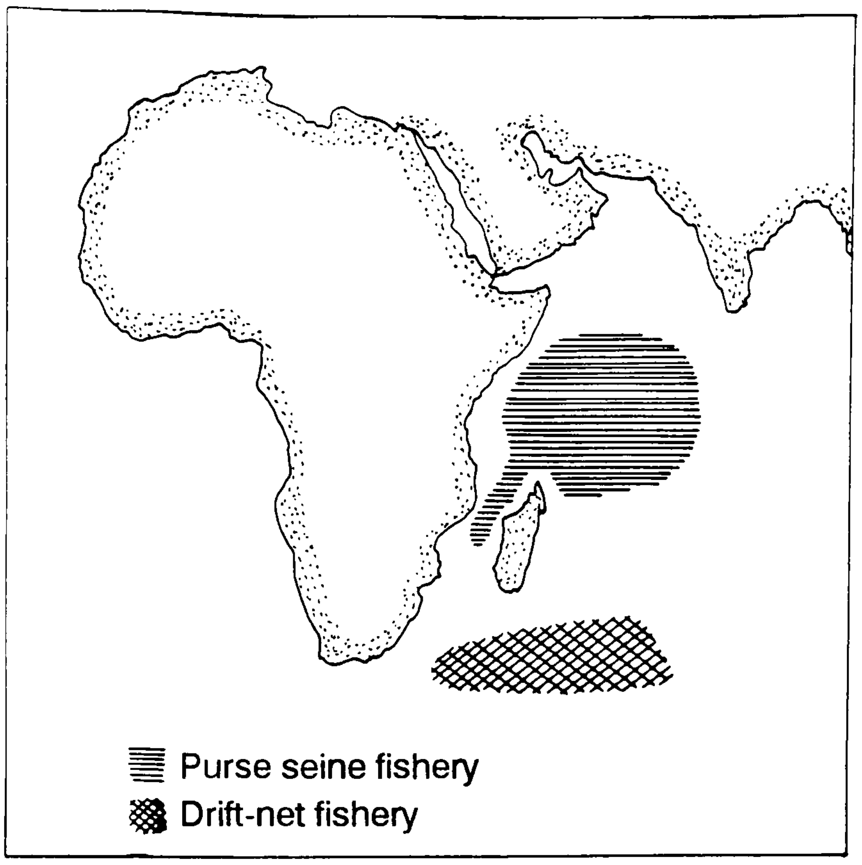

Fig. 7. The southwestern Indian Ocean. The position and extent of the tuna purse-seine and Taiwanese large-mesh driftnet fisheries are shown.

150 vessels in the recent past (Anonymous, 1990b). There is concern that many of these vessels may have relocated to the Indian Ocean (Anonymous, 1989a), with evidence also of the presence of the use of drift gillnets in the southern Atlantic Ocean. Little information is currently available for this fishery in the southwestern Indian and southeastern Atlantic oceans, although some evidence for this expansion is available.

(A) Taiwanese Indian Ocean industrial large mesh drift gillnet fishery (Fig. 7)

LOCATION OF PORTS

Kaohsiung is the major domestic port and there are a number of foreign ports used: Bangkok; Port Louis (Mauritius); Singapore; Penang and Cape Town (South Africa).

TARGET SPECIES

The target species of this fishery are the various tuna fishes. Historically albacore (*Thunnus alalunga*) tuna was the primary target, but latterly yellowfin (*T. albacares*) and bigeye (*T. abesus*) tuna are increasingly targeted. Although blue fin (*T. thynnus thynnus*) is not specifically targeted, catches of this species are retrieved and sold.

AREA OF OPERATION

The northwestern Indian Ocean and the south central to southwestern Indian Ocean (Fig. 7) are the main areas in which this fishery is concentrated.

VESSELS AND CREW

Many of the vessels used in this fishery are converted trawlers or long liners and, consequently, the specification of vessels used is highly variable. In the 1987/88 fishing season, 149 vessels were in operation. The officers are normally Taiwanese nationals, whereas the crew may consist of individuals of a number of nationalities, including South Africans. Captured tuna are stored refrigerated until trans-shipment either at a home or foreign port or at sea to a 'mothership'.

GEAR AND OPERATIONS

Nylon monofilament nets appear to be the standard gear used by these vessels. Net mesh is between 20 and 22cm, with each panel being about 45m in length and between 20 and 24m in depth. Vessels carry between 700 and 900 panels each, all of which may be joined and set during one operation (on average 37 to 47km per set). Nets are set to drift at the surface in the late afternoon (from one report). Soak time is apparently about 12hrs, with recovery beginning at about midnight. Floats are spaced at 20m intervals and the use of radio transponders at the ends of each net probably facilitates recovery. The main fishing season within the Indian Ocean is apparently five to six months, between January and May.

ECONOMICS AND HISTORY

This fishery was initiated in 1983 and the number of vessels engaged in the Indian Ocean has steadily increased since (cf. below). This indicates that the fishery may still be expanding, particularly as grounds in the southern Atlantic are explored and exploited subsequent to fishing in the Indian Ocean. Fish are sold both fresh, if landed at the home port, and canned to both foreign and domestic markets. Processing may occur at some of the foreign ports listed above (not Cape Town) although this is not known with certainty. There is one record of a vessel off-loading fish for processing in Puerto Rico.

TOTAL LANDINGS AND EFFORT DATA

Catches and available effort data are given in Table 3. The average weight of albacore netted was 9kg and that for bigeye tuna 26kg, for both 1986/87 and 1987/88.

INTERACTIONS WITH CETACEANS

Bycatches of non– marketable resources are not recorded and there is no information on the extent of any cetacean involvement with this fishery, or indeed any marine mammals.

DISCUSSION

Cetacean bycatch in this fishery is highly probable and may be considerable. A wide variety of cetacean species (38 listed for area 51 (Northridge, 1984) may occur in this area and could be captured during operations. To obtain some idea of the potential bycatch, if we assume an average vessel deployment of 42km of nets per day, for each of 149 vessels, and a cetacean catch rate of 0.54/10km of net/day [the mean of driftnet catches in the Arafura/Timor Sea, Tasman Sea, North Pacific tuna and flying squid fisheries (Anonymous, 1990b)], this could result in up to 350 cetacean captures per day, or over an assumed five month fishing season, in excess of 50,000 cetaceans for this Taiwanese fleet alone. The extent of this bycatch may be doubled by other Taiwanese vessels which appear to fish with driftnets in the Indian Ocean while in transit to the southeastern Atlantic (cf. below).

Interestingly, South African law prohibits the landing of any gillnetted fish at South African ports, even though Hsu and Liu (1990) report that only tuna caught using driftnets is off-loaded in Cape Town. This indicates that the origins of fish caught in this fishery and probably also those from the Southern Atlantic fishery, may purposely be kept concealed for fear of the problems arising from the use of driftnets.

Table 3

Catch and effort data for the Taiwanese Indian Ocean drift gillnet fishery.

Season	Effort (vessels)	Catch (tonnes)	Season	Effort (vessels)	Catch (tonnes)
1983/84	1	24	1986/87	123	18,281
1984/85	36	3,941	1987/88	130	18,486
1985/86	74	13,777	1988/89	149	

Landings (tonnes) by Port 1987/1988:

Kaohsiung = 13,162.4 tonnes (9,732.7 t. *albacore*)	Singapore = 461.9 tonnes (446.8 t. *albacore*)
Bangkok = 3,643.4 tonnes (2,829.4 t. *albacore*)	Penang = 362.6 tonnes (357.7 t. *albacore*)
Port Louis = 37.7 tonnes (37.7 t. *albacore*)	Cape Town = 817.5 tonnes (773 t. *albacore*)

No information is available for South Korean or Japanese vessels fishing in the southwestern Indian Ocean area, although it seems likely that, with the reduction of vessels in the South Pacific, substantial numbers of these vessels may operate in this area (1 South Korean and 13 Japanese vessels were due to dock in Cape Town in 1990 after transiting the Indian Ocean). The entire fleet should be encouraged to report on their fishing operations in the southwestern Indian Ocean. Monitoring of this fishery and any cetacean bycatch, similar to that recommended for the North and South Pacific fleets, is urgently needed.

Driftnet fisheries in the southeastern Atlantic

There is little documentary evidence for driftnet fishing in the southeastern Atlantic Ocean (Anonymous, 1990b), although there are increasing signs of a substantial fishery in pelagic waters and also, possibly, within the EEZ of some states. There were 4,658 'line-boat' (tuna long liners) dockings at Cape Town during 1989. Additionally, the discharges and trans-shipments of frozen tuna in Cape Town harbour have increased from an average of 87,165 fish in the years 1982 to 1986 to 131,632 fish for 1987 to 1989 (Portnet, unpublished harbour statistics). This increase (51%) has not been matched by comparative long line discharge figures issued by the International Commission for the Conservation of Atlantic Tunas (ICCAT), but was coincident with a very large increase in landings of angelfish (*Brama brama*), a known bycatch of driftnet fishing. This may roughly indicate when large scale driftnetting in the South Atlantic started.

During the 1989/90 season, South African authorities granted 167 driftnet vessels (153 Taiwanese, 13 Japanese and 1 South Korean) permission to call at South African ports *en route* to the South Atlantic. Only 14 of these vessels had permission to fish within the Falklands 150 mile Fishery Conservation Zone (FCZ) in 1989 and five in 1990. Another 123 vessels were licensed to fish within the Falklands FCZ during 1990. Some of these ships may have engaged in driftnet fishing in transit to the Falklands, implying a substantial potential fishing effort in the Southern Atlantic.

It is unclear whether the Taiwanese vessels issued South African permits were from the large mesh Indian Ocean gillnet fishery, although the dates of their call in Cape Town infer they were not. The Indian Ocean gillnet season begins in December/January, between 70° and 100°E, but moves westwards to 30°E by March/April (Hsu and Liu, 1990). In contrast, Taiwanese vessels bound for the Falklands called at Cape Town between November and January. This disparity implies that a large number of vessels, apart from the 149 driftnetters in the Taiwanese Indian Ocean fleet, may fish while in transit from Taiwan to Cape Town. After off-loading the catch and refuelling, most of this fleet proceeds to the Southern Atlantic to fish, before moving to the Falklands to jig for squid (Anonymous, 1989b). This may not be a typical pattern, however, as the movements of at least one driftnet vessel show that Ponce, Puerto Rico, was the next port of call after Cape Town (Rice, N., 1990).

Unequivocal evidence for driftnetting off Tristan da Cunha and Gough Island is provided by Ryan and Cooper (1991), who document the presence of Taiwanese vessels driftnetting within the EEZ of the islands. In an interview before an attorney, a South African crew member from a Taiwanese ship that docked in Cape Town, indicated that during approximately one month of driftnet fishing (probably off Tristan or Gough), 15 - 20 'dolphins', three to four 'small whales' and many penguins were incidentally captured. The cetaceans were discarded and the fish caught during this time were trans-shipped at sea before the fleet proceeded to the Falklands. This was one of five vessels fishing in the area.

South African authorities have found and confiscated driftnets from several Taiwanese and South Korean fishing boats. A Taiwanese vessel returning from the Falklands, the *An-Hung 1*, recently ran aground on the Southern Cape (South Africa) coast carrying 145km of gillnet, more than triple the length of net that these vessels are reported to carry. Besides carrying a full load of tuna in its holds, several rockhopper penguins and two sub-Antarctic fur seals (*Arctocephalus tropicalis*) were found, which indicate that this vessel was probably driftnetting off Tristan da Cunha (Ryan and Cooper, 1991). The gear used on these vessels is apparently different from that used by those in the Indian Ocean and consists of mesh of 30 to 40cm, 20m deep panels, with a total set of about 35km (Anonymous, 1989b). Soak time is approximately three hours, but hauling takes some five hours, so sections laid last remain in the water for considerably longer.

Fishing interests in South Africa believe that this fishery takes more than the MSY and is decimating stocks of tuna in the Southern Oceans (Anonymous, 1989b). Its impact on cetaceans is unknown and quantitative estimates of the extent and identity of bycatch are urgently required. Judging from catch rates in the Pacific, the extent of pelagic marine mammal bycatch could be substantial, probably of the order of several tens of thousands, and the spectrum of species captured may be wide (Northridge, 1984).

The fact that driftnetting takes place within the EEZ of Tristan and its dependencies, and probably South Africa, indicates that it could be used elsewhere within the EEZs of the other states in this area. This has clear implications for neritic species of cetaceans, some of which may also be subject to incidental captures in the inshore region.

GENERAL DISCUSSION

Generally, coastal set and drift gillnet fisheries in the Southern African Atlantic and Indian Ocean region are artisanal and most are at subsistence level. There are indications that stocks of some cetacean species, particularly bottlenose and hump-backed dolphins from adjoining areas such as South Africa and Mozambique, may be subject to heavy depletion pressure, raising concern for the continued survival of these stocks. Available data for bottlenose and hump-backed dolphins off Natal, South Africa, indicate that geographically separated groups are distinct (Cockcroft *et al.*, 1989), which suggests that depletion of individual groups may lead to local extinctions. If a similar depletion is occurring off Mozambique and Madagascar, the prognosis for these and other coastal species in south western Indian Ocean waters is cause for concern.

Recently, there has been an increase in aid to the developing countries of this region, especially aid involving the expansion of fishing operations and the deployment of gillnets. Consequently, it seems likely that artisanal gillnet fisheries will expand and that the probability of cetacean bycatch in coastal fisheries will increase concurrently. The majority of states in this area are undeveloped and their financial and manpower resources are limited. Therefore, any regulation or monitoring of their artisanal fisheries is difficult. Consequently, it would seem logical to encourage the donors of aid, particularly aid in the form of gillnets, to require or promote the documentation of catch and bycatch and also to provide instruction on how best to use this gear to minimise entrapment of cetaceans and other non-target species. Given that most of the states specifically protect marine mammals, the best course of action would seem to be liaison with existing regulatory bodies and the promotion of monitoring and research through these bodies.

In many of the states dealt with here, the killing of marine mammals and possession of their remains is illegal. To some degree this mitigates against the adequate monitoring of any bycatch as fishermen would rather discard and disclaim any knowledge of bycatches for fear of the law. This suggests that efforts should be made to formulate model legislation and encourage its use in all countries. This legislation should, obviously, fulfil the main requirement of protecting marine mammals, but encourage the reporting of those captured incidentally and facilitate their retention for examination.

In contrast to coastal artisanal fisheries, the probable effects of the massive pelagic driftnet fishery in the southwestern Indian and southeastern Atlantic Oceans is likely to have a significant impact on a broad spectrum of cetacean species. Although estimates of cetacean mortality in these fisheries is speculative, they indicate that tens of thousands may perish annually. Given this and in view of the fact that to wait for quantitative data may be disastrous, a number of courses of action are recommended.

High seas driftnet fisheries have a number of disadvantages. These include; the bycatch of non-commercial but possibly ecologically important species; the size non-selectivity of the gear, which may lead to overexploitation of the resource; damage to the target species, leading to a high discard proportion; death and loss of commercially important species, which are then subsequently not available. These deficiencies have clear socio-economic implications for the undeveloped coastal states of this region. States with vested interests in the ecology of their coastal and bordering pelagic seas, including investments in fisheries, should be encouraged to immediately protect their natural resources.

Communication of concern for the proper management of non-target species resources to the management bodies of regulated regional fisheries is imperative. For those regions where there are no regulatory bodies, the formation of co-operative regional organisations with management function should be encouraged. Given co-operation between adjacent coastal states and their fisheries management bodies, the regional assessment and management of non-target species is possible. In this context, the promotion of on-board observers and vessel surveillance, whatever the shortcomings of these, should be immediately recommended.

The coastal states of the southwestern Indian and southeastern Atlantic Ocean areas should be encouraged to amend their legislation in accordance with and to take advantage of the United Nations General Assembly international moratorium on the use of high seas driftnets.

Given the equivocal findings of past research on the effectiveness of size and species selectivity of gillnets and the bycatch reduction of sub-surface positioning of driftnets, further research aimed at bycatch reduction is urgently required.

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SC/O90/G22

Review of Gillnet Fisheries and Cetacean Bycatches in the Northeastern Indian Ocean

R. S. Lal Mohan

Research Centre, Central Marine Fisheries Research Institute, West Hill, Calicut 673–005, India[1]

ABSTRACT

Small cetaceans and some great whales become entangled and die in gillnets in a variety of fisheries in the northeastern Indian Ocean. Information on operational details, present status and future plans for development of fisheries was compiled from published literature, widely-distributed questionnaires the author's own research. The study concentrated on fisheries for 14 fish species or groups of species (seerfish, tunas, pomfrets, sharks, skates and rays, catfish, polynemids, oil sardines, mackerels, lesser sardines, whitebait, hilsas, riverine catfish and prawns) and cetaceans entangled and killed during their operations. In general, documentation of the extent of cetacean mortality is poor but sufficient to suggest that mortality is high in at least some fisheries (e.g. driftnet fisheries) and in some countries (e.g. Sri Lanka and India). Apparently low levels of mortality noted for Bangladesh and Burma may be due to low fishing effort. It is suspected that the primarily hook-and-line methods employed in the Maldives minimise the chance of serious levels of cetacean entanglement. Virtually all cetacean species known to inhabit the areas of operation become entangled at some time, and rates of mortality for some species in some areas appear high. This fishery-related mortality occurs at a time when national programmes are encouraging further expansion and development of fisheries to feed burgeoning human populations. Recommendations are made to increase programmes of cetacean research, public awareness and monitoring of cetacean mortality and its impact on cetacean populations.

KEYWORDS: INCIDENTAL CAPTURE; INDIAN OCEAN; SPINNER DOLPHINS; HUMP-BACKED DOLPHINS; BOTTLENOSE DOLPHINS; FINLESS PORPOISE; COMMON DOLPHINS; STRIPED DOLPHINS; RISSO'S DOLPHINS; SPOTTED DOLPHINS; FRASER'S DOLPHINS; SPINNER DOLPHINS; ROUGH-TOOTHED DOLPHINS; PYGMY KILLER WHALES; PYGMY SPERM WHALE; DWARF SPERM WHALE; GANGES RIVER DOLPHINS; IRRAWADDY DOLPHINS

INTRODUCTION AND METHODS

The aim of this study was to obtain information on gillnet fisheries in the northeastern Indian Ocean that take marine mammals incidental to their operations and, when possible, to assess the magnitude and impact of that take. The approach was twofold: (1) relevant published literature was reviewed; (2) a questionnaire was distributed to scientists and resource managers within the five countries bordering the northeastern Indian Ocean (Fig. 1) and to specialists outside the region who were known or believed to have information on gillnet fisheries within this region that affect marine mammals.

India, Bangladesh, Burma, Sri Lanka and the Maldives have a combined coastline of 11,000km and it is not surprising that fishing is dominant in the economy of the region. However, the coasts of these countries are substantially different from one another and therefore support different combinations of marine, estuarine and even riverine fisheries. The traditional fishing vessels and methods which have developed within each region, and the current economic conditions as they affect use of more modern fishing equipment and techniques, also differ. Although fishing is important in all the studied countries, the levels of information available on the fisheries in general, and the involvement of cetaceans in fisheries in particular, vary within and among countries. There is good information, for example, from India and Sri Lanka, but virtually no information for Burma. This report is thus preliminary and is intended to stimulate further research in this region.

[1] Present address: *Conservation of Nature Trust, B/24, Gandhinager, Calicut 673005, Kerala, India*

REVIEW OF LITERATURE ON THE FISHERIES

Scientific investigations into gillnetting were initiated early in this century when Nayudu (1920) and Hornell (1924; 1938) began studies on the vessels and gear of the Malabar coast of India and such studies have continued (e.g. Chopra, 1951; Nagaraja Rao, 1958; Jhingran, 1985; Bal and Virabhadra, 1984). Recent Indian studies include Gulbrandsen's (1984) review of the fishing vessels of Kerala and Kalavathy and Tietze's (1984) investigation of artisanal vessels and fishing gear of Orissa. Considerable attention has also focussed on small-scale fisheries (e.g. Roy, 1981; Silas *et al.*, 1980; Williams, 1981; BOBP, 1985). Balachandran (1983) and Leatherwood and Reeves (1989) studied the fishing vessels and gear of Sri Lanka. Fishing gear used in Bangladesh was investigated by Ali and Haq (1980), Bergstrom (1982), Pajot and Das (1981, 1984), Kashem (1985) and BOBP (1985). Preliminary investigations on the fisheries of Burma were made by Drushinin (1970), Naumov (1971), Pauly (1984) and Sivasubramanian (1985).

Sten (1978) examined the fisheries of the Maldives and found the pole-and-line method to predominate there. About 95% of the tuna landed are taken by motorised *thonies* using this technique (Jonklass, 1962). As cetacean entanglement is not thought to be a problem in this area it is not considered further in this report.

A detailed comprehensive study of the development and structural and operational details of vessels and gillnets of northeastern Indian Ocean countries is still needed to determine the impact of, and to predict the future for, gillnet fisheries. The Bay of Bengal Project (BOBP) and the efforts of the Central Marine Fisheries Research Institute (CMFRI) in India have helped in this assessment. Details of the vessels and fishing gear of India are given in Table 1.

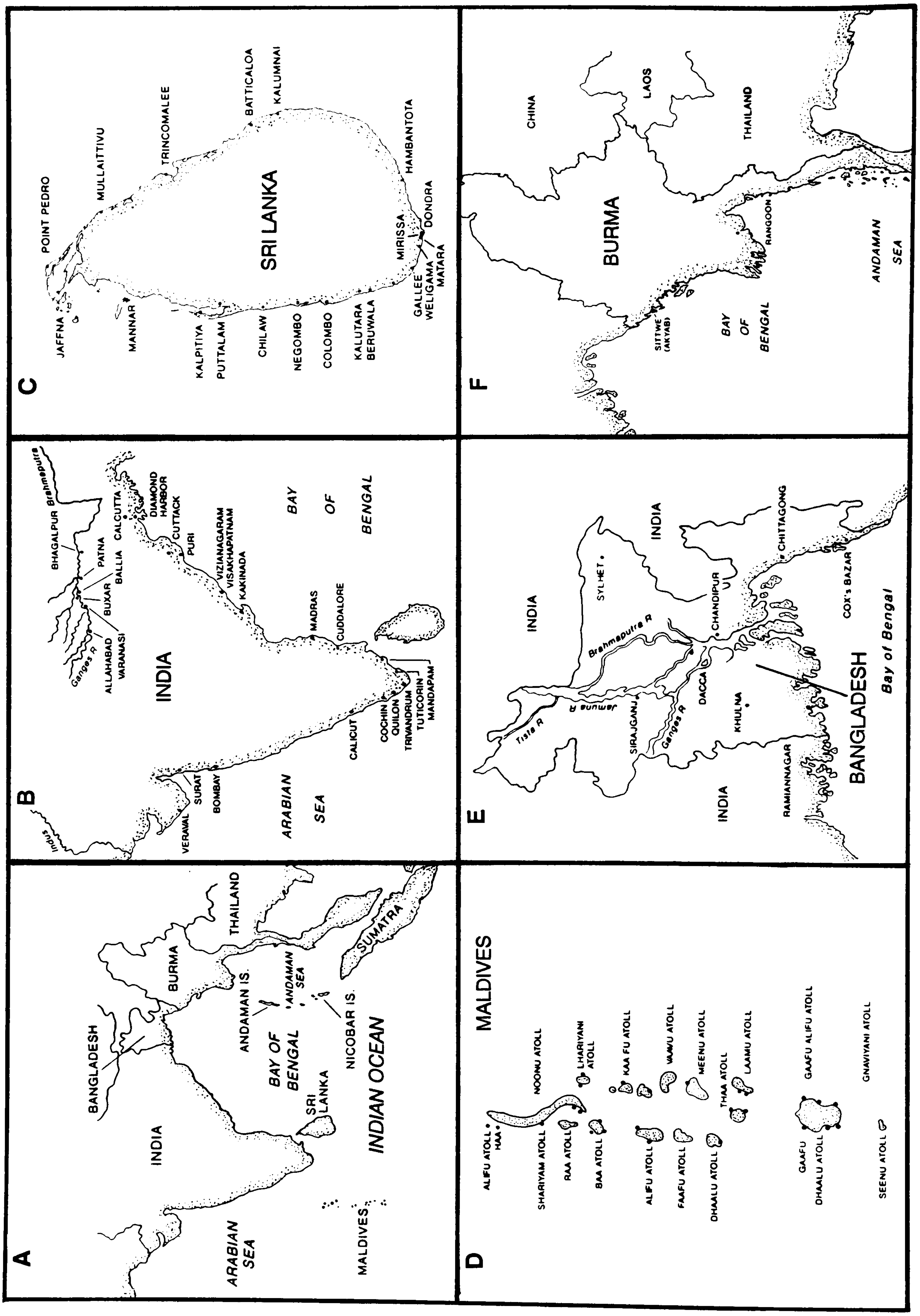

Fig. 1. The northeastern Indian Ocean (A) with some of the important fish-landing and/or trading centers in the countries treated: India (B), Sri Lanka (C), the Maldives (D), Bangladesh (E), and Burma (F).

Large-scale pelagic driftnet fisheries and their impacts on the living marine resources of the oceans were addressed recently by the Indian Ocean Fisheries Commission (IOFC, 1990) and in December 1989, the United Nations passed a resolution recommending a moratorium on all large-scale pelagic driftnet fishing by June 1992. This review however deals primarily with national fisheries, i.e., within the Exclusive Economic Zones (EEZs) of the countries named. It builds on a FAO-sponsored review by Northridge (1984) on the interactions of cetaceans with gillnet fisheries worldwide.

SYNOPSES OF THE FISHERIES

To simplify presentation, countries have been abbreviated as follows: India (**I**), Sri Lanka (**SL**), Bangladesh (**Ba**) and Burma (**Bu**). The first such appearance, after the name(s) of the target species, indicates the presence of a fishery for the target species in that country. If a fishery exists but there is no entry under a given subheading, that signifies that no information was available to the author. All landings are given in metric tonnes.

Seerfish

References
I: CMFRI (1992–1993); Yohannan and Balasubramanian (1989); Silas *et al.* (1984). **Ba**: Bergstrom (1982); Mohiuddin *et al.* (1980). **Bu**: Sivasubramanian (1985); Anon. (1982). **SL**: Leatherwood and Reeves (1989); Fernando (1980); BOBP (1984); Alling (1985); IWC (1986); Kasim and Hansa (1989).

Primary ports
I: multiple but unlisted. **Ba**: Khulna, Sylhet, Cox's Bazar and Chittagong.

Target species
I: *Scomberomorus commersoni* and *S. guttatus*. **Ba**: *S. commersoni* and *S. guttatus*; (**Bu**) Indian round scads and *Dendrophysa russelli*. **SL**: *S. commersoni* and *S. guttatus*.

Vessels
I: northwest coast – dugout canoes (*satpati* and *machuva*); southwest coast – dugouts (*thonies, vanchi* and *odum*) and plank boats (*kettuvallam*); east coast – *catamaram*, Tuticorin-type boats, fibreglass outboard and *pablo* (8–10m) inboard. **Ba**: *dinghi, chhandi, balam* and motorised traditional vessels. **Bu**: motorised and non-motorised vessels. **SL**: *theppam, catamaram, oru, thonies, vallam* and motorised vessels.

Nets
I: drift- and gillnet (setnet) – 500–1,000m length multifilament synthetic twine (0.5–0.9mm), 25–200mm mesh size, 8–10m depth. **Ba**: drift- and gillnet – 10–17cm mesh multifilament nylon twine (5–8mm), 500-1,500m length. **Bu**: gillnet. **SL**: drift- and gillnet – 10–15cm mesh multifilament twine (0.5–0.8mm), 100–600m length, 8–10m depth.

Operations
I: 10–30m depth; 45–60min set time; 4–6hr soak time. **Ba**: 5–60m depth; 9–13+ or 5–9 day trips. **SL**: 1–6 day trips, 15–16 miles from shore, 5–40m depth, 4–5hr soak time.

Total landings
I: 1,200–8,900t (1956–1960); 18,897–29,547t (1975–1979); 33,611–35,820t (1982-1985); 29,841–42,894 (1990–1992). **Bu**: 430,800t (1982). **SL**: 174,462t (1981).

Table 1

Number and type of marine fishing craft and gear in India by state in 1980 (from CMFRI, 1981).

	West Bengal	Orissa	Andhra Pradesh	Tamil Nadu	Pondi, Karai Maheo, Yenam	Kerala	Karnataka	Goa Daman	Gujarat	Total	%
I. Fishing crafts											
A. *Mechanised*											
Trawlers	-	-	447	2,295	176	745	808	407	1,410	6,288	67
Gillnetters	247	106	9	324	-	215	23	213	1,225	2,362	25
Dol netters	-	-	-	-	-	-	-	-	241	241	2
Purse seiners	-	-	-	-	-	9	173	39	-	221	2
Others	63	-	-	8	-	14	74	-	18	177	1
Totals	310	106	456	2,627	176	983	1,078	659	2,894	9,289	100
B. *Non-mechanised*											
Plank-built	3,972	3,262	11,359	8,957	83	4,376	1,747	1,108	3,040	37,904	29
Dugout canoes	89	186	1,781	2,210	72	10,415	4,454	1,397	1,080	21,684	16
Catamaram	-	6,276	22,198	31,851	1,595	11,480	23	8	-	73,431	54
Others	-	4	675	325	-	-	718	-	-	1,722	1
Total	4,061	9,728	36,013	43,343	1,750	26,271	6,942	2,513	4,120	134,741	100
II. Fishing gear											
Trawl nets	-	-	823	6,219	437	1,454	1,788	772	2,672	14,165	2
Purse seines	-	-	-	-	-	9	188	41	-	238	0
Drift/gillnets	2,467	10,427	42,385	118,300	1,851	23,307	6,571	3,346	7,383	216,037	36
Boat seines	-	2,676	9,738	7,220	375	9,779	23	165	-	29,976	5
Fixed bag net	6,200	2,778	14,617	1,842	152	-	941	430	21,857	48,817	8
Hook and line	869	15,265	10,752	22,111	720	2,949	1,507	127	2,376	56,676	9
Rampans	-	-	-	-	-	-	86	101	-	187	0
Shore seines	436	2,893	3,042	4,549	84	2,926	3,924	987	-	18,841	3
Traps	61	515	130	8,919	9	2,239	-	-	86,952	98,825	16
Scoop nets	345	37	2,925	1,040	362	1,371	-	-	-	6,080	1
Others	2,433	5,201	37,199	6,339	120	2,761	10,925	2,813	28,013	95,804	16

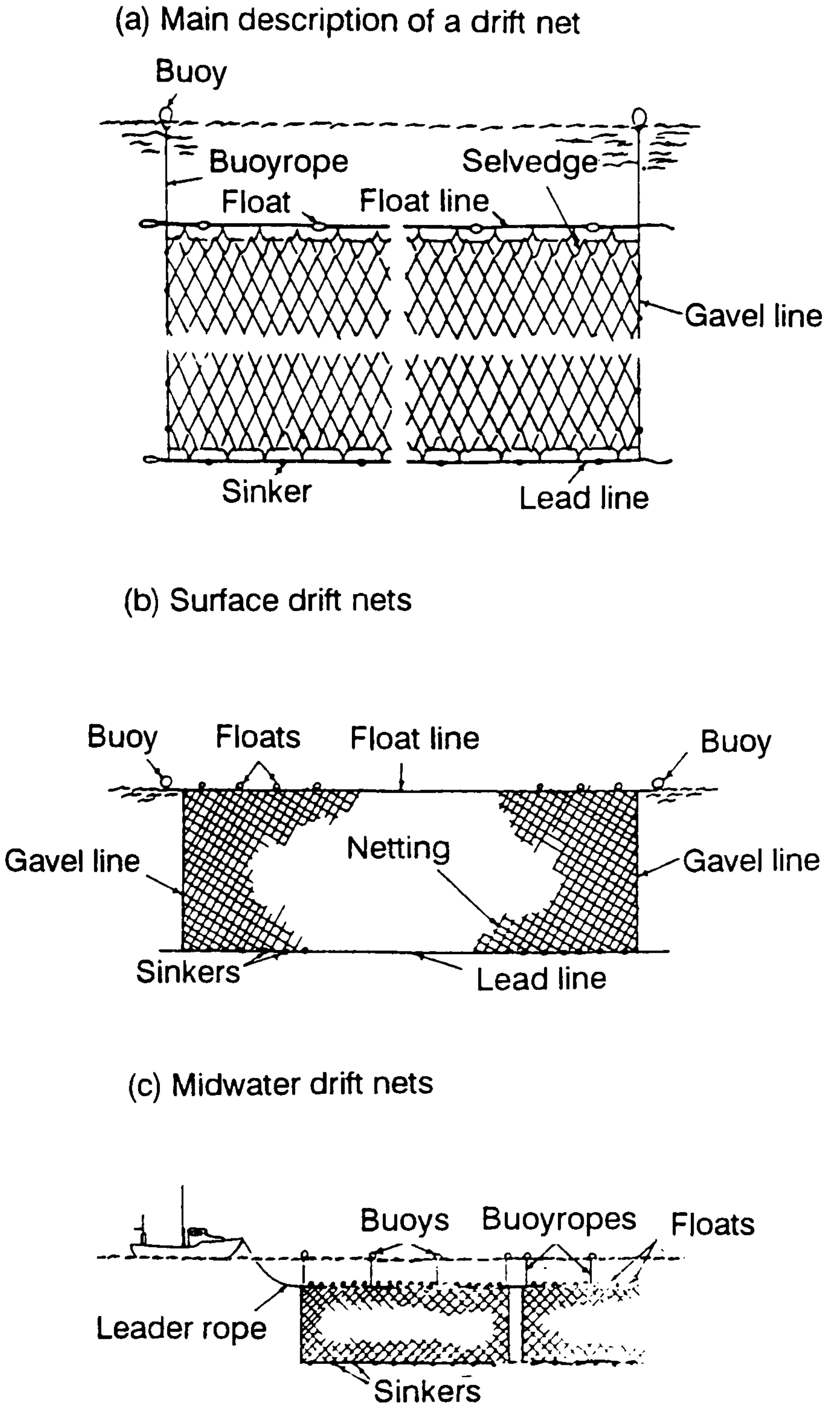

Fig. 2. Configurations and deployments of driftnets (a-c) used in portions of the northeastern Indian Ocean. (Modified from Nedleck and Prado.)

Cetacean bycatch
I: spinner dolphins (*Stenella longirostris*); Indo-Pacific hump-backed dolphins (*Sousa chinensis*); bottlenose dolphins (*Tursiops truncatus*); finless porpoises (*Neophocaena phocaenoides*); common dolphins (*Delphinus delphis*). **SL**: (in this and a variety of other fisheries) bottlenose dolphins, spinner dolphins (45% at Tricomalee in 1984–86), striped dolphins (*Stenella coeruleoalba*, 8%), Risso's dolphins (*Grampus griseus*, 15%), spotted dolphins (*Stenella attenuata*, 17%) and ten other species (totalling 15%).

Tuna

References
I: CMFRI (1989; 1993). **SL**: BOBP (1984); Joseph and Amarasiri (1988); Leatherwood and Reeves (1989).

Primary ports
I: Veraval, Mangalore, Calicut, Cochin, Vizhijam, Tuticorin. SL: Colombo, Galle, Trincomalee, Beruwala, Tangalle, Mirissa, Myliddy, Jaffnaa.

Target species
I: *Katsuwonus pelamis, Thunnus albacares, Auxis rochi, A. thazard, Euthynnus affinis, Kishoniella tonggol, Thunnus alalunga, T. orientalis.* **SL**: *T. albacares, Kishoniella tonggol, Katsuwonus pelamis, Auxus thazard, Euthynnus affinis.*

Vessels
I: northwest coast – *machwa, galbat*; Maharastra coast – *rampani, chemboke, thanga, vallam, patta, vala, thonies, pagar*; southwest coast – dugout canoes, *kettuvallam*; east coast – *catamaram*, Tuticorin-type boat, *masula*; Orissa and Coramandal coasts – bar boat, *padava, padagu*, fibreglass outboard, *pablo* inboard; **SL**: *vallam, catamaram*, fibreglass outboard, fibreglass inboard.

Nets
I: driftnet – 105–140mm mesh multifilament synthetic twine (0.2–1.0mm). **SL**: drift- and gillnet – 100–180mm mesh multifilament synthetic twine (0.5–1.0mm), 7–10m depth.

Operations
I: 15–18hr trip length, 15–30m depth, 5–6hr soak time. **SL**: 15–18hr or 2–3 day trip length, 15–35m depth, 5–6hr soak time.

Total landings
I: 3,201t (*Katsuwonus pelamis* 1985); 3,076t (*Auxis rochi, Auxus thazard* 1985); 16,625t (*Euthynnus affinis* 1985); 1,087t (*Kishoniella tonggol* 1985); 31,725–52,060t (all species, 1990–1993). *SL: 29,374t (1982).*

Cetacean bycatch
I: common dolphins; bottlenose dolphins; spinner dolphins. **SL**: (see **seerfish** above).

Pomfrets

References
I: Srinath *et al.* (1987). **Ba**: FAO (1980; 1981; 1982).

Primary ports
I: Veraval, Surat, Bombay, Mangalore, Calicut, Cochin, Vizhinjam, Puri. Ba: Khulna, Cox's Bazar, Chittagong. **SL**: Sylhatt, Chandipur, Mohipur, Nayahata, Bhagykal, Bheramara, Sirajgang, Bahadurpur, Tista.

Target species
I: *Pampus argenteus, P. chinensis, Formio niger.* **Ba**: *P. argenteus, P. chinensis.*

Vessels
I: northwest coast – *satpati, machwa*; South Kanara coast – *rampani, odam, vanchi, thonies, beputhoni,* and *pasta thoni*; southeast coast – *catamaram, masula*. **Ba**: *chhandi, balam*, Cox's Bazar type.

Nets
I: drift- and gillnet – 30–150mm mesh nylon multifilament (0.5–0.8mm). **Ba**: drift- and gillnet – 100mm mesh, 1750m length.

Operations
I: northwest coast – 3–4 day trip length; southwest coast – overnight trips, 4–5hr soak time, 20–60m depth. **Ba**: 15hr 4 day trip length, 4–5hr soak time.

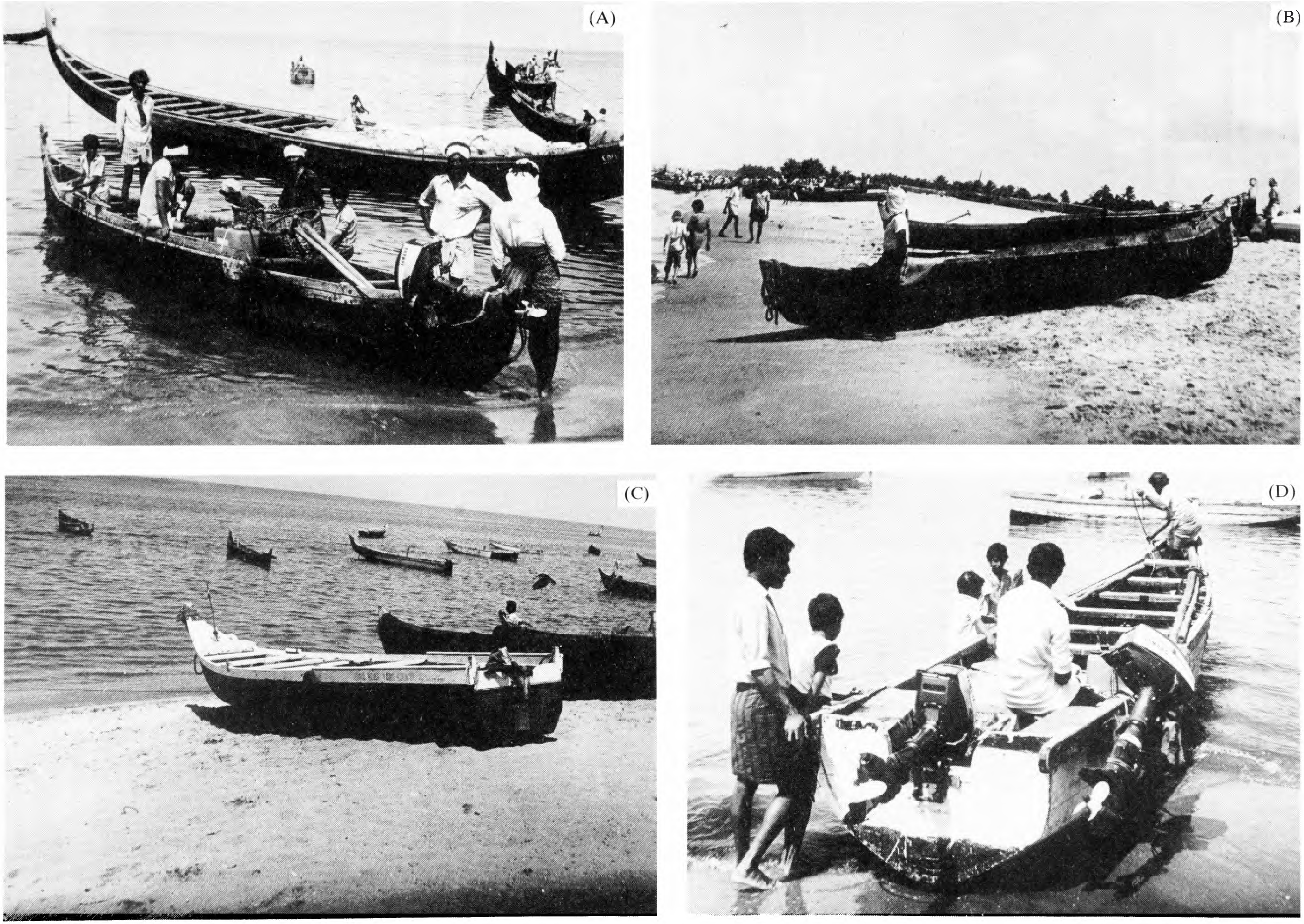

Fig. 3. Some of the fishing vessels involved in gillnetting off India: (A) a motorised large dugout (*odam*) with an indigenous *chundanvallan*, used for purse seining, in the background, (B) a smaller dugout (*thoni*) of the Malabar coast, (C) a plank-built *kettuvallam* of the southwest coast, and (D) a typical fibreglass boat with two outboard motors at Calicut.

Total landings
I: 13,718t (1980); 23,427t (1984); 33,912–42,649t (1990–1992). **Ba**: 157,593t fish (1982–1983), 4,824t shrimp and 87,000–141,000t fish (1972–1982).

Cetacean bycatch
I: common dolphins, spinner dolphins, Indo-Pacific humpbacked dolphins, bottlenose dolphins.

Sharks

References
I: Devadoss *et al.* (1989); CMFRI (1993). **Ba**: Hussain, pers. comm. (1987). **SL**: Sivasubramanian (1985).

Primary ports
I: Veraval, Bombay, Mangalore, Calicut, Cochin, Tuticorin, Madras, Visakhapatnam. **Ba**: Khulna, Cox's Bazar, Chittagong. **SL**: Jaffna, Mannar, Kalpitiya, Puttalam, Chilaw, Negombo, Colombo, Kalutara, Beruwala, Ambalangoda, Gallee, Weligama, Matara, Mirissa, Dondra, Hambantota, Kalumanai, Batticaloa, Trincomalee, Mullaitivu, Point Pedro.

Target species
I: *Carcharhinus limbatus, C. melanopterus, Scoliodon laticaudus, Rhizoprionodon acutus, Galeocerdo cuvier.* **SL**: *C. melanopterus, C. falciformis, C. longimanus, C. limbatus, Sphyrna blochii.*

Vessels
I: same as for tuna and pomfret fisheries. **Ba**: *dinghi, chhandi, balam,* motorised non-traditional boats. **SL**: same as for tuna fishery.

Nets
I: drift– or gillnet – 70–150mm mesh or 140–185mm mesh multifilament twine (0.7–1.0mm). SL: 100–150mm mesh size nylon with filament (1–1.2mm), 900–1400m length.

Operations
I: same as for tuna fishery.

Total landings
I: 56,145t; 25,013–44,303t (1993). **Bu**: 430,800t (1982). **SL**: 18,739t (1982).

Cetacean bycatch
I: common dolphins; spinner dolphins; bottlenose dolphins; Indo-Pacific hump-backed dolphins; finless porpoises. **Ba**: kills known to occur, but no details known. SL: bottlenose dolphins; spinner dolphins; Fraser's dolphins (*Lagenodelphis hosei*); Risso's dolphins.

Skates and rays

References
I: Devadoss *et al.* (1989); CMFRI (1989;1993). **SL**: Joseph and Amarasiri (1988); Anon. (1982); Leatherwood and Reeves (1989).

Primary ports
I: Veraval, Bombay, Mangalore, Cochin, Vizhinjam, Tuticorin, Cuddalore, Madras, Kakinada, Visakhapatnam. SL: Puttalam, Chilaw, Negambo, Colombo, Kalutara, Galle, Matara, Hambantota, Kalmani, Batticola, Tricomalee, Mullaitivu, Jaffna, Mannar.

Target species
I: *Pristis cuspidatus, P. microdon, Rhynchobatus djiddensis, R. granulatus, Gymnura poeilura, Himanutura uarnak, Aetobatus narinari, Rhinoptera javanica.* **SL**: *P. cuspidatus, R. sephens, A. narinari, Himanutura uarnak.*

Vessels
I: northwest coast – *machwa*; southwest coast – *vanchi, vallam, kettuvallam*; east coast – *catamaram*, Tuticorin-type boat, *masula*, bar boat, fibreglass outboard, *pablo* inboard. **Ba**: *chhandi*, Cox's Bazar type. **SL**: *catamaram*, dugout canoe, fibreglass inboard, fibreglass outboard.

Nets
I: drift– and gillnet – 500–800m length, 6–8m depth, 150–300mm mesh multifilament twine (0.8–1.0mm). **Ba**: gillnet – 150–200mm mesh, 50 mesh deep. SL: Bottom driftnet – 100–250mm mesh, 700–1000m length; 6–7m depth, synthetic fibres.

Operations
I: up to 40m depth, 12–15hr trip length; 5–7hr soak time. **SL**: up to 40m depth, fishing at night, 5–6hr soak time; 15–40m depth.

Total landings
I: west coast – 3,472t (skates and rays, 1985-1986); east coast – 16,148t (skates and rays, 1985-1986); 17,941–28,644t (1992–1993). **Ba**: 7,014t (1982).

Cetacean bycatch
I: **SL**: spinner dolphins (*Stenella attenuata*), striped dolphins, rough-toothed dolphins (*Steno bredanensis*), pygmy killer whales (*Feresa attenuata*), pygmy sperm whales (*Kogia breviceps*), dwarf sperm whales (*Kogia simus*).

Catfish

References
I: Silas *et al.* (1980); James *et al.* (1989); CMFRI (1993). **Ba**: Hussain, pers. comm. (1987); Sivasubramanian (1985).

Primary ports
I: Veraval, Bombay, Karwar, Mangalore, Calicut, Cochin, Kakinada, Tuticorin, Visakhapatanam. Ba: Khulna, Chittagong, Cox's Bazar.

Target species
I: *Tachysurus sona, T. platystomus, T. malabaricus, T. tenuispinis, T. thalassinus.* **Ba**: *T. gagora, T. thalassinus.*

Vessels
I: *machwa, padu, ratnagiri, hodi, odam, thoni, kettuvallam, catamaram*, Tuticorin-type. **Ba**: *dinghi, chhandi, balam*, Cox's Bazar-type.

Nets
I: drift– and gillnet – 100–180mm mesh nylon monofilament (7–10mm), 5–8m depth.

Operations
I: northwest coast – 2–3 day trip length; southern coast – 15–18hr trip length, 10–60m depth.

Total landings
I: 45,450t (1985–1986), 52,290t (1984–1985); 34,110–39,374t (1990–1992).

Fig. 4. Mortality of cetaceans in gillnets in the northeastern Indian Ocean. (A) Indo-Pacific hump-backed dolphin, in Calicut fish market, brought alive to market and killed; (B) live Indo-Pacific hump-backed dolphins caught in gillnets off Calicut; (C) Indo-Pacific hump-backed dolphin kept in captivity in a polythene film-lined pond at Calicut for public display; (D) finless porpoises entangled in a gillnet off Calicut; (E) bottlenose dolphins (3.2 m) entangled in a drift gillnet off Calicut; and (F) spinner dolphins for sale in the Calicut fish market.

Fig. 5. Indo-Pacific hump-backed dolphin meat for sale (head in the foreground) at Quilandy (near Calicut) fish market.

Cetacean bycatch
I: common dolphins; bottlenose dolphins; spinner dolphins.

Polynemids

References
I: Kagwade (1970); Bal and Rao (1984); CMFRI (1993); **BA**: BOBP (1985). **Bu**: no gillnet fishery. **SL**: larger polynemids not fished.

Primary ports
I: Veraval, Bombay. Ba: Khulna, Cox's Bazar, Chittagong.

Target species
I: Polynemus indicus, P. eleutheronema, P. tetradactylum.

Vessels
I: *valion, matada, hodi, galbat, dinghi*. **Ba**: *balam, chhandi*, motorised vessels.

Nets
I: drift- and gillnet - 1200–5000m length, 180–210mm mesh. Ba: 1400m length.

Operations
I: 20–40m depth, 4–5 days or 10–15 day trip length, 15–60m depth, 5–6hr soak time. Ba: 5–6hr or 15–18hr soak time.

Total landings
I: 9,059t (1985); 6,837–7,849t (1990–1992).

Cetacean bycatch
I: entanglements known. **Ba**: entanglements known.

Oil sardines

References
I: CMFRI (1989; 1993). SL: Anon (1977); Nevill (1887); Lantz and Gunasekera (1955). No fishery in **Ba** and **Bu**.

Primary ports
I: Karwar, Mangalore, Calicut, Cochin, Vizhinjam. **SL**: Jaffna, Mannar, Kalpitiya, Puttalam, Chilaw, Negombo, Colombo, Kalutara, Beruwala, Ambalangoda, Gallee, Weligama, Matara, Mirissa, Dondra, Hambantota, Kalumanai, Batticaloa, Trincomalee, Mullaitivu, Point Pedro.

Target species
I: *Sardinella longiceps*. **SL**: *S. longiceps*.

Vessels
I: *odam, thoni, vanchi, kettuvalam, pandi, hondi*. **SL**: *oru, kulla, thoni, vallam, log rafts, catamaram, theppam*.

Nets
I: drift- and gillnet - nylon monofilament/multifilament (0.5–0.7mm), 20–25mm mesh, 5–6m depth, 200–300m length. **SL**: gillnet - 25–35mm mesh.

Operations
I: 30 min - 1hr soak time.

Total landings
I: 34,420t (1950); 189,016t (1960); 301,446t (1968); 168,078t (1978); 128,724t (1985-1986); 104,062 - 260,995t (1990–1992).

Cetacean by catch
I: no mortality in nets. **SL**: no mortality in nets.

Mackerel

References
Sources: **I**: CMFRI (1993); Srinath *et al.* (1987); Yohannan and Balasubramanian (1989); Jhingran (1989); Bal and Virabhadra Rao (1984). **SL**: BOBP (1984).

Primary ports
I: Mangalore, Calicut, Cochin. Ba: Khulna, Sylhet, Cox's Bazar, Chittagong.

Target species
I: *Rastrelliger kanagurta*. **Bu**: *R. brachysoma*.

Vessels
I: northwest coast - *machwa*; southwest coast - *vanchi, vallam, kettuvallam*; east coast - *catamaram*, Tuticorin-type, *masula*, bar boat, fibreglass outboard-type, *pablo* inboard. **Ba**: *dinghi, chhandi, balam*, Cox's Bazar-type. **SL**: *catamaram, theppam, vallam, oru, kulla, thoni*, fibreglass reinforced plywood (FRP).

Nets
I: gillnet - 25–55 mm, 6–8m mesh, 10m depth. **Ba**: driftnet - synthetic nets, 50–100mm mesh, 1700m length, 6–7m depth. **Bu**: drift- and gillnet. **SL**: gillnet: 50–60mm mesh, 500–1000m length, 5–6m depth.

Operations
I: up to 25m depth, 3–6hr trip length, 1–2hr soak time. **Ba**: in water from 10–30m deep with net fishing at 5–15m depth, trip length averages about 15 hours, soak time is about 4–5hr.

Table 2
Common fishing craft of Bangladesh.

Name	Length (m)	Breadth (m)	Depth (m)	Crew	Propulsion	Fishing gear
Plank built (traditional):						
Dinghi	5-7	10-1.2	0.9	2-3	oar/sail	gillnet/long
Chhandi	10-15	3	1.0	7-15	oar/sail	gillnet/Hilsa
Dugout						
Balam (medium)	10-15	1.5-2.0	1.2	10-15	oar/sail	gillnet
Balam (large)	15-20	1.5-2.0	1.2-1.5	20-30	oar/sail	gillnet/Behundi
Motorized (traditional):						
Cox's-Bazar type	12-14	3.0-3.2	1.2-1.5	8	22-33 hp	gillnet/Behundi
Modified Cox's-Bazar	12	3	1.2	6	22hp	gillnet/Behundi
Chhandi	12-13	1.6-1.8	1.0	10	9hp	gillnet
Longliner	6-7	1.0-1.2	10.9	6	10-15hp	longline

Total landings
I: 204,575t (1971); 23,863t (1967); 65,152t (1985–1986); 113,658–184,380t (1990–1992). **SL**: 751,000t (1983–1984).

Cetacean bycatch
I: not entangled. **SL**: probably not entangled.

Lesser sardines

References
I: Bennet and Arumugham (1989). **Ba**: no major gillnet fishery. Bu: no gillnet fishery. **SL**: Leatherwood and Reeves (1989).

Primary ports
I: Vizhinjam, Tuticorin, Madras, Visakhapatanam. **SL**: Jaffna, Mannar, Kalpitiya, Puttalam, Chilaw, Negombo, Colombo, Kalutara, Beruwala, Ambalangoda, Gallee, Weligama, Matara, Mirissa, Dondra, Hambantota, Kalumanai, Batticaloa, Trincomalee, Mullaitivu, Point Pedro.

Target species
I: *S. fimbriata, S. albella, S. gibbosa, S. sirm, S. dayi, Tenualosa toli, Dussumieri acuta*. **SL**: *S. gibbosa, S. albella, S. sirm, S. dayi, S. clupeoides, Thrissocles* spp.

Vessels
I: *masula, catamaram*, Tuticorin-type, dugout canoe, *odam, thoni, kettuvallam*. **SL**: *theppam, catamaram, vallam, oru, thoni, pathia*.

Nets
I: multifilament/monofilament synthetic twine (0.3–0.5mm), 25–40mm mesh. **SL**: drift- and gillnet – 20–40mm mesh, 500–700m length, synthetic twine (0.4–0.6mm).

Operations
I: (**SL**) 1–3hr soak time, up to 10m depth.

Total landings
I: 52,467t (1969); 68,351t (1979); 60,828t (1985–1988).

Cetacean bycatch
I: probably not entangled. **SL**: not usually entangled.

Whitebait

References
Sources: **I**: Luther *et al.* (1982); Bennet and Arumugham (1989); CMFRI (1989; 1993). **Ba**: no whitebait fishery. **Bu**: no information from Burma coast. **SL**: Leatherwood and Reeves (1989).

Primary ports
I: Mangalore, Calicut, Cochin, Vizhinjam, Tuticorin; Vizhinjam, Tuticorin, Madras, Visakhapatanam. **SL**: Jaffna, Mannar, Kalpitiya, Puttalam, Chilaw, Negombo, Colombo, Kalutara, Beruwala, Ambalangoda, Gallee, Weligama, Matara, Mirissa, Dondra, Hambantota, Kalumanai, Batticaloa, Trincomalee, Mullaitivu, Point Pedro.

Target species
I: *Stolephorus indicus, S. bataviensis, S. buccaneeri, S. devisi, S. commersoni*. **SL**: *S.* spp., *Thrissocles* spp.

Table 3
Distribution of traditional fishing vessels in Bangladesh (from BOBP, 1985)

Districts	Plank built	Dugout	Total
Chittagong	4,055	1,871	5,926
Nokhali	780	185	965
Barisal	1,025	-	1,025
Patuakhali	1,077	11	1,088
Kulna	445	3	448
Jessore	11	3	14
Total	7,393	2,170	9,563

Vessels
I: dugout canoe, *thoni, odam, vanchi, kettuvallam, catamaram*, Tuticorin-type, *vallam, Masula*. **SL**: *catamaran, theppam, oru, thoni, vallam*, fibreglass reinforced plywood (FRP).

Nets
I: 25–30mm mesh, monofilament/multifilament twine (0.3–0.4mm), 70–100m length, 6–8m depth. SL: drift- and gillnet – 20–25mm mesh, 60–70m length, 6–7m depth, synthetic fibre.

Operations
I: 4–8hr trip length, 5–8m depth, 2–3hr soak time. SL: 4–6hr trip length, up to 15m depth, 1–3hr soak time.

Total landings
I: 63,692t (1985–1986); 77,447–93,300t (1990–1992).

Cetacean bycatch
I: not entangled. SL: probably not entangled.

Hilsa

References
I: Pillay (1958); Sharma and Grover (1982); (CMFRI) (1980, 1989); Jhingran (1989). **Ba**: Ali and Haq (1980); Karim (1977); Hossain *et al.* (1987); Sivasubramaniam (1985); Shahidullah (1986). **Bu**: Sivasubramaniam (1985). **SL**: no hilsa gillnet fishery.

Primary ports
I: Varanasi, Buxar, Ballia, Patna, Allahabad, Bhagalpur, Diamond Harbour. **Ba**: Khulna, Sylhet, Chittagong, Cox's Bazar, Chandipur, Mohipur, Nayahata.

Target species
I: *Hilsa ilisha, Tenualosa toli*. **Ba**: *H. ilisha*.

Vessels
I: *donga, ekhta, jalia dinghi, chhandi, bachari, chhot*. **Ba**: *dinghi, chhandi, balam*, Cox's Bazar-type, motorised boats.

Nets
I: nylon twine driftnets, 1500m long, 3m wide, mesh sizes from 50–110mm. **Ba**: surface driftnets – 75–120mm mesh monofilament or multifilament synthetic fibre (0.4–0.8mm), 360–600m long in coastal fishery, and 400–1500m long in the offshore fishery. Bu: gillnet, little other information available.

Operations
I: 5–12m depth. **Ba**: 5–6hr (river) or 2–3 day (offshore) trip length, 5–30m depth, 1–4hr soak time.

Total landings
I: marine sector only: 404–1,769t/yr (1964–1974); 4,189–12,068t/yr (1975–1979); 1,909t (1984–1985); 5,543t (1985–1986); 14,243–28,895t (1990–1992). **Ba**: 132,000t/yr (1980–1982); 234,000t (1985). **Bu**: 322,895t (1972–1973); 442,920t (1982–1983).

Cetacean bycatch
I: Ba: Ganges river dolphins (*Platanista gangetica*); Irrawaddy dolphins (*Orcaella brevirostris*).

Riverine catfishes

References
I: Jhingran (1985); Mohan (1989a; 1989b); Sharan and Sinha (1989). **Ba**: Mohan (1989b); Shahidullah (1986). **Bu**: Hershkowitz (1966). **SL**: no riverine catfisheries.

Primary ports
I: Agra, Allahabad, Kanpur, Varanasi, Buzar, Ballia, Patna, Bhagalpur, Dhubri, Guhathi, Tezpur, Dibrugarh. **Ba**: Chandpur, Bhagykal, Bheramara, Sirajgang, Bahadurpur, Tista.

Target species
I: *Mystus aor, M. seenghala, Wallago attu, Notopterus chitala, Pangasius pangasius, Eutropichthys vacha*. **Ba**: *M. aor, M. seenghala, Clupisoma garua, Bagarius bagarius, Clarius batrachus*.

Vessels
I: *donga, ekhta, jalia dinghi, chhandi, bachari*. **Ba**: *chhandi, dinghi*.

Nets
I: drift- and gillnet – 300m length, 3m width, 76–102mm or 12–250mm mesh cotton, nylon or Assam silk nets. **Ba**: 300m length, 5–8m depth, 100–150mm mesh.

Operations
I: 3–30m depth; 3–8hrs trip length; 4–5hrs soak time.

Total landings
I: **Ba**: 580,000t (inland only).

Cetacean bycatch
I: Ganges river dolphins. **Ba**: Ganges river dolphins.

Prawns

References
I: CMFRI (1993); **SL**: Sivasubramaniam (1985); FAO (1986).

Primary ports
I: Veravel, Bombay, Goa, Mangalore, Calicut, Cochin, Quilon, Mandapam camp, Tuticorin, Madras, Kakinada, Vishakapatnam, Puri, Calcutta.

Target species
I: *Penaeus indicus, P. monodon, P. semisulcatus, Metapenaeus dobsoni*.

Vessels
I: northwest coast – *machwa, satpati*; southwest coast – *odam, thoni, vanchi, kettuvallam*; east coast – *catamaram*, Tuticorin-type, *masula, chhandi*, fibreglass outboard, *pablo* inboard.

Table 4

Names of set- or drift-gillnets deployed for mackerel from various fishing craft along the Indian coast (Srinath *et al.*, 1987; Jhingram, 1989; Bal and Rao, 1984; Yohannan and Balasubramanian, 1989).

State	Craft	Local name(s) of set- or drift-gillnet(s) operated
1. Maharastra	Dugout canoes	Bangdajal
	Pagar & Thoni	Petite bale
2. Karnataka	Dugout canoes	Kandadi bale
	Thoni	Patta bale, Chala bale
	Canoe boat	Kantha bale
	Pandi	Ida bale
3. Kerala	Dugout canoes	Ozhuku vala, Noo vala
	Odam & Thoni	Vengadu vala
	Canoe boat	Ayilachala vala
	Vallams	
	Catamaram	
	Kattaumaram	
4. Tailnadu	Plank-built boat	Vazhi valai
	Vallam, Padagu	Vala valai
	Catamaram	
	Kattumaram	
	Periamaram	
	Chinna maram	Podi valai
5. Andhra pradesh	Plank built boat	
	Padava	Gillnet
	Masulas	
	Catamaran	
	Theppalu	
6. Orissa	Plank-built boat	
	Ber	
	Masula	
	Chhoat	Phasi Jalo
	Palia	Ilishi Jalo
	Dhingy	Behendi Jalo
	Danga	Bhasani Jalo
	Salti	Jagawala (Bottomset net)
	Catamaraan	Kilumala (Bottomset net)
		Katlala (Surface driftnet)

Nets
I: drift- and gillnet – 15–30mm mesh nylon twine (0.5–0.7mm), 100–500m length, 8–10m width.

Operations
I: 5–30m depth, 12–15hr trip length, 3–5hr soak time.

Total landings
I: 132,198t (1985); 29,204t (1985) (Penaeid prawns alone); 164,580–190,434t (1993). **Ba**: 4,824t (1982–1983). **SL**: 7,493t (1982).

Cetacean bycatch
No evidence of cetacean involvement in **I** or **SL**.

RECENT DEVELOPMENTS IN THE FISHERIES

Gillnets are one of the most important types of fishing gear in small-scale traditional fisheries. Mechanised vessels also have taken up gillnetting because of the advantages they offer. The relatively recent introduction of synthetic twines made of polyamide (PA), polyester (ES), polyethylene (PE), polypropylene (PP) and polyvinyl chloride (PVC) in the place of cotton and hemp has increased the efficiency of gillnets, while the use of outboard engines on traditional vessels and the introduction of fibre glass boats has increased operational efficiency. Fishermen can thus remain on the fishing ground for more time and still bring catches to shore in better condition than in earlier days.

In India, there were 18,169 driftnets and gillnets in 1950 (Chopra, 1951). By 1980 that number had risen to 216,037 (CMFRI, 1980). There are about 35 such gillnets per kilometre of Indian coast. About 150,000 indigenous vessels and 6,000–8,000 small, mechanised boats operate the gear. The usual gillnet panels are 25–75m in length, with a total net length of less than 1.8km. These are multi-meshed, multi-species nets and operate mostly within 50m depth.

In Bangladesh, Burma and Sri Lanka, driftnets and gillnets are also used extensively in small-scale coastal marine fisheries. Increases in landings in such coastal fisheries as those for seerfish, tuna and pomfret are mainly due to the introduction of synthetic driftnets and gillnets (Bal and Virabhadra, 1984). Increases in effort in the hilsa fishery in Bangladesh (BOBP, 1985) and the tuna fishery in Sri Lanka are a direct result of deployment of more gillnets. Synthetic gillnets of various mesh sizes were introduced in 1962 and since then have become very popular. The fish landings of the coastal fisheries increased from 103,636t in 1966 to 180,816t in 1980. In 1982, gillnets contributed some 42.4% of total fish production; during a period of increasing gillnet use, tuna production went up from 23,159t in 1977 to 32,307t in 1982 (BOBP, 1984). There are about 2,000 boats of 3.5–4.0t and 70 boats of 11t operating gillnets, in addition to other traditional vessels. The nets are made of small panels of 100 units with mesh sizes of 90–180mm (the most commonly used mesh size is 140–150mm). The total length of the net is about 3.0–4.5km. About 90% of the offshore catches come from driftnets. Skipjack and yellowfin tuna, along with small tuna, form 70% of the driftnet catches.

Gillnets contributed about 97% of the 100,000t of hilsa landed in Bangladesh. Mechanised vessels operating large-mesh nets averaged 1,340kg/trip, 190kg/fishing day, while those operating small-mesh nets averaged 2,060kg/trip, and 280kg/fishing day (Sivasubramanian, 1985).

The Taiwanese fished for tunas on the high seas of the Indian Ocean, deploying 200–220mm mesh nets with a depth of 100–120mm mesh (vertical depth of 20–24m). The total number of nets deployed is 700–900, and the length of the nets is 37–47km. They captured about 111,480t of tuna in 1988 with yellowfin tuna (*Thunnus albacares*) forming about 106,969t (IOFC, 1990).

The total catch of tuna and other large pelagic fish by gillnets in the Indian Ocean was about 105,577t in 1988 (IOFC, 1990). Most came from Sri Lanka (25,551t, 24.2%), followed by India (20,935t, 19.8%), Iran (19,420t, 18.3%), Pakistan (19,402t, 18.3%), Malaysia (5,603t, 5.3%), Indonesia (2,950t, 2.7%), Thailand (522t, 0.5%) and Bangladesh (16t, 0.01%). The total catch of Taiwanese vessels operating drift gillnets in the Indian Ocean increased from about 24t in 1983–1984 to 18,486t in 1987–1988. The number of boats operating also has increased from 1 to 39. *Thunnus albacares* contributed 91 to 95% of the catch during 1987–1988 (IOFC, 1990).

CETACEAN BYCATCHES

Dolphins are known to become entangled in gillnets along the Indian coast (Jones, 1976; Lal Mohan, 1985; Lal Mohan, 1989a; Lal Mohan, 1989b; CMFRI, 1988; IOFC, 1990). The introduction of synthetic gillnets and driftnets has increased dolphin mortality. An estimated 1,000–1,500 dolphins may be killed by gillnets annually along the Indian coasts. The southwest coast has been found to be the core area for entanglement of dolphins in gillnets, accounting for about 90% of the known entanglements (CMFRI, 1988). A total of 202 dolphins were observed entangled in coastal gillnet fisheries during 1986–1987; the southwest coast accounted for 197 of them. Spinner dolphins comprised 61.6% of the total followed by common dolphins (23.6%) and bottlenose dolphins (12.1%). Gillnets from Cochin landed 123 dolphins, while 27 were landed at Calicut. Almost all (92%) of the landed spinner dolphins were in the length group 100–199cm, the rest being larger (200–249cm). A similar pattern was seen for common dolphins where 84% were from 100–199cm in length and 16% from 200–299cm. However, the reverse was true for the largest of the three species, 88.8% of bottlenose dolphins were in the 200–299cm length group, while 11.2% were in the range 100–199cm. It has been estimated that about 350 Ganges river dolphins are killed annually throughout its range (Lal Mohan, 1992; Reeves *et al.*, 1993). Lal Mohan *et al.* (1993) counted 268 Ganges river dolphins in the River Brahmaputra from Dhubri to Shaikwaghat, a distance of about 600km in Assam. They estimated that the total population of the river dolphins in the river may not be more than 400 and about 50 dolphins are killed in the gillnets annually.

Sri Lanka

Leatherwood and Reeves (1989) have recently reviewed the history, current status and immediate future plans of Sri Lankan fisheries and the involvement of marine mammals in those fisheries. Marine mammal fishery interactions in Sri Lanka have been known since the last century (Nevill, 1887). Blegvad (1951) and Medcof (1963) stated that dolphins caused considerable financial loss to fishermen both by damaging nets and feeding on the fish caught in them. They advocated measures to kill the dolphins and suggested developing a dolphin fishery in Sri Lanka, a view supported by Lantz and Gunasekera (1955). However, it was not until 1983 that the problem of cetacean mortality in Sri Lankan gillnet fisheries was confirmed to be widespread and began to receive attention (Alling, 1983; Joseph *et al.*, 1983).

With increased fish production in Sri Lanka, the mortality of dolphins has also increased. For example, nearly 13,000 dolphins, mainly spinner dolphins, were killed by gillnet fishing in 1988 (IOFC, 1990). Small cetaceans are killed directly and indirectly and are used for human consumption and for bait in longline fisheries. Until recently, the dolphin mortality was not monitored and its effect on the populations was not studied. There have been various attempts to monitor cetacean landings along the coast of Sri Lanka and estimates of total mortality have ranged from around 10,000 (e.g. Alling, 1983; Joseph and Siddeek, 1985) to as many as over 40,000 (Alling, 1985). Leatherwood and Reeves (1989) carefully reviewed the numerous problems associated with any estimates of total cetacean mortality in the Sri Lankan fishery.

More recently the Sri Lankan National Aquatic Resources Agency (NARA) estimated that approximately 13,000 small cetaceans are caught in gillnets annually (Dayaratne and de Silva, 1990) but the methods used were not presented in sufficient detail to warrant critical evaluation. Joseph and Dayaratne (1993) estimated that 5,181 dolphins were caught off the Sri Lankan coast during 1992 and suggested that 'the number of dolphins caught in Sri Lankan coast is too small to warrant drastic management action at present'. Most recently, Leatherwood (1994) re-examined data originally presented in Leatherwood and Reeves (1989) on fishing effort and dolphin catches in Sri Lanka from 1984–86 and estimated that at least 8,042–11,821 small cetaceans and a few great whales were taken annually, the estimate depending on the assumptions used. The conclusion that 'All attempts to estimate mortality of cetaceans in Sri Lankan fisheries ... are compromised in significant ways' (Leatherwood and Reeves, 1989), remains valid.

Bangladesh and Burma

Data on the interaction of gillnets and cetaceans in Bangladesh and Burma are too fragmentary for any estimates of bycatches.

DISCUSSION

The designation of the Indian Ocean as a whale sanctuary by the International Whaling Commission in 1980 also served to focus attention on the status of marine mammals in general in that region. A series of cetacean reviews and research projects were subsequently conducted and reported on, mainly in meetings and symposia in the region (e.g., see the summary in Leatherwood and Donovan, 1991). Many of those reports showed that marine mammal mortality in gillnets was extensive in the region and, in at least a few well-documented cases, (e.g., Sri Lanka) was, and remains, cause for concern. Although conservation laws related to cetaceans exist for most of the countries bordering the northeastern Indian Ocean, enforcement is generally poor. Furthermore, notwithstanding evidence of overfishing of many target resources, there is continuing pressure to expand and develop marine fisheries within the area to keep pace with burgeoning human populations (James, 1988); increased effort will lead to increased cetacean mortality. Finally, increasing tendencies to use cetaceans caught incidental to fishing operations may ultimately result in the development of directed fisheries for cetaceans, as it has in Sri Lanka (Leatherwood and Reeves, 1989). These factors make it especially difficult for managers to implement methods to prevent unintended entanglements and deaths of cetaceans in gillnet fisheries. Gillnet operations are responsible for the livelihoods of thousands of people and proposals to ban this type of fishing to protect cetaceans will be difficult, if not impossible, to introduce and enforce.

Cetacean mortality in gillnets is a global phenomenon (e.g. International Whaling Commission, 1994) and experience has shown that resident coastal populations may be particularly at risk. In this region this includes species such as the Indo-Pacific hump-backed dolphin and the Ganges river dolphin, that are subjected not only to heavy fishing pressure but also to the effects of pollution and other human interference leading to habitat degradation.

RECOMMENDATIONS

Data collection

(1) Comprehensive surveys should be made of cetacean entanglement in the coastal gillnet fisheries of Bangladesh, Burma, Sri Lanka and India, with special attention being paid to coastal dolphins, such as Indo-Pacific hump-backed dolphins, finless porpoises and Irrawaddy dolphins, especially populations inhabiting shallow lagoons such as Chilka Lake in India and those ascending the estuaries of large rivers.

(2) Effort should also be made to collect information on the gillnet fisheries of the Ganges and Brahmaputra Rivers and other riverine fisheries in Bangladesh and Burma and their associated dolphin entanglement.

(3) Stock identity studies should be initiated on those species vulnerable to gillnetting.

(4) The population status of the various species subjected to gillnet mortality should be determined.

Legislation

(5) National cetacean protection agencies should be formed in India, Bangladesh, Burma, Sri Lanka and the Maldives to monitor and to take follow-up action on the conservation of cetaceans. Periodic national and regional reviews of progress should occur. The national agencies should be linked to international agencies (e.g. IUCN, IWC) to ensure coordinated distribution and analysis of the collected information.

(6) The preservation of natural habitats of cetaceans should be given importance and monitored on a continuous basis. For example, the pollution of the River Ganges and the habitat degradation of Chilka Lake should be studied in relation to the Ganges river dolphin and the Irawaddy dolphin and the effect of large dams on dolphin populations should also be monitored. In particular, areas where dolphins are highly vulnerable to driftnets and gillnets should be declared protected areas. Initially, the areas from Puttalam to Trincomalee in Sri Lanka (all species), Cochin to Goa in India (all species); Patna to Bhagalpur in the River Ganges (Susu) and Tezpur to Dibrugarh in the Bramahputra (Susu), should be considered for designation as protected.

Alternative technology/methods

(7) As dolphins are killed for bait in longline fisheries in Sri Lanka and the catfish fishery of the Ganges and Bramahputra, efforts should be made to find alternatives to the use of dolphin meat as bait.

(8) Studies should be initiated to find ways to make gillnets less dangerous to dolphins, as discussed in IWC (International Whaling Commission, 1994), with emphasis on co-operation with local fishermen and fishermen's societies.

Awareness programmes

(9) Public awareness programmes should be initiated to explain the nature of the threats to cetaceans from fishery interactions. Attention must be directed particularly at the fishermen themselves, local communities (e.g. schools and colleges) and local fisheries scientists who should also be involved in attempts to improve the situation. The use of whale/dolphin watching, as a way to raise public awareness and perhaps as a supplementary or alternative economic proposition, should be encouraged.

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Brief Review of Passive Fishing Gear and Incidental Catches of Small Cetaceans in Chinese Waters

Zhou Kaiya

Department of Biology, Nanjing Normal University, Nanjing, PR China

and

Wang Xiaoyan

Bureau of Fisheries, Ministry of Agriculture, Beijing, PR China

ABSTRACT

A total of 139 types of passive fishing gear are used in Chinese marine fisheries. Finless porpoises, false killer whales, bottlenose dolphins and common dolphins are known to be caught incidentally in the fisheries. Finless porpoises are probably killed in considerable numbers; recorded incidental catches suggest that dozens or perhaps hundreds have been caught annually in gillnets, drifting trammels, stow nets and pound nets along the coast of Liaoning, Hebei, Shandong, Jiangsu and Fujian Provinces. Individuals of the Yangtze River finless porpoise population are caught incidentally in rolling hook longlines and encircling gillnets. Attention has been focused on the kill of the baiji, *Lipotes vexillifer*, by rolling hook longlines and fyke nets in the same river. The rolling hook longlines have accounted for 53% and 23% of the known deaths of the dolphin in the middle and lower reaches of the Yangtze, respectively, and fyke nets accounted for 16% of the deaths in the lower Yangtze.

KEYWORDS: FISHERIES; INCIDENTAL CAPTURE; BAIJI; NORTH PACIFIC; FINLESS PORPOISE; BOTTLENOSE DOLPHIN; COMMON DOLPHIN; KILLER WHALE; PACIFIC WHITE-SIDED DOLPHIN; INDO-PACIFIC HUMP-BACKED DOLPHIN

INTRODUCTION

In 1988, the total fish production of Chinese marine and freshwater fisheries was about 4,630,000 tons and 650,000 tons respectively. Numerous fishing methods are used in Chinese coastal, distant and fresh waters. Some 250 different types of fishing gear used at sea in Chinese fisheries have been described (Feng *et al.*, 1989). In terms of total marine fisheries production, trawling is the most important fishing method in China, taking cutlassfish (*Trichurus haumela*), jack (*Decapterus maruadsi*), needlefish (*Ablennes anastomella*), mullets (*Liza haematocheila, Mugil cephalus*), filefish (*Navodon septentrionalis*), cowrie (*Amussium japonica*), cuttle fish (*Sepia esculenta*), prawn (*Penaeus japonicus*), swimming crab (*Portunus trituberculatus*) and some other species. It accounted for about 40% of the total fish production in 1988. Catches from stow netting and bottom set gillnetting comprised about 24% of the total while those from drift gillnetting and surround netting contributed about 15% and 13%, respectively. Other types of traps in addition to stow nets are used in coastal areas, as are longlines. In Chinese inland waters the main fishing methods used are trapping, longlining and gillnetting.

Dolphins and porpoises are killed incidentally in Chinese marine and freshwater fisheries. For instance, rolling hook longlines and traps in the Yangtze River have been implicated in the decline of the baiji, *Lipotes vexillifer* (Zhou, 1982; Chen and Hua, 1989; Zhou and Li, 1989). However, the incidental catches of small cetaceans in Chinese marine fisheries have not been monitored, nor have their effects on the cetacean populations been systematically addressed. The present paper is a brief review of passive fishing nets and traps used by Chinese fisheries and available records of incidental catch of small cetaceans. In addition to the literature review, brief accounts of previously unpublished data on incidental catches of small cetaceans in passive fishing gear are included.

PASSIVE FISHING GEAR IN THE SEA

Gillnets

There are more than 3,500,000 gillnets in use in China. They range in length up to 15,000–20,000m (Feng *et al.*, 1989). Most are used in coastal waters although some are used in distant waters by more powerful vessels.

Drift gillnets

Driftnet fisheries are distributed widely in Chinese coastal waters, catching species such as butterfish (*Pampus argenteus*), mackerels (*Scomberomorus niphonius, Pneumatophorus japonicus*), Chinese herring (*Ilisha elongata*), yellow croaker (*Pseudosciaena crocea*), common sea bass (*Lateolabrax japonicus*), anchovy (*Setipinna taty*), mullets, prawns, lobster (*Panulirus stimpson*), jellyfish (*Rhopilema esculenta*) and others. Mesh size varies from 30mm to 360mm according to the size and shape of the target species (Table 1). Motorised vessels fishing with driftnets are of various sizes: (1) 12 ton boats, 17m long, with 12–25HP inboard engines, 6–7 crew members and carrying 40–50 nets; (2) 17 ton boats, 19m long, with 40–60HP inboard engines, 9 crew members and carrying 60–100 nets; (3) 67 ton boats, 24m long, with 80–150HP engines, 10–12 crew members and carrying 150–300 nets (Zhou and Li, 1986).

Set gillnets

The target species of set gillnet fisheries include smooth dogfish (*Triakis scyllium*), spiny dogfish (*Squalus fernandinus*), gizzard shad (*Clupanodon punctatus*), Chinese herring, maochang croaker (*Megalonibea fusca*), bummalo (*Harpadon nehereus*), common sea bass, sweetlips (*Plectorhynchus*), emperors (*Letherinus*), groupers (*Epinephelus*), javelinfish (*Pomadasys*), yellow porgy (*Taius tumifrons*), butterfish, bigcod croaker (*Nibea albiflora*), tonguefish (*Cynoglossus*), righteye flounder (*Pleuronichthys cornutus*), halibut (*Paralichthys olivaceus*, *P. orientalis*), lobster, mantis shrimps (*Squilla*), swimming crab, apus (*Tachypleus tridentatus*), cuttle fish and others. The set gillnet fisheries occur in shallow near shore waters. In the *chongyu* (butterfish) set gillnet fishery, the mesh size is 93mm. About 40 panels are carried by motorised junks equipped with 40–60HP engines and three rowboats are used in the net operation. These 15–18m junks carry a crew of 12. Data for various set gillnet fisheries are given in Table 2.

Table 1

Drift gillnets in Chinese marine fisheries.

Name	Mesh size (mm)	Panel length and height (m)	Target species	Locality
Taiyu driftnet	82	47.17 x 13.40	Common mackerel	Changhai, Liaoning
Duixia qua net	60	60.48 x 6.70	Prawn	Yingkou, Liaoning
Luyu santui driftnet	130	24.97 x 9.75	Common sea bass	Tanggu, Tianjin
E'zhenyu driftnet	43	45.65 x 0.60	Needlefish	Leting, Hebei
Qinglinyu driftnet	35	14.00 x 5.98	Common herring	Changli, Hebei
Bayu driftnet	90	54.00 x 8.60	Mackerel	Penglai, Shandong
Suoyu gillnet	72	30.68 x 0.90	Mullet	Rushan, Shandong
Yinchong driftnet	123	29.00 x 11.07	Butterfish	Qidong, Jiangsu
Leyu driftnet	84	33.26 x 12.6	Chinese herring	Guannan, Jiangsu
Huangji driftnet	40	24.20 x 8	Anchovy	Ganyu, Jiangsu
Hetunyu driftnet	100	41.40 x 1.65	Puffers	Ninghai, Zhejiang
Maochangyu driftnet	360	15.05 x 3.78	*Maochang* croaker	Dinghai, Zhejiang
Mianyu driftnet	160	18.72 x 4.72	Slate cod croaker	Dinghai, Zhejiang
Ziyu driftnet	85	72.00 x 1.28	Striped mullet	Ninghai, Zhejiang
Suozi driftnet	36	54.00 x 1.98	Mullet	Ninghai, Zhejiang
Meitongyu driftnet	43	18.00 x 3.40	Baby croaker	Yueqing, Zhejiang
Suozixie driftnet	160	18.00 x 3.52	Swimming crab	Daishan, Zhejiang
Jiali ling	210	38.84 x 2.94	Genuine porgy	Tong'an, Fujian
Qingling ling	30	32.24 x 3.30	Common herring	Xiamen, Fujian
Damu ling	173	26.00 x 17.39	Mackerel, etc.	Dongshan, Fujian
Bazhi lian	150	46.00 x 9.90	Butterfish, Mackerel	Xiapu, Fujian
Shayu lian	170	22.68 x 25.50	Sharks, Mackerel	Jinjiang, Fujian
Menshan net	135	43.72 x 3.44	Pike conger	Yangjiang, Guangdong
Bai lian	57	44.90 x 1.45	Threadfin bream	Yangjiang, Guangdong
Feiyu net	36	33.48 x 1.46	Flying fish	Lingao, Hainan
Longli driftnet	80	32.11 x 4.84	Tonguefish, Pike conger	Beihai, Guangxi
Xia driftnet	47	96.33 x 1.60	Prawn	Hepu, Guangxi
Hongyu gillnet	185	30.02 x 8.42	Snapper	Ledong, Hainan
Erceng menshan gillnet	130 110	51.17 x 11.92	Pike conger, Sharks	Haikang, Guangdong
Shuangceng sanjiao lian	130 105	41.00 x 4.96	Sharks, Yellow croaker	Hui'an, Fujian
Lezi ling	98	40.00 x 4.90	Chinese herring	Xiamen, Fujian

Table 2

Set gillnets in Chinese marine fisheries.

Name	Mesh size (mm)	Panel length and height (m)	Target species	Locality
Mao net	56	57.19 x 5.39	Gizzard shad	Zhuanghe, Liaoning
Damu mao net	200	16.40 x 1.00	Tonguefish, etc.	Suizhong, Liaoning
Luyu mao gillnet	150	20.00 x 6.75	Common sea bass	Ginhuangdao, Hebei
Xiagu gillnet	73	59.95 x 0.80	Mantis shrimps	Qinhuangdao, Hebei
Huangguyu set gillnet	74	46.60 x 5.92	Bigcod croaker	Tanggu, Tianjin
Suozixie set gillnet	79	60.00 x 10.17	Swimming crab	Tanggu, Tianjin
Shayu gillnet	220	80.53 x 3.14	Smooth dogfish	Haiyang, Shandong
Bimuyu gillnet	133	25.80 x 3.63	Halibut	Haiyang, Shandong
Ludeng net	76.7	95.95 x 7.48	Chinese herring	Haiyang, Shandong
Chongyu set gillnet	93	18.58 x 8.93	Butterfish	Qidong, Jiangsu
Maochangyu set gillnet	245	15.25 x 2.33	*Maochang* croaker	Xiangshan, Zhejiang
Longtouyu set gillnet	33	26.61 x 2.84	Bummalo	Cangnan, Zhejiang
Hou ling	300	108.00 x 1.05	Apus	Dongshan, Fujian
Moyu gillnet	130	49.20 x 0.60	Cuttle fish	Wuchuan, Guangdong
Longxia gillnet	105	102.10 x 1.47	Lobster	Nan'ao, Guangdong
Bazhishi bottom gillnet	145	94.27 x 1.52	Sweetlips	Beihai, Guangxi
Xie gillnet	139	70.13 x 0.97	Swimming crab	Hepu, Guangxi
Hou gillnet	320	52.69 x 2.40	Apus	Qinzhou, Guangxi

Encircling gillnets and trammel nets

Fisheries using encircling gillnets are mainly distributed off the coast of Guangdong Province and Guangxi Zhuang Autonomous Region (Fig. 1), catching gizzard shad or yellow croaker. Set trammel nets and drifting trammel nets are used in coastal fisheries both in northern and southern China. The target species of the trammel net fisheries include mullets, hilsa herring (*Macrura reevesi*), mackerel, butterfish, yellow croaker, tonguefish and sharks (Table 3). Boats fishing with set trammel nets are powered by 4HP engines or propelled by oars. Those fishing with drifting trammel nets are powered by 7–20HP engines.

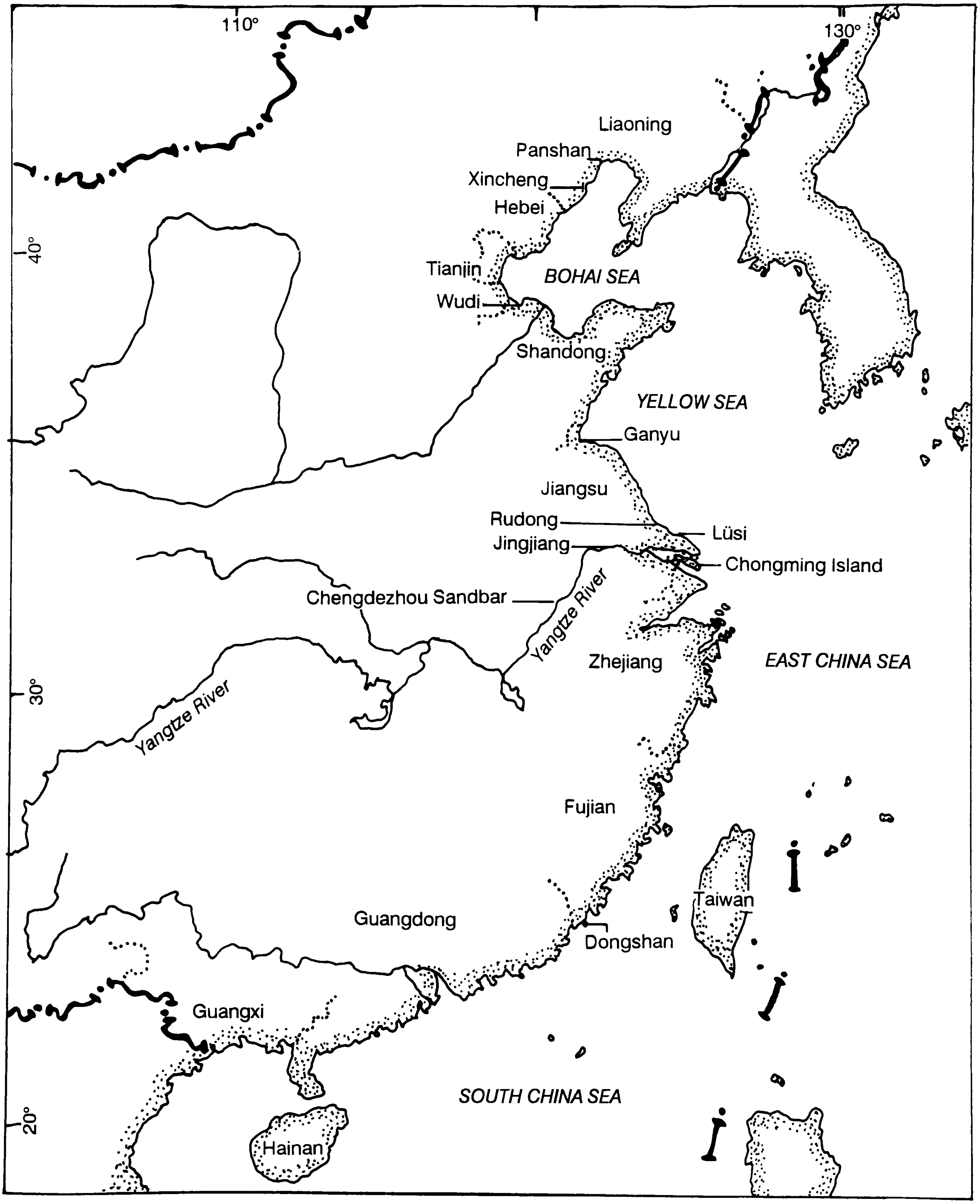

Fig. 1. Map of the area.

Table 3

Encircling gillnets and trammel nets in Chinese marine fisheries.

Name	Mesh size (mm)	Panel length and height (m)	Target species	Locality
Encircling gillnets				
Huanghuayu gillnet	120	63.75 x 20.50	Yellow croaker	Taishan, Guangdong
Huangyu gu	50	64.93 x 7.03	Gizzard shad	Qinzhou, Guangxi
Set trammel nets				
Sanchong gillnet	330 83	56.70 x 0.83	Mullet	Qinhuangdao, Hebei
Sanchong lian	565 46	39.34 x 1.56	Mullet, Tonguefish	Zhongshan, Guangdong
Drifting trammel nets				
Sanli net	600 100	37.66 x 3.30	Hilsa herring	Panyu, Guangdong
Sanchong ling	520 98	63.93 x 5.72	Butterfish, Mackerel	Zhangpu, Fujian
Zisuoyu sanchong driftnet	260 50	30.00 x 1.56	Mullet	Ganyu, Jiangsu

Table 4

Stow nets in Chinese marine fisheries.

Name	Type[1]	Mesh size (mm)	Dimension (m)	Target species	Locality
Fan stow net	1	400-33	180.00 x 124.97	Butterfish	Qidong, Jiangsu
Dabu net	1	147-21	116.32 x 78.77	Butterfish, Cuttle fish	Dinghai, Zhejiang
Yuguazi net	2	63.3-8.3	19.88 x 20.01	Bigcod croaker, etc.	Rongcheng, Shandong
Yangfang	2	87-20	19.50 x 9.31	Baby croaker, Anchovy	Qidong, Jiangsu
Xi net	2	133-50	18.86 x 12.35	Butterfish, Jellyfish	Dinghai, Zhejiang
Sangang net	2	70-2x2	17.40 x 11.74	Bummalo, Shrimps	Putuo, Zhejiang
Gaoxi net	2	147-73	11.00 x 5.57	Butterfish, Mackerel	Nanhui, Shanghai
Shumuchun stow net	2	100-5x3	16.00 x 13.00	Swimming crab, Butterfish	Luannan, Hebei
Haizhe net	2	330-95	17.80 x 11.77	Jellyfish	Chongming, Shanghai
Haizhe stow net	2	200-5x3	16.00 x 11.40	Jellyfish	Luannan, Hebei
Dongmeng	2	51-11.2	23.90 x 28.09	Shrimps	Changle, Fujian
Jiazi net	2	40-8	16.20 x 11.91	Shrimps	Tanggu, Tianjin
Kaikoushi xiaban net	2	100-2x2	16.00 x 11.50	Shrimps	Fengnan, Hebei
Maoxia guazi net	2	30-7.5	16.00 x 10.56	Shrimps, Palaemon, etc.	Zhanhua, Shandong
Dangenfang	3	167-20	39.00 x 39.71	Butterfish	Qidong, Jiangsu
Xiao net	3	33-10	20.40 x 19.09	Shrimps	Ganyu, Jiangsu
Sanjiaoleng net	3	33-9	10.05 x 10.96	Shrimps, Bummalo, etc.	Dongtou, Zhejiang
Danmao stow net	3	267-27	83.52 x 79.80	Butterfish	Qidong, Jiangsu
Ankang net	3	133-12	75.34 x 70.17	Common sea bass, etc.	Donggou, Liaoning
Paoding stow net	3	33-8	28.96 x 17.80	Shrimps	Cangnan, Zhejiang
Jie net	3	2x3-1x1	9.98 x 6.73	Shrimps, Icefishes, etc.	Haiyang, Shandong
Tanzi net	4	90-13.3	38.40 x 35.32	Cutlassfish, Octopus	Rizhao, Shandong
Shenshui stow net	4	110-15	35.10 x 22.18	Shrimps, Long-tailed herring, etc.	Baoshan, Shanghai
Fangang stow net	4	53-2x2	25.60 x 19.25	Bummalo, Shrimps	Yinxian, Zhejiang
Wangmen	4	80-4x4	35.84 x 36.52	Gizzard shad, Anchovies	Beihai, Guangxi
Qiheng	4	59-2x2	32.00 x 31.61	Shrimps, Anchovies, etc.	Pingtan, Fujian
Mao stow net	4	57-23	25.08 x 17.17	Baby croaker, Icefishes	Tanggu, Tianjin
Hu net	4	59-7.5	51.60 x 60.63	Anchovies, etc.	Longhai, Fujian
Yuchi net	4	70-10	23.00 x 24.54	Shrimps, Baby croaker	Sheyang, Jiangsu
Xiahu net	4	26-7	33.80 x 24.16	Baby croaker, etc.	Pingyang, Zhejiang
Chuang net	4	85-2x2	22.68 x 16.04	Shrimps, Cuttle fish, Prawns	Haiyang, Shandong
Qiang stow net	4	35-7.4	13.34 x 9.12	Shrimps, Miscellaneous fishes	Luannan, Hebei
Hemanmiao stow net	4	12-1x1	10.36 x 9.65	Elver	Cangnan, Zhejiang
Liubudai net	4	1x1	8.80 x 7.60	Chaff shrimps	Tanggu, Tianjin
Shanmen stow net	4	67-12.5	17.40 x 15.18	Bummalo, Shrimps, etc.	Linhai, Zhejiang
Daban zeng	5	270-12	91.80 x 59.63	Lanternfish, Cutlassfish, Cuttle fish	Xiapu, Fujian

[1] The type no. is explained in the text.

Traps

Stow nets

Stow nets are set mostly in the coastal areas of the East China Sea, Yellow Sea and Bohai Sea. They are fixed by stakes, anchors, masts or boats in shallow nearshore waters and catch shrimps, crabs and small fishes. The prey is driven into the net by water currents. Stow nets are next to trawls in importance in Chinese marine fish production.

There are five basic types of stow nets differing in the way the mouth of the net is kept open, and each type is subdivided into different sub-types (Table 4):

(1) *Zhanggang* (spreading rope) stow net – mouth held open by ropes;
(2) *Kuangjia* (frame) stow net – mouth stretched on frame;
(3) *Henggan* (beam) stow net – mouth kept open by upper and lower poles;
(4) *Shugan* (stake) stow net – mouth stretched on two vertical poles;
(5) *Youyi dannang* (winged single pocket) stow net – two wings set by two stakes, mouth kept open by floats and stones.

Other traps

Three other types of traps are used in Chinese fisheries. Fixed pound nets are usually constructed in tidal waters and fixed on bamboo poles or stakes. They are about 2–3m high and usually long, up to 3,000m. The prey is simply intercepted by the net or is guided into chambers or pockets. Anchored pound nets are shorter and higher than those of the fixed type, with various types of fish herding and retaining devices. Data for different kinds of pound nets are given in Table 5. Fish barriers are usually made of bamboo poles. The *yubo* (a kind of barrier used in Guangxi Province for mackerel and gizzard shad) has two guiding wings about 700m in length. Fyke nets are mostly used in freshwater fisheries and therefore are reviewed below.

Longlines

Several different types of lines are used in China: baited single-hook lines; artificially baited single-hook lines; baited multi-hook lines; hookless lines; etc. Baited single-hook set longlines are the most common. Rolling hook set longlines are similar to the former in structure, but have sharper, unbaited hooks and shorter interval between the branch lines. Data for different kinds of longlines in coastal fisheries are given in Table 6.

PASSIVE FISHING GEAR ON THE YANGTZE RIVER

Freshwater gillnets in China vary in structure, mesh size and operating period. *Daoyu* (long-tailed herring – *Coilia ectenes*) encircling gillnets in the lower reaches of the Yangtze operate from April-June. The term 'rolling hooks' is applied to set snagging longlines for silver carp (*Hypophthalmichthys molitrix*), puffers (*Fugu*), long-tailed herring, etc. They are operated by two fishermen in a small fishing boat. The lengths of the main line and branch lines are about 85m and 9cm, respectively. About 1,000 sharp, close-set unbaited hooks are carried by each longline. Both ends of the longline are anchored on the river bottom with stones. Drifting longlines, locally known as 'drifting hooks', are operated by two small fishing boats. Usually five longlines each with 100 unbaited hooks are lowered into the river during an operation. The lengths of the main line and branch lines are about 100m and 10cm, respectively. This gear can catch large fish such as black carp (*Mylopharyngodon piceus*) up to 50kg in weight and sturgeon (*Acipenser sinensis*) up to hundreds of kg in weight. Fyke nets, locally known as *mihunzhen* (brush weir) or *duanbo* (hedge), are set in shallow water along the river bank and consist of bamboo poles, panels and a pocket. The prey are guided into the pocket by wings constructed of panels.

Table 5

Pound nets in Chinese marine fisheries.

Name	Mesh size (mm)	Panel length and height (m)	Target species	Locality
Fixed pound nets				
Mi net	60-25	3000.00 x 2.85	Mullet, Prawn	Nantong, Jiangsu
Zhao net	35	2520.00 x 1.75	Mullets	Dafeng, Jiangsu
Cha net	33-16	2400 x 2.47-2.07	Mullet, Shrimps, Crabs	Fengnan, Hebei
Zu net	26.6	2000.00 x 1.33	Mullets	Dongtai, Jiangsu
Jiang net	97	1634.64 x 3.20	Butterfish, Mackerel, etc.	Dongtai, Jiangsu
Liang net	26-19	1404.54 x 1.66	Anchovies, Common herring	Zhuanghe, Liaoning
Diaoqian	25	1350.00 x 8.00	Mullet, Herrings, etc.	Nan'an, Fujian
Chuanyang net	130	1243.00 x 2.60	Hilsa herring	Nanhui, Shanghai
Qinqxia daolian net	11.1	321.30 x 2.33	Palaemon	Beidagang, Tianjin
Suoyu maodou net	50	8.35 x 0.17	Mullet	Jinxian, Liaoning
Dugu	35-12	2128.32 x 1.89	Baby croaker, Shrimp, Crab	Taishan, Guangdong
Suoyu tiao net	32-28	1148.00 x 1.30	Mullet	Shouguang, Shandong
Xuzi net	23-16.6	828.00 x 1.00	Common herring, Mackerel	Shouguang, Shandong
Chuan net	45-16	369.60 x 2.20	Mullet	Yueqing, Zhejiang
Chaxi net	32-6	200.00 x 2.35	Crab, Palaemon, etc.	Rui'an, Zhejiang
Liu net	39-36	184.86 x 1.50	Bigcod croaker, Crab	Shouguang, Shandong
Lanbo	70-30	22.40 x 3.15	Gizzard shad, Golden-lined spinefoot, etc.	Qiongshan, Hainan
Qiluo net	22	690 x 3.50-1.93	Mullet, Butterfish	Hangu, Tianjin
Anchored pound nets				
Luo net	120-40	397 x 34.22-23.6	Mackerel, Bigcod croaker	Weihai, Shandong
Dazhe net	500-60	377.84 x 24-16.7	Miscellaneous fishes	Jinxian, Liaoning
Liudai jian net	66.7-40	138.90 x 13.11	Mullet, Cuttle fish, etc.	Haiyang, Shandong
Sandai jian net	60-20	29.20 x 8.13	Flatfishes, Bigcod croaker	Laoshan, Shandong

Table 6

Longlines in Chinese marine fisheries. LML: length of the main line; IBL: interval between the branch lines, the total number of lines trolled is given in parentheses; TH: total number of hooks of a longline or that of the operating branch lines of troll lines.

Name	LML	IBL	TH	Target species	Locality
Baited single-hook set longlines					
Yaoyu longline	500.2	2.70	130	Rays	Changdao, Shandong
Shayu gang	419.2	9.02	20	Sharks, Groupers, Pike conger	Yangjiang, Guangdong
Dasha gun	470.2	7.76	18	Blue shark, Sharks	Hui'an, Fujian
Menshan gang	388.4	8.36	40	Pike conger, Sharks	Yangjiang, Guangdong
Manyu longline	227.2	3.60	30	Pike conger	Dongtou, Zhejiang
Manyu line	202.8	4.99	23	Pike conger	Lianjiang, Fujian
Hetunyu longline	326.7	0.08	60	Puffers	Putuo, Zhejiang
Heidiao longline	320.2	0.60	80	Porgy	Yinxian, Zhejiang
Huangheiyu longline	307.5	1.60	120	Greenlings, Jacopever	Dalian, Liaoning
Shibanyu longline	2007.3	1.70	600	Groupers	Fangcheng, Guangxi
Luyu longline	184.0	0.94	100	Common sea bass	Lianyungang, Jiangsu
Mianyu longline	170.0	1.30	70	Slate cod croaker, Common sea bass, etc.	Xiangshan, Zhejiang
Xiahuyu longline	127.0	0.20	250	Gobies	Leting, Hebei
Baited single-hook drifting longlines					
Majiao line	594.0	6.26	60	Mackerel	Haikang, Guangdong
Baiyu gun	456.0	1.95	126	Cutlassfish	Hui'an, Fujian
Baited single-hook troll lines					
Tuo line	26.4-130.4	(7)	7	Tunas	Wenchang, Hainan
Bienban line	100-202	(4)	460	Threadfin bream, Bigeye, etc.	Dianbai, Guangdong
Artificial bait single-hook troll lines					
Tuomao line	48.9-92.2	(8)	42	Tunas, Mackerel, etc.	Wenchang, Hainan
Majiao line	86.4	(3)	3	Mackerel	Pingtan, Fujian
Rolling hook set longlines					
Kong hook	105.0	0.11	1000	Mullet, Common sea bass	Haixin, Hebei
Ban hook	50.0	0.24	180	Rays, Flatfishes	Minhou, Fujian
Sha hook	36.0	0.14	249	Rays, Flathead	Rudong, Jiangsu

INCIDENTAL CATCHES OF SMALL CETACEANS

Baiji (*Lipotes vexillifer*)

Attention has been focused on the kill of the baiji in fisheries using rolling hook longlines and fyke nets in the Yangtze River (Zhou 1982; 1986; 1989; Lin *et al.*, 1985; Chen and Hua, 1989; Zhou and Li, 1989). Of 31 baiji found dead in the lower Yangtze between 1978 and 1985, seven were incidentally entangled by rolling hook longlines. In the middle reaches of the Yangtze, rolling hook longlines have accounted for 15 of 28 recorded deaths between 1973 and 1983. Fyke nets are another threat to the baiji. In the lower Yangtze these have accounted for five known deaths. Although the baiji is protected by the Law of Protection of Wildlife as one of the 'national protected animals' and regulations prohibiting the use of rolling hook longlines, fyke nets as well as bombing, poisoning and electric power in freshwater fishing exist, deaths and injuries caused by incidental entrapment in these gears continue to occur. For example, an injured baiji bearing dozens of hooks was seen floating near Chengdezhou Sandbar, Anhui Province, on 5 March 1990. Eight days later, an adult female baiji died because of hook injuries in the river section near Jingjiang, Jiangsu Province, about 370km downstream of Chengdezhou. It is not clear whether these were the same individual (Zhou, unpublished data). The baiji is one of the most endangered mammals of the world and is close to extinction (Perrin and Brownell, 1989). According to the census surveys and photo-identification studies conducted by researchers at Nanjing Normal University between 1989 and 1991, less than one hundred and fifty remain in over 1,700km of the Yangtze River. Incidental catches in passive fishing gears are one of the main factors that have caused the decline.

Finless porpoise (*Neophocaena phocaenoides*)

A total of 80 specimens of the Yangtze population of finless porpoise have been collected since 1974 by the Cetacean Research Laboratory of the Biology Department of Nanjing Normal University (NJNU). Most were caught incidentally by rolling hook longlines and encircling gillnets. Shi and Li (1986) reported the incidental catches of several finless porpoises at the east end of Chongming Island, located at the mouth of the Yangtze River. The finless porpoises were found in pound nets and driftnets; e.g. 11 were caught in fixed pound nets in March/April 1980. Killing of the finless porpoise in passive fishing gears (drift gillnets, stow nets and pound nets) has also occurred in the Yellow Sea off the coast of Jiangsu Province (Table 7). About 1,000 driftnetters, 700 set gillnetters and 2,000 boats using stow nets fish along the coast of Jiangsu, and thousands of other types of traps are set in the same area.

The target species of drift gillnet fisheries off the Jiangsu coast are primarily butterfish and anchovy. Usually the nets are set twice a day (in the morning and the afternoon) and retrieved 7–8 hrs later. Incidental catches of the finless porpoise in the drift gillnets have been reported on the Lüsi fishing ground off the Jiangsu coast; a net hauled on 11 April 1986 contained 2 males and 3 females.

No information on incidental catches of the finless porpoise in set gillnets has been reported so far.

Several kinds of stow nets are used in Jiangsu coastal fisheries including *tanzi, dangenfang* and *yangfang*. The number of *tanzi* netters counted in 1989 was 1,228, while that of *dangenfang* and *yangfang* netters was 496. About 40 nets are set by each of the boats during the fishing season from March through June. The fishermen haul up the pocket of the net and remove the catch every 24 hours. Sometimes a single finless porpoise is found in the pocket. Occasionally an adult female and a calf are caught in the same net.

Table 7

Incidental catches of the finless porpoise in passive fishing gear along Jiangsu coast.

Year	Date	Locality	Catch	Fishing gears
1983	Sept. 23	Ganyu	3	*Zhao* net
	Oct. 5-11	Rudong	3	*Zhao* net
	Nov. 7	Rudong	11	*Jiang* net
1984	May 15-31	Lüsi	11	Driftnet
1985	May 12	Lüsi	4	Driftnet
1986	Apr. 4-30	Lüsi	23	Stow net & Driftnet
1989	Apr. 21-May 10	Lüsi	19	Stow net & Driftnet

Most of the traps operated along the Jiangsu coast are of fixed pound net type. The *jiang* net is used primarily for butterfish and Chinese herring and is about 1,600m long. Eleven finless porpoises were caught in such a net in Nantong in November 1983. The *zhao* net is used primarily for mullets and is about 2,500m long. Incidental catches of the finless porpoise in this net were recorded in Ganyu County and Rudong County in the autumn of 1983.

Usually the carcasses of entangled porpoises are sold to local people for use as livestock feed. Therefore, while only 74 specimens have been collected from the coastal waters of Jiangsu since 1983 by NJNU, the recorded incidental catches suggest that dozens or perhaps hundreds of finless porpoises were drowned or caught in passive gear fishing in this Province annually over the past decade.

Incidental capture of the finless porpoise occurs also in the Bohai Sea and the East China Sea. Some were caught in gillnets in the Bohai Sea along the coast of the Hebei and Shandong Provinces in June and July (Wang, 1979; 1984). Ten specimens from the Bohai Sea were collected by the staff of NJNU at Xincheng, Liaoning Province in June and October 1990 (Zhou, unpublished data). Nine of these were taken in *sanceng* nets (a kind of drifting trammel net, not listed in Table 3).

Fifty-eight finless porpoises were caught in one fixed pound net set on the coast of Panshan, Liaoning Province, in June 1960, 48 in one fixed pound net set in the shallow waters of Wudi, Shandong Province in June 1959 (Wang, 1979; 1984), and another by a *liudai jian* net (a kind of anchored pound net, see Table 5) set near Xincheng, Liaoning in June 1990.

In the south part of the East China Sea, eight finless porpoises were taken by *sanchong ling* nets (a kind of drifting trammel net, see Table 3) in November 1987 near Dongshan, Fujian. Thirty individuals were caught in the same net in this region in December 1990 (Zhou, unpublished data).

Marine dolphins

One bottlenose dolphin (*Tursiops truncatus*) and one common dolphin (*Delphinus delphis*) were recorded killed in a drifting trammel net of *sanchong ling* type in December 1990 off Dongshan (unpublished data). False killer whales (*Pseudorca crassidens*) have been recorded captured in the Bohai Sea, Yellow Sea and East China Sea (Wang *et al.*, 1965; Wang, 1979; Wang, 1980; Zhou *et al.*, 1982). Some were caught in *liang* nets (a kind of fixed pound net, see Table 5) set along the coast of Liaoning Province in 1958 and 1961 (Wang, 1979) and September 1965 (Shi and Wang, 1983).

Other small cetaceans known to occur in the waters off the Chinese mainland include the spotted dolphin (*Stenella attenuata*), Pacific white-sided dolphin (*Lagenorhynchus obliquidens*), rough-toothed dolphin (*Steno bredanensis*) and Indo-Pacific hump-backed dolphin (*Sousa chinensis*) (Huang *et al.*, 1978; Huang and Tang, 1979; Wang, 1979; 1982; Huang, 1980; Zhou *et al.*, 1980). No information concerning incidental catches of these species in passive fishing gear is available to date.

CONCLUSIONS

Very large numbers of gillnets, traps and longlines are set in Chinese coastal waters. Information concerning the incidental capture of small cetaceans in this gear is extremely limited. The best information available at this time indicates that large numbers of finless porpoises and a few individuals of three other cetacean species have been caught in gillnets, stow nets and other coastal traps in the Bohai Sea, Yellow Sea and East China Sea. A survey of coastal regions and fishing ports to determine the cetacean species present and document the incidental mortality of cetaceans is urgently needed.

The rolling hook longlines that are threatening the baiji in the Yangtze with extinction are illegal. The use of this gear in the middle and lower reaches of the Yangtze River must be stringently prevented. Information on fishing effort and kill rates for the Yangtze population of the finless porpoise is needed to evaluate the impact of the longline and gillnet fisheries in the river.

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SC/O90/G29

Incidental Takes of Small Cetaceans in Fisheries in Palawan, Central Visayas and Northern Mindanao in the Philippines

Ma. Louella L. Dolar

Marine Laboratory, Silliman University, Dumaguete City, 6200, Philippines

ABSTRACT

Incidental takes of dolphins in fisheries in selected towns and villages in Palawan, Central Visayas and northern Mindanao are discussed. Dolphins are taken with the following types of fishing gear: troll lines, drivenets, bagnets, bottom setnets, driftnets and purse seines. The purse seines include those set by relatively small municipal boats around fish aggregating devices (FADs, locally known as *payaw*) within (and outside) 7km of shore and those set around free-swimming schools of fish by large commercial vessels operating seaward of 7km. Fishing methods are briefly described and total annual takes by each method are estimated. Dolphin species so far known to be involved are the spinner dolphin, *Stenella longirostris* (troll lines, bagnets, driftnets and purse seines); pantropical spotted dolphin, *S. attenuata* (purse seines and driftnets); bottlenose dolphin, *Tursiops truncatus* (bagnets and driftnets); Fraser's dolphin, *Lagenodelphis hosei* (driftnet and purse seines); Risso's dolphin, *Grampus griseus*, melon-headed whales, *Peponocephala electra* and pygmy killer whales, *Feresa attenuata* (driftnets). Additional species are probably taken. Only driftnet landings have been directly observed.

KEYWORDS: INCIDENTAL CAPTURE; FISHERIES; ASIA; BOTTLENOSE DOLPHIN; SPINNER DOLPHIN; SPOTTED DOLPHIN; FRASER'S DOLPHIN; RISSO'S DOLPHIN; PYGMY KILLER WHALE; MELON-HEADED WHALE

INTRODUCTION

Southeast Asia has been referred to as the 'sea of islands'. Fourteen thousand of these islands belong to Indonesia and 7,100 to the Philippines, while hundreds of others dot the Andaman and South China Seas. The countries of this region are dominated by coasts, making fishing an integral part of the industry and culture of their people (except perhaps for Singapore and Hong Kong). Indonesia, Thailand and the Philippines rank among the top ten fish producers of the world (Anon., 1986). For example, fishery products contributed $1.2 billion, or more than 5%, of the GNP of the Philippines in 1986 (Anon., 1986) and 8.75% of Thailand's total national output in 1982 (ICLARM, 1987). Given that fishery products from small scale fisheries are often not included in national statistics, the importance of fishing to these economies is underestimated even by these impressive figures.

Because of the region's heavy dependence on fishing, much research effort has focused on developing and improving fishing gear and methods to increase fish catches, often with little or no regard to the impact on either the target or non-target resources, including marine mammals. Interactions among cetaceans and fisheries are now well documented in many parts of the world (e.g. Northridge, 1984; Leatherwood and Reeves, 1989; Perrin, 1989). However, there has been no dedicated investigation of the interactions of cetaceans with fisheries anywhere in the Southeast Asian region. This paper presents some preliminary information on the types of fishing activity known to kill cetaceans in Palawan, the Central Visayas and northern Mindanao in the Philippines and estimates annual levels of mortality. Dolar *et al.* (1994) discuss directed takes of cetaceans in the Philippines.

METHODS

Information was obtained from trips on fishing vessels, visits to fish markets, and interviews with crew members and owners of commercial and municipal fishing vessels, local fishermen, market vendors and middlemen. Associates and I collected information directly in Basay and Malabuhan in Negros, Pamilacan Island in Bohol, Brooke's Point and Rio Tuba in Palawan, and Selinog and Aliguay Islands in Mindanao (Fig. 1) during the periods shown in Table 1. Information has been collected opportunistically on subsequent visits.

Table 1

Area	Dates information collected
Palawan	29-31 March 1991
Central and southern Visayan Islands	8 April 1990, 30 June 1990, 20 July 1990, January-April 1991, June 1991
Pamilacan, Bohol	30 April 1990, 1 May 1990, 10 July 1990, 5-6 April 1991
Selinog	14 February 1991, 7-8 April 1991
Aliguay	15 February 1991

During visits to fishing vessels and villages, fishermen and other knowledgeable local people were asked a series of questions.

(1) What are the different fishing methods used in this village?
(2) Which of these methods are known to catch dolphins?
(3) Please describe at least the size of the fishing vessel(s), the type and size of the net(s) used, the number of people employed and the procedures involved.
(4) May I see the boat and equipment you use in fishing.
(5) How many of these (boats, gear) operate in this village?
(6) Where do these boats fish?
(7) How long does one fishing operation take?
(8) How many operations do you conduct in one day, one month, one year?
(9) Is fishing seasonal? At what time of year does fishing peak?

(10) What is/are the target species?
(11) How many dolphins are accidentally caught in one fishing operation?
(12) What are the kinds of dolphins taken incidentally? (Determined by the interviewee's unprompted review of illustrations by Pieter Folkens in Reeves and Leatherwood (1987) and the poster 'Cetaceans of the World' by Pieter Folkens, and photographs in Reeves and Leatherwood (1987), Leatherwood and Reeves (1989) and Leatherwood *et al.* (1988)).
(13) Does the dolphin bycatch vary within the year? What time of year is the dolphin bycatch the highest? The lowest?
(14) What do you think influences the changes in dolphin bycatch?
(15) What do you do with the dolphins caught accidentally? Release them, catch and eat them, or sell them to markets?

For the driftnet fishery at Malabuhan, Siaton, Negros, data on number, length and sex of dolphins landed during the period February through June, 1991 were collected by a resident student trained by myself. I determined species of the dolphins by examining colour photographs taken by the student. The number of boats fishing each day and the number of dolphins taken by each boat were also monitored. Data for purse seiners fishing off southeastern Negros were collected during actual fishing trips.

RESULTS

There are five fishing methods/gear known to kill cetaceans in the studied areas of the Philippines: (in descending order of probable impact) purse seines, driftnets, bottom setnets, 'bagnets' and drive nets, longlines with multiple hooks and tuna troll lines.

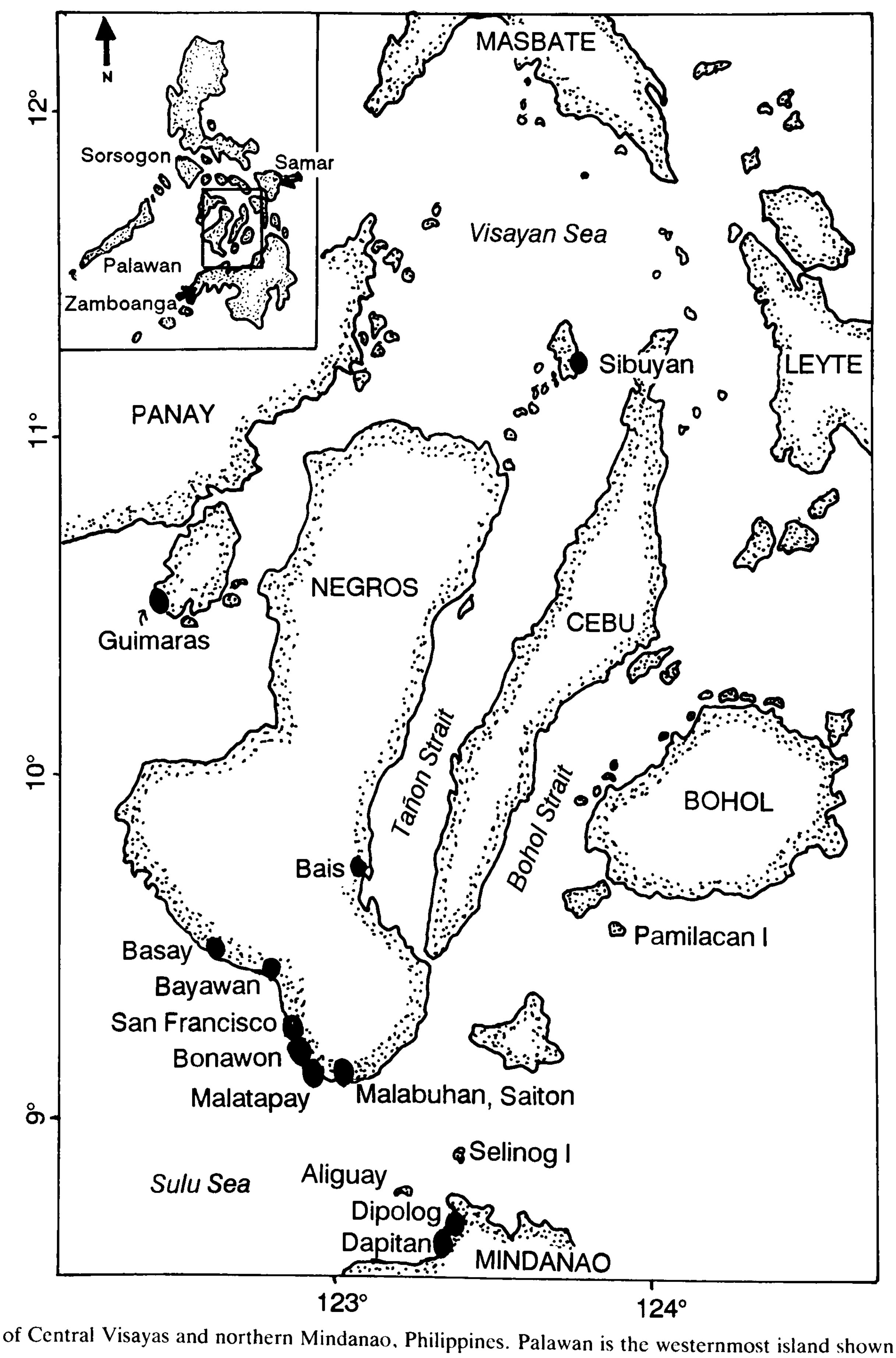


Fig. 1. Map of Central Visayas and northern Mindanao, Philippines. Palawan is the westernmost island shown in the inset.

Purse seines

There are both 'municipal' and 'commercial' purse seiners based in the Philippines. The municipal boats are generally smaller and lighter (<10 GRT), are widely based and may fish within 7km of the shore. The commercial boats are larger and heavier (>100 GRT) and fish largely around Palawan and in the Sulu Sea (Fig. 1). Cetacean bycatch in purse seines was investigated out of the small fishing town of Basay, located on the southwestern shore of Negros Island (Fig. 1). The region of the Sulu Sea off Basay has one of the country's many tuna fisheries and is visited annually by large numbers of purse seiners. The vessels fish in the Sulu Sea for six months each year during the northeast monsoon (November-April), when both coastal and offshore areas are shielded from strong winds by Negros Island. At other times of the year, they fish in various other areas (Fig. 1): Sibuyan (May), Samar (June-August), Masbate (August), Burias in Sorsogon (September-October), and Guimaras (May-October). During my eight days of observations in 1989–90 I saw five purse seiners and nine fish carriers operating in the area. The latter are vessels that collect catches from the seiners and ferry them to port for sale and processing, leaving the seiners to continue fishing.

Commercial purse seiners

The vessel whose operations I observed was *Catcher 1*, a 25m x 6m mechanised commercial purse seiner catching tuna for local markets. It is a steel hulled vessel of 142 GRT with a catch capacity of 80 metric tons, equipped with sonar for locating fish and a power block for hauling the net. It is manned by a crew of 32 (captain, masterfisherman, two assistant masterfishermen and 28 net handlers, swimmers and auxiliary boat handlers). There are four auxiliary motorised boats, two with outriggers and two without. One of the four (the light boat) has lights for attracting fish. The net is 400 fathoms long (about 740m), 60 fathoms deep (about 110m) and has a mesh size of 2.5cm near the bottom and 5cm near the top. It is made of no. 36 nylon twine. The floats are 11–13cm in diameter and attached at intervals of 5–10cm.

Both commercial and municipal purse seining in the Philippines may or may not involve the use of a fish shelter or aggregating device (FAD or *payaw*). Both techniques are practised in Basay, for example when the owner of a FAD requests that a purse seine captain catch the fish for an agreed share.

The traditional *payaw* consists of one or two layers of bamboo (approximately 5–10 poles, each about 10m long)

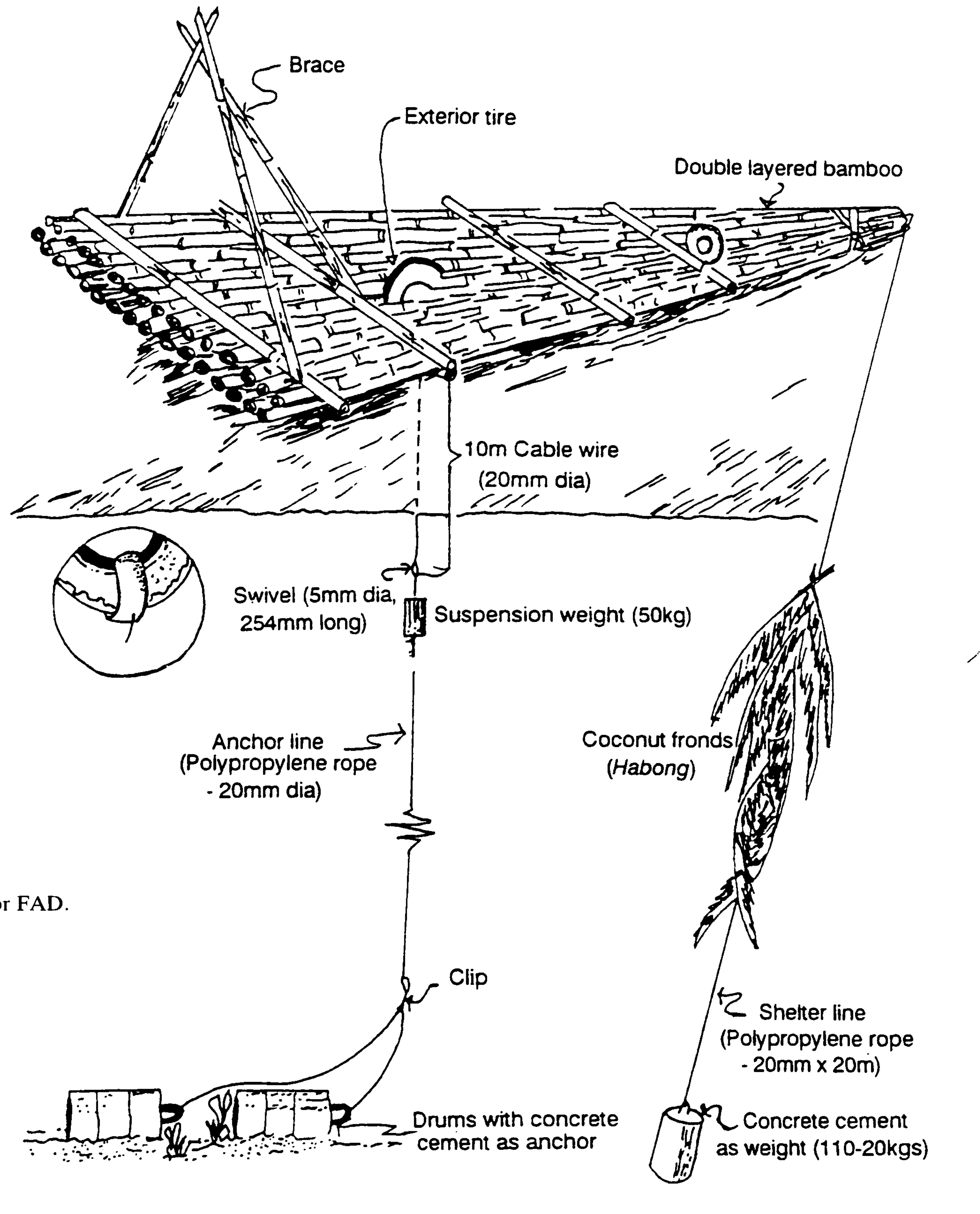


Fig. 2A. *Payaw* or FAD.

tied together as in a raft. It is rigged beneath with bundles of twigs and coconut fronds and is anchored with a steel barrel filled with concrete and rocks (Fig. 2A). A new modification uses a steel buoy 1.5m in diameter instead of bamboo poles. The *payaw* is set at a predetermined location, tagged with the owner's tag and periodically checked for the presence of tuna and other pelagic fishes. *Payaws* are anchored in 500 to 2,500 fathoms of water (900m-4,600m), a few hundred meters to several km offshore.

The seiners leave port at 1800hrs almost every day throughout the fishing season. When the *payaw* is reached, fish biomass is estimated with sonar or by a swimmer, who makes his estimate based on the amount of bioluminescence activated by the fish. If biomass is high, the fish are harvested. The light boat moves near the *payaw* to attract the fish and then moves slowly away, taking the fish with it. At the same time, the *payaw* is moved in the opposite direction by an auxiliary boat, until light boat and *payaw* are approximately 500m apart. With the FAD out of the way, the seiner, with the help of another auxiliary boat, surrounds the school of fish with the net. When the school is completely surrounded, the seiner retrieves the leadline to close the bottom of the net and hauls the net until the remaining bag is of manageable size. The catch is brailed using a scoop net and the *payaw* is put back into position. The FAD will be fished again after two or three months. The fishing operation lasts two to three hours. The total trip, including travel time, takes 10–14 hours. Catches are transferred to carrier boats near shore for distribution to various landing areas in Visayan cities and sometimes in Manila. Catches are sold in local markets.

The masterfisherman on *Catcher 1* roughly estimated (no record was available) that each of the five seiners caught 120 metric tons of fish per month. If correct, this means that the fleet catches 2,400 to 3,600 metric tons during the four to six months of the season.

Among the major fish species caught are: yellowfin tuna, *Thunnus albacares*; bigeye tuna, *T. obesus*; Indian mackerel, *Rastrelliger kanagurta*; bullet mackerel, *Auxis rochei*; frigate mackerel, *A. thazard*; eastern little tuna, *Euthynnus affinis*; narrow-barred Spanish mackerel, *Scomberomorus commerson*; pompano dolphinfish, *Coryphaena equiselis*; needlefish, *Belonia* sp.; and golden trevally, *Gnathanodon speciosus*.

Although I did not witness any cetacean kills during my trip on *Catcher 1*, interviews revealed that sizable numbers of dolphins are caught by purse seiners in this area. For example, *Catcher 1* caught 60 dolphins in a single set two days before I boarded the boat and another 20 in a set two weeks earlier. Seven interviews of crew members and the captains of other vessels confirmed these estimates. This suggests that one seiner catches an average of five dolphins per trip/day/set, or (assuming 15 days of fishing a month) 300–450 during the four to six month season. This extrapolates to 1,500–2,250 dolphins per season for the fleet of five seiners, or one dolphin for every two tons of fish caught. This is of necessity a very rough estimate because of the small sample of vessels and sets upon which it is based. Information on the total number of purse seiners in the Philippines or on the proportion of sets made on FADs is not available.

From descriptions and photographs, the dolphins caught appear to include pantropical spotted dolphins, *Stenella attenuata* (easily identified by the spots); spinner dolphins, *S. longirostris*; and Fraser's dolphins, *Lagenodelphis hosei*.

The dolphins are sometimes kept for sale. Only a small part of the dolphin catch of the Basay-based seiners is sold at the Basay market. A large proportion is transported to other ports, e.g. Bayawan and Bais (Fig. 1) where dolphin meat is more highly valued.

Municipal purse seiners

The 'municipal' purse seiners (locally called *kubkub* or 'ringnet') are similar in structure and mode of operation to the commercial seiners but are slightly smaller (15–20 x 6m) and often lack sonar. Some also lack a power block. They are usually constructed of wood, making them considerably lighter (≤8 GRT) than the steel commercial seiners. Each is manned by a crew of 26 (captain, masterfisherman and 24 hands) and can operate both in municipal (to 7km offshore) and oceanic waters. The net is 250 fathoms (about 460m) long (some 60% of the length of the commercial net) and 80 fathoms (150m) deep. It is made of no.7 twine, lighter than that used in the commercial nets. Mesh size is 2.5cm near the bottom and 5.0cm near the top. There are two corkline configurations: one using large 30cm floats placed 4m apart and another using 10cm floats at 11–20cm intervals. Ten of these vessels operate in the Basay area during the fishing season (November-May), fewer at other times of the year. From June to October, some vessels fish elsewhere, e.g. on the lee side of Negros, Bohol and Mindanao Islands.

Each fishing trip lasts about 10–12 hours. Roughly the same fish species are captured as by the commercial seiners. Although some *kubkubs* employ carrier boats to transport fish to distant cities where the demand is higher, most return to their home port to sell the catch.

Interviews with boat crews, owners and fish vendors revealed that each of the ten Basay-based *kubkub* caught about three dolphins a week (five fishing days). This extrapolates to an average of 48 dolphins killed per four-month fishing season per boat, or 72 in a six-month season. Thus the ten *kubkub* in the Basay area alone may account for the deaths of very roughly 480–720 dolphins during the principal fishing season. The ten boats catch about ten dolphins during the remaining six to eight months, raising the total to 490–730.

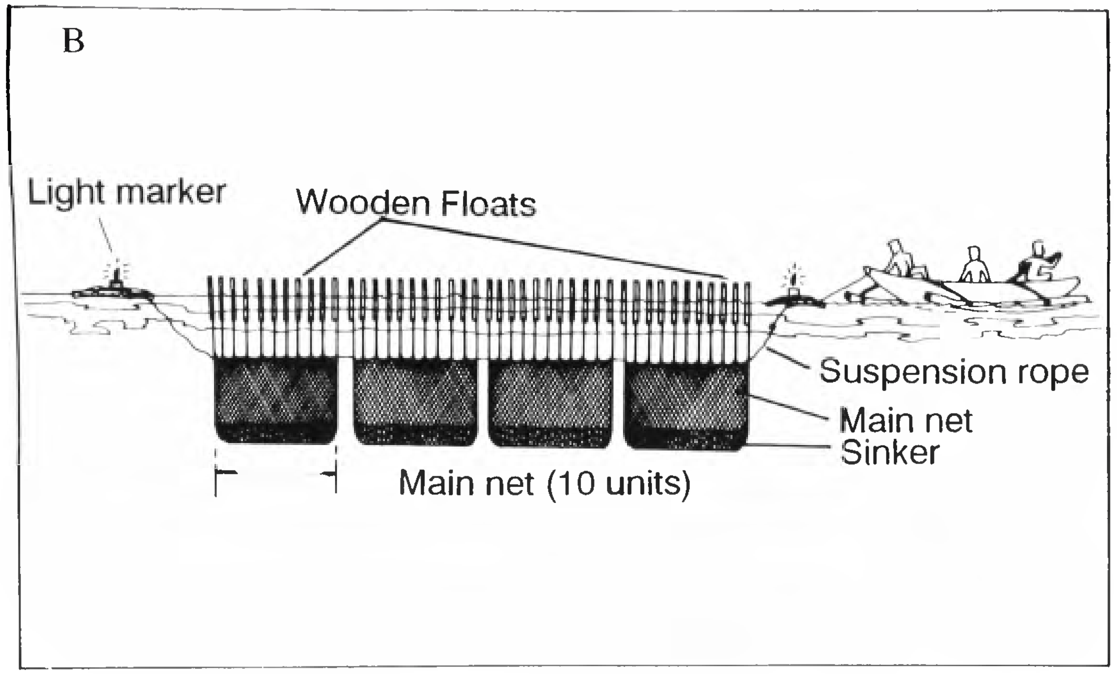
If these figures and those for the commercial purse seiners are correct, then some 2,000–3,000 dolphins may be dying in purse seining operations based at one Philippine town alone. It may be possible to estimate the kill for the Philippines overall if the total number of registered commercial and municipal purse seiners and the total number of fishing days were known; this, in addition to the accumulation of more reliable incidental capture data, should be made the goal of a long-term research programme.

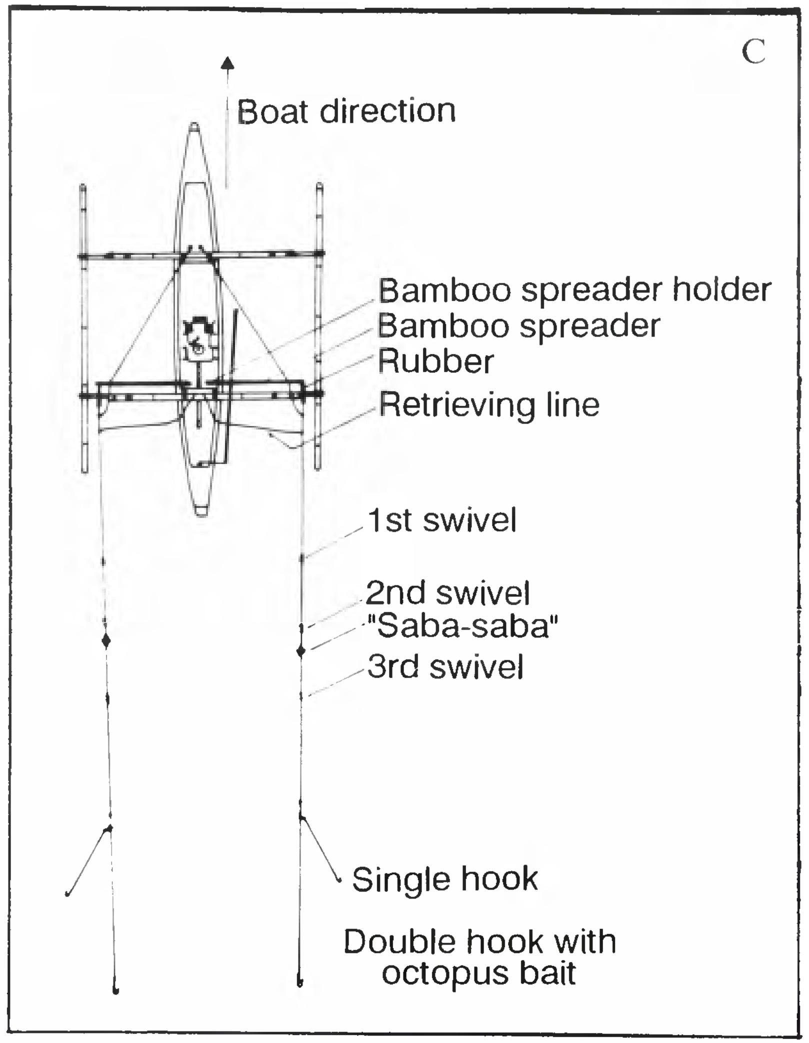
Driftnets

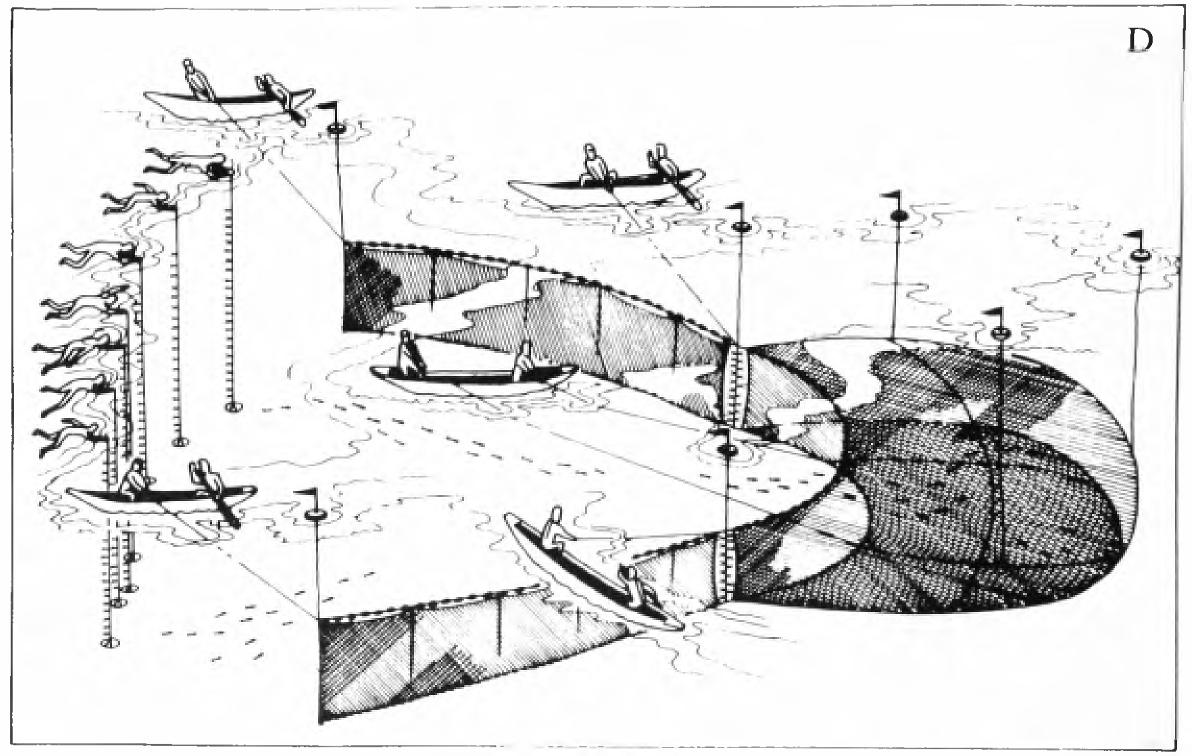
Driftnet fisheries in the study sites visited in the central Visayas and northern Mindanao involve the use of a 10m inboard-powered boat with outriggers, a 500–3,000m x 18m multifilament net with a mesh size of 15cm and kerosene lamps floated on the surface at regular intervals to mark the position of the net (Fig. 2B). The lamps prevent the net from being run over by other boats at night and aid in retrieval of the net in problem sets.

Malabuhan, Siaton, Negros Island

There are 50 driftnet vessels based in Malabuhan and fishing in the Sulu Sea (Fig. 1). Their nets range from 1–3km in length and are 18m deep. Fifteen of the vessels are







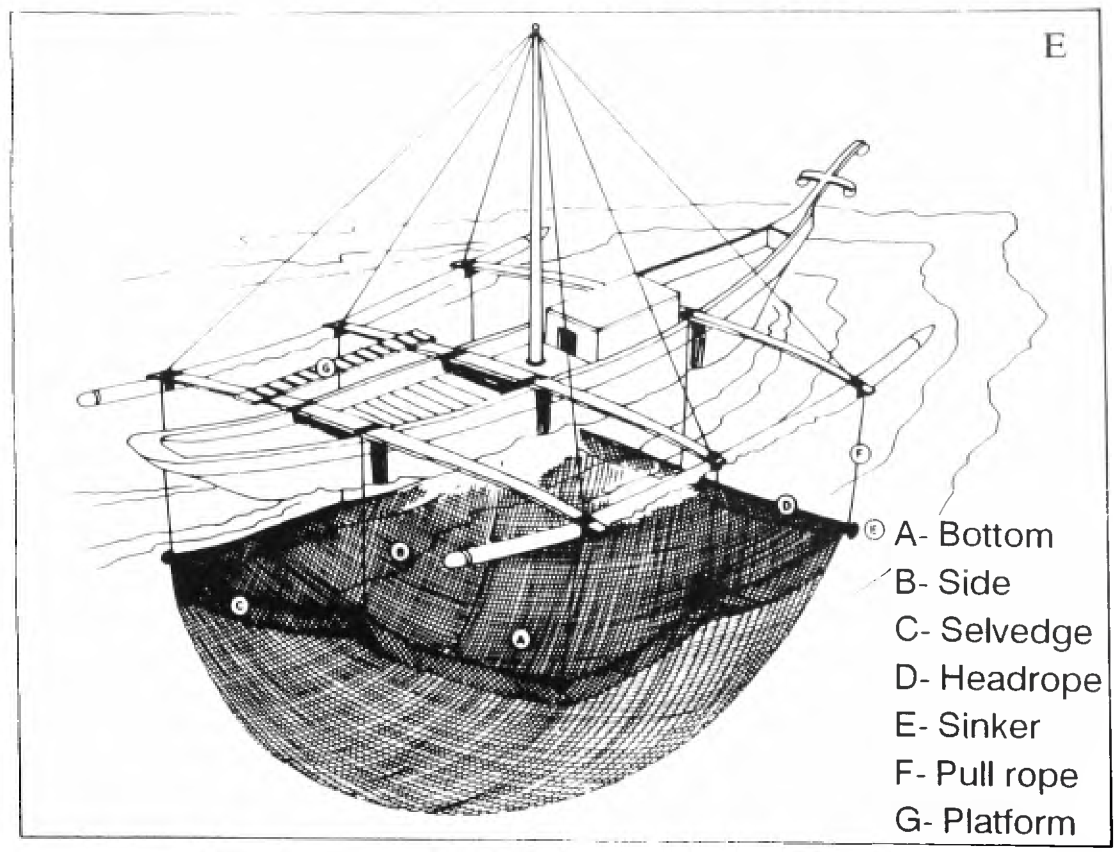


Fig. 2B–E. Other gear in which dolphins are incidentally caught.
(B) Driftnet fortuna.
(C) Troll lines.
(D) Drive net.
(E) Bagnet.

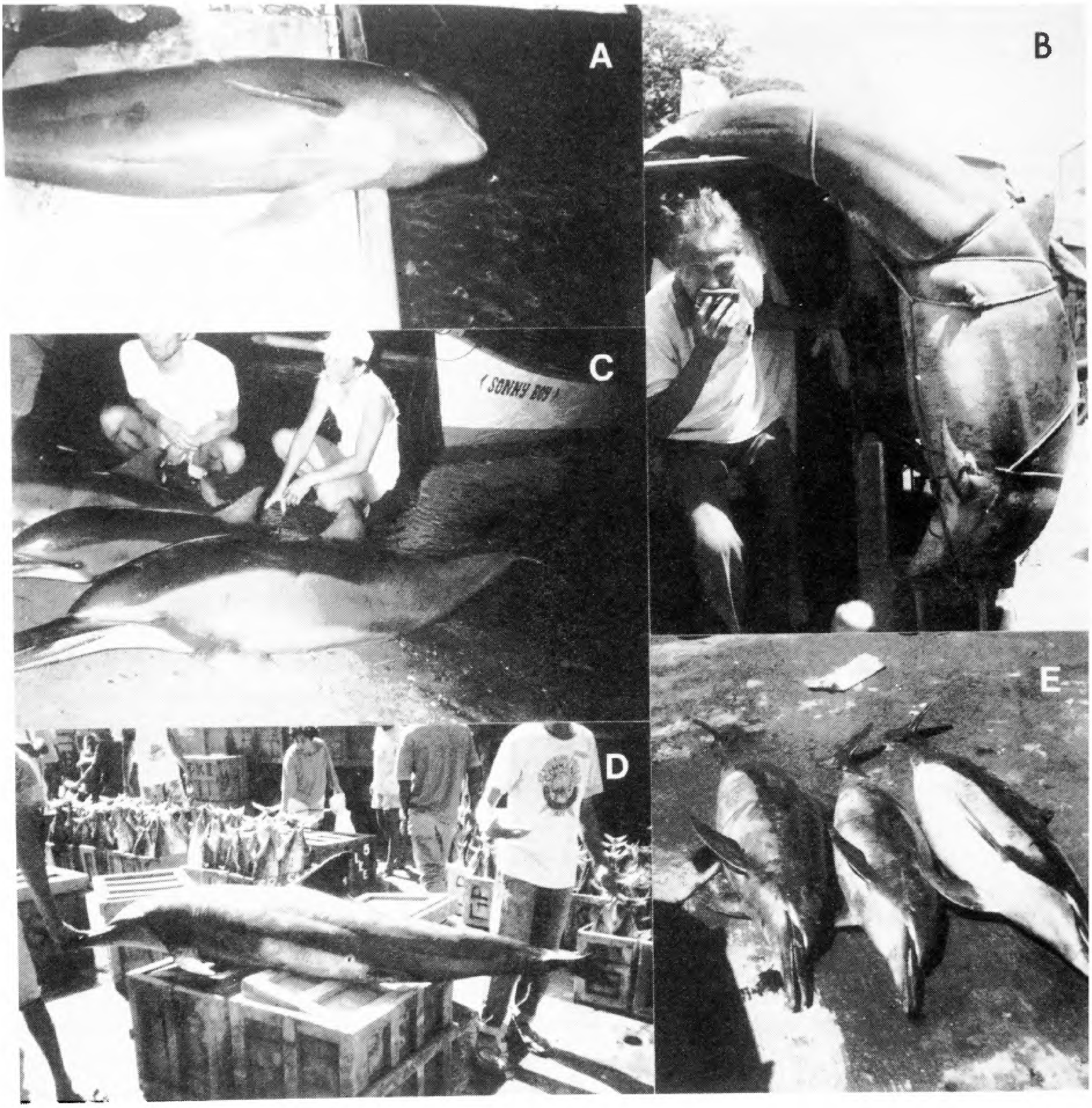


Fig. 3. Dolphins caught in driftnets (A-D) and purse seine (E). (A) Risso's dolphin. (B) Fraser's dolphin. (C) Spinner dolphin. (D) Spinner dolphin, with yellowfin tuna at the Dumaguete fish market, Negros. (E) Spinner dolphin caught by purse seiner off Basay, Negros; at Bayawan fish market.

owned by village residents who fish year round. The other 35 are owned by residents of northeastern Mindanao, who are based in this area during the principal fishing season from January to June. During this period, vessels usually fish 23 days a month, taking about seven days a month to repair the nets, boats and other gear. On any one day from January to June (seven days a week), 11–19 driftnet vessels are at sea fishing (1,980–3,420 vessel fishing days). Estimates of effort during the rest of the year (monsoon season) cannot be made, because fishing is highly variable, depending on the weather.

These driftnetters depart at 1500–1630hrs and reach the fishing grounds between 1700 and 1800hrs, setting their nets as soon as possible thereafter. Nets are often set when dolphins are seen in the area, as the fishermen believe that tuna schools are associated with dolphins. During my voyage with the fishermen, we observed Risso's (*Grampus griseus*), spinner and Fraser's dolphins. Setting the net usually takes 45–90 minutes; soaking time is usually 5–6 hours. The nets are pulled manually, which usually takes 2–3 hours. The catch usually consists mainly of yellowfin tuna ranging from 50 to 80cm in length. Other species caught (based on direct observations and photographs) include swordfish, *Xiphias gladius*; and manta rays, *Manta* sp.

The catch was monitored at the landing site for 16 days between 17 February and 4 June 1991. A total of 50 dolphins were landed (Fig. 3): 20 (40%) Fraser's dolphins (147–240cm long), 18 (36%) spinner dolphins (78–225cm) and 12 (24%) Risso's dolphins (105–300cm) (Table 2). The

Table 2

Dolphin bycatch of the driftnet fishery off Malabuhan, Siaton Negros, during the sixteen observation days. F = female; M = male; T = total; * sex not determined; nc = not counted.

Date	*S. longirostris*			*L. hosei*			*G. griseus*			Total	No. boats went fishing	No. boats with dolphin bycatch
	F	M	T	F	M	T	F	M	T			
17/02/91						1 *				1	nc	1
12/02/91									1 *	1	nc	1
23/03/91						4 *				4	nc	3
26/03/91						1 *			2 *	3	nc	3
06/04/91		4	4	1	1	2	1	2	3	9	19	5
08/04/91	1		1		1	1				2	15	2
09/04/91		2	2							2	11	2
19/04/91		1	1	1	2	3	3		3	7	16	5
20/04/91	3	5	8	1	1	2		1	1	11	nc	8
14/05/91					1	1				1	nc	1
20/05/91		1	1							1	nc	1
21/05/91						2 *				2	nc	2
22/05/91			1 *						1 *	2	nc	2
23/05/91									1 *	1	nc	1
03/06/91						2 *				2	nc	1
04/06/91						1 *				1	nc	1
Total	4	13	18	3	6	20	4	3	12	50	x=15	x=2.4
%		36%			40%			24%				
Lactating females	2 (167 & 180cm)			2 (190 & 22.5cm)			2 (180 & 267cm)					
Size range (cm)	78-225			147-240			105-300					
Mean no. of dolphins caught/day (all boats) = 3.1 ± 1.8												

majority (62%) of the dolphins caught were between 175 and 225cm long. The sex ratio (M:F) was 3:1 for both spinner and Fraser's dolphins and 1:1 for Risso's dolphins. At least half of the females of each species (all landed from April to June) were lactating (Table 2). One female was entangled together with a 105cm calf.

Four more species have been reported caught in recent years: the melon-headed whale, *Peponocephala electra* (1992); the pygmy killer whale, *Feresa attenuata* (1993, 1994), the bottlenose dolphin, *Tursiops truncatus* (1992, 1993) and the spotted dolphin (1992, 1993, 1994).

During the four days when the number of boats fishing was noted, 11–19 boats went out and 2–5 caught dolphins. The average dolphin bycatch per day during the 16 days of observation was 3.1±1.8. If these preliminary figures are taken as representative of the fishing effort and catch from January to June, the total bycatch would be about 428 dolphins (3.1 x 23 fishing days/month x 6 months). I learned through interviews with fishermen and market vendors that there is no dolphin bycatch during the rest of the year.

Pamilacan Island

There are 30 0.5–3km x 14–18m driftnets with a mesh size of 2.5cm at Pamilacan Island. They are used to catch clupeids and needlefishes. The nets are set for 12 hours, often at night, each day during the fishing season, March-June. They are known to entangle a few dolphins (roughly 20 per season). During visits to the island, I found a Fraser's dolphin which had been recently caught and a few skulls of spinner dolphins scattered on the beach. Based on descriptions by fishermen, the pantropical spotted dolphin may also be caught in the area.

Aliguay and Selinog

Fishermen from Aliquay and Selinog, two small islands (*ca* 60ha) in the Sulu Sea off northern Mindanao (Fig. 1) use a total of 40 driftnets (1km x 18m, mesh size 11cm) from December to May. Cetacean species caught probably include spinner, spotted, Fraser's and Risso's dolphins.

Setnets

At Selinog Island, 30 setnets (120 x 54m, mesh size 35cm), mainly used to catch manta rays, also catch some dolphins. This fishing gear has been used here longer than driftnets and is the first known to capture dolphins here. The fishermen estimate that roughly three to four dolphins are caught per net each fishing season. This amounts to about 90–120 dolphins per year.

Other fishing methods

Other gear known to catch dolphins on rare occasions (Fig. 2) are multi-hook longlines set to catch pelagic fishes (Selinog), troll lines (Bonawon), drive nets (in waters around Palawan), bagnets (Rio Tuba, Palawan) and bottom setnets (Rio Tuba and Brooke's Point, Palawan). Estimates of bycatches cannot be made.

Utilisation of the bycatches

Dolphin meat is acceptable for human consumption in some places in the Philippines but not in others. Markets known to sell dolphin meat are located in Basay, San

Francisco, Bonawon, Malatapay, Bayawan and Bais in Negros and Dipolog and Dapitan in Mindanao (Fig. 1). In the first four of the above, a 50kg dolphin can be sold for P6.00/kg ($US=P27). Visceral organs, including heart, liver, stomach and intestines, are also sold; liver fetches a higher price of P9.00/kg. In Bais and Bayawan, a 50kg dolphin can sell for P400 at the market place (to vendors); the retail price for meat and viscera is P15/kg. Dolphins caught at Selinog Island are sold to middlemen for P100–150 (for a 80–100kg dolphin). In addition, teeth are sold at P1.25 each in Zamboanga in Mindanao, where they are set in gold and worn as pendants. In addition to being sold in fish markets, dolphin meat is also consumed locally in Selinog, Pamilacan and Aliguay.

Dolphins are also used as bait for tiger sharks, *Galeocerdo cuvieri* and blacktip sharks, *Carcharinus springeri*. Fishermen at Pamilacan and Selinog Islands and in some parts of Negros use blood and blubber as shark bait. They place blood inside a plastic bag tied shut with a long cord and weighted with lead. The bag is lowered into the water and the blood released by pulling on the cord. Blubber is considered by some to be a superior bait for sharks, because it is difficult to remove from the hook. The shark makes several passes at the bait, increasing the chances of it being caught. At Brooke's Point, dolphin meat is used as bait for nautilus.

DISCUSSION

The high dolphin mortality in the Basay area during the months November – May period may be attributed not only to increased fishing effort due to fair weather but also to increased abundance of small tuna, which move close to the coast at this time of year (personal observation). Local people often refer to this season as *tingkapaw* or 'season for small tuna' when large schools of small tuna move inshore. The Sulu Sea off the west coast of Mindanao and the South China Sea off the west coast of Palawan have been identified as principal spawning areas and nursery grounds for yellowfin tuna and skipjack tuna, *Katsuwonus pelamis*, in the West Pacific. Peak spawning time is April to July for skipjack and October to December for yellowfin tuna (Aprieto, 1987).

The use of FADS to aggregate fish, especially juvenile tuna, needs to be reviewed. Combined with purse seining, it can increase cetacean mortality and reduce tuna stocks to suboptimum levels. The efficiency of *payaw* in aggregating juvenile tuna makes dolphins more susceptible to being caught by *kubkubs*, since dolphins are attracted to the schools of small tuna which aggregate to feed on smaller fish. In addition, the *payaw*/purse-seine operation may cause overexploitation of tuna by catching juveniles before they reach reproductive maturity. If tuna catches decrease, fishermen may be encouraged to catch more cetaceans to compensate for the reduced fish catches, as has been observed in Peru (Perrin, 1989) and Sri Lanka (Leatherwood and Reeves, 1989).

The use of driftnets is becoming more popular on the Island of Negros. For example, seven years ago, there were only three driftnets owned by locals in Malabuhan, Siaton. The number has since increased to fifteen and there are plans to buy more. This increasing popularity of driftnets may have been engendered by fishermen visiting from Surigao, Mindanao who obtained their nets and boats through a government loan about ten years ago, under the *Biyayang dagat* or 'Blessings from the sea' program.

In December 1992, the Department of Agriculture issued Administrative Order No. 185, banning the 'taking or catching, selling, purchasing, possessing, transporting and exporting of dolphins'. Although the order stopped the sale of dolphins openly in the markets, it did not stop incidental or direct killing of dolphins in many places (e.g. Malabuhan, Selinog and San Francisco). The impact of the ban on incidental catches requires investigating.

Observations to date indicate that there are significant numbers of cetaceans killed during fishing operations in many parts of the Philippines. This is probably the case throughout Southeast Asia (IWC, 1994). Governments have tended to ignore this problem because of the more pressing concerns of increasing population and poverty. The population of the Philippines is growing at an annual rate of 2.9% and that of Indonesia at 2.2%. Poverty in coastal areas forces people to exploit the existing living resources beyond sustainable limits. Regulation is difficult in areas where poverty abounds. In fact, further development of fisheries is encouraged in many parts of Southeast Asia despite evidence of resource depletion. Overfishing seems to be the rule rather than the exception. Pauly (1989) contends that

> 'because the economies of Southeast Asian countries are 'developing', policymakers generally assume that the fisheries sector also needs to be developed...with the exception of Singapore, which imports most of its fish, the fisheries of Southeast Asian countries are in decline due to overexploitation. Fishing effort in the Philippines as a whole is two to three times in excess of optimum exploitation rates and even Brunei Darussalam, although its fishery is not as strongly exploited as in other Southeast Asian countries, shows a declining trend.'

Until poverty is alleviated, governments become serious in their implementation of laws and the public realises that it is counterproductive to 'kill the goose that lays the golden egg', problems of fishery resource overexploitation, together with the slaughter of dolphins, shall prevail.

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A Review of the Japanese Squid Driftnet Fishery with Notes on the Cetacean Bycatch

Akihiko Yatsu, Kazuhiko Hiramatsu and Shigeo Hayase

National Research Institute of Far Seas Fisheries, 7-1 Orido 5 chome, Shimizu-shi, Shizuoka, 424 Japan

ABSTRACT

The Japanese squid driftnet fishery began in 1978 in the northwestern Pacific, targeting the flying squid, *Ommastrephes bartrami*, and was effectively closed in 1992. In response to the rapid growth of the fishery, the Japanese Government adopted a limited-entry licensing system in 1981, under which various regulations were implemented. The regulations established a seven month fishing period from 1 June to 31 December, and a fishing area between 20°N and 46°N and between 170°E and 145°W; the northern boundary changed monthly to minimise the bycatch of salmonids while maintaining the squid catch. Fishing effort was mostly confined to the north of 38°N. Most squid driftnet vessels were also engaged in other fisheries during the year. They were usually converted from salmon driftnet, long-line, jig and trawl vessels. Their gross tonnages ranged from about 60 to 500 GRT. A typical vessel deployed about 1,000 tans of net per operation. A tan is a unit of gillnet with a length and depth of 30–50m and 7–10m respectively. The net material was nylon monofilament and the mesh size ranged from 110–135mm, but mostly 110–120mm. The number of licensed vessels gradually decreased from 534 in 1981 to 231 (actually operated) in 1992, while the number of operations (fishing days) per year fluctuated between 13,775 and 35,549 during 1983–92. The total number of tans (not standardised) deployed per year gradually increased from 21 million (1982) to 36 million (1986) and then became stable at 32–36 million (1987–89). The total number decreased to 16 million tans in 1992. The annual flying squid catch also fluctuated between 123,719 and 215,778 tonnes, resulting in annual average catch rates of 3.8–7.9 t/day or 7.2–8.6 kg/tan. The estimated total cetacean bycatches for the 1989, 1990 and 1991 fishing seasons respectively are: 3,065, 3,093 and 3,204 (Dall's porpoises), 12,449, 7,909 and 9,320 (northern right-whale dolphins), 6,154, 4,447 and 3,784 (Pacific white-sided dolphins), 286, 562 and 1,035 (common dolphins), and 1,079, 624 and 664 (other and unidentified cetaceans). Possibilities for mitigating the bycatch of the cetaceans are discussed with respect to (1) the modification of driftnets including subsurface nets and smaller mesh size, (2) time-area regulation and (3) squid jigging.

KEYWORDS: INCIDENTAL CAPTURE; NORTH PACIFIC; MANAGEMENT; SQUID FISHERIES; DALL'S PORPOISE; RIGHT WHALE DOLPHIN; PACIFIC WHITE-SIDED DOLPHIN; COMMON DOLPHIN; STRIPED DOLPHIN; SPOTTED DOLPHIN; SPINNER DOLPHIN; BOTTLENOSE DOLPHIN; RISSO'S DOLPHIN; SHORT-FINNED PILOT WHALES; FALSE KILLER WHALES; SPERM WHALE; PYGMY SPERM WHALE; CUVIER'S BEAKED WHALE; HUMPBACK WHALE; BLUE WHALE; MINKE WHALE; SEI WHALE; BRYDE'S WHALE; FIN WHALE; RIGHT WHALE

INTRODUCTION

The flying squid, *Ommastrephes bartrami*, is an oceanic species which attains over 50cm in mantle length and over 4kg in weight. Japanese fishermen began a commercial jig fishery for this species in 1974 in order to compensate for the drastic decline in the catch of the Japanese common squid, *Todarodes pacificus*, around Japan (cf. Osako and Murata, 1983). The largest annual catch (124,000 tonnes) of flying squid by the jig fishery was recorded in 1977 (Murata, 1990).

Driftnet fishing, introduced in 1978, proved much more effective for this species than jigging (Osako and Murata, 1983) and as a result jigging effort decreased and driftnet effort rapidly increased. The rapid expansion of the squid driftnet fishery was also influenced by a combination of: (1) the decline of distant water fisheries, especially the Japanese salmon driftnet fishery, in the late 1970s and early 1980s; and (2) the location of the fishing grounds in the high seas of the North Pacific outside the EEZs (exclusive economic zones) of other countries. Korea and Taiwan began squid driftnet fishing in 1979 and 1980 respectively. This fishery became one of the most important fisheries for these three Asian nations. In the late 1980s/early 1990s annual catches were between 200,000 and 300,000 tonnes.

The fishery became a high seas management problem for a number of reasons, including the take of non-target species (marine mammals, sea birds, salmonids and juvenile albacore) and their conservation, and problems of lost and discarded nets and subsequent navigation safety (FAO, 1990; Garcia and Majkowski, 1990). Since 1984, the Fisheries Agency of Japan has conducted scientific research surveys on flying squid using driftnets and jigging gear. A scientific observer programme began in 1988 to obtain catch rates and information on the biology of various marine organisms that were incidentally caught by the commercial fishery. The programme was expanded in 1989 as a cooperative study between Canada, Japan and the USA. It was further expanded in 1990 in order to be able to obtain statistically reliable catch rates. More than 50 documents on this fishery, including those on incidental take and net debris, have been submitted to the International North Pacific Fisheries Commission (INPFC). A worldwide moratorium on the high seas driftnet fishery took effect at the end of 1992 according to the United Nations General Assembly Resolution 46/215. This effectively closed the Japanese squid driftnet fishery. Yatsu *et al.* (1993) described this fishery.

DESCRIPTION OF THE FISHERY

Designated landing ports

Each vessel had to select five out of the 39 ports designated by the Ministry of Agriculture, Forestry and Fisheries for landing the catch from the squid driftnet fishery (Fig. 1). The major landing ports were Hakodate, Hachinohe, Hanasaki, Kushiro, Shiogama and Kesennuma.

Target species

The target species was the flying squid, *Ommastrephes bartrami*. Its biology has been discussed by Naito *et al.* (1977), Roper *et al.* (1984), Murata (1989; 1990) and Murata and Hayase (1993) and is summarised below. It is an oceanic species occurring worldwide in subtropical and temperate waters (7–24°C surface water temperature). The maximum mantle length and body weight are about 50cm and 4.5kg for females and 39cm and 1.6kg for males. Although its life span is assumed to be about one year, some females probably live longer than that. The Japanese driftnet fishery mainly exploited the larger animals (mostly females of 35–50cm in mantle length) due to mesh selectivity.

The flying squid undertakes seasonal migrations. In the North Pacific, spawning occurs south of about 32°N in the winter, spring and possibly autumn. The squid then migrate to the north, feeding around the Sub-arctic Boundary in the summer (females are found in higher latitudes than males) and then returning to the south in the autumn and winter. During the feeding season, diurnal vertical migration has been observed between near surface waters at night and deeper layers (about 300–600m) in the daytime. Flying squid feed on fish (lantern fishes, sardines, saury, etc.), squid (including a high percentage of cannibalism) and pelagic crustaceans.

Okutani (1977) estimated a total potential catch of 150,000–600,000 tonnes for this species in the North Pacific. This figure was obtained prior to the start of the driftnet fishery and although its lower figure has been exceeded by the fishery, the upper figure seems plausible. Osako and Murata (1983) postulated an annual sustainable catch in the jigging grounds west of 170°E in the North Pacific at 80,000–150,000 tonnes.

Regulation of fishing season and area

The Japanese squid driftnet fishery began in 1978 in the northwestern Pacific and then expanded rapidly to the central North Pacific in 1979 and 1980 (Osako and Murata, 1983). In response to its rapid growth, the Japanese Government adopted a limited-entry licensing system for this fishery in 1981 under which various regulations were implemented. The regulations established a seven month fishing period, from 1 June to 31 December and a fishing area between 20°N and 46°N and between 170°E and 145°W. The northern boundary changed monthly to minimise the incidental take of salmonids while catching squid (Fig. 2). In 1981 the northern boundary was designated as 40°N for June and December, 42°N for July and November, 44°N for August and October, and 46°N for September (Fisheries Agency of Japan, 1982; 1985b; Nakata, 1987). After 1989, it was designated as shown in Fig. 2. Fishing effort has been mostly confined within 2–3° latitude of the northern boundary.

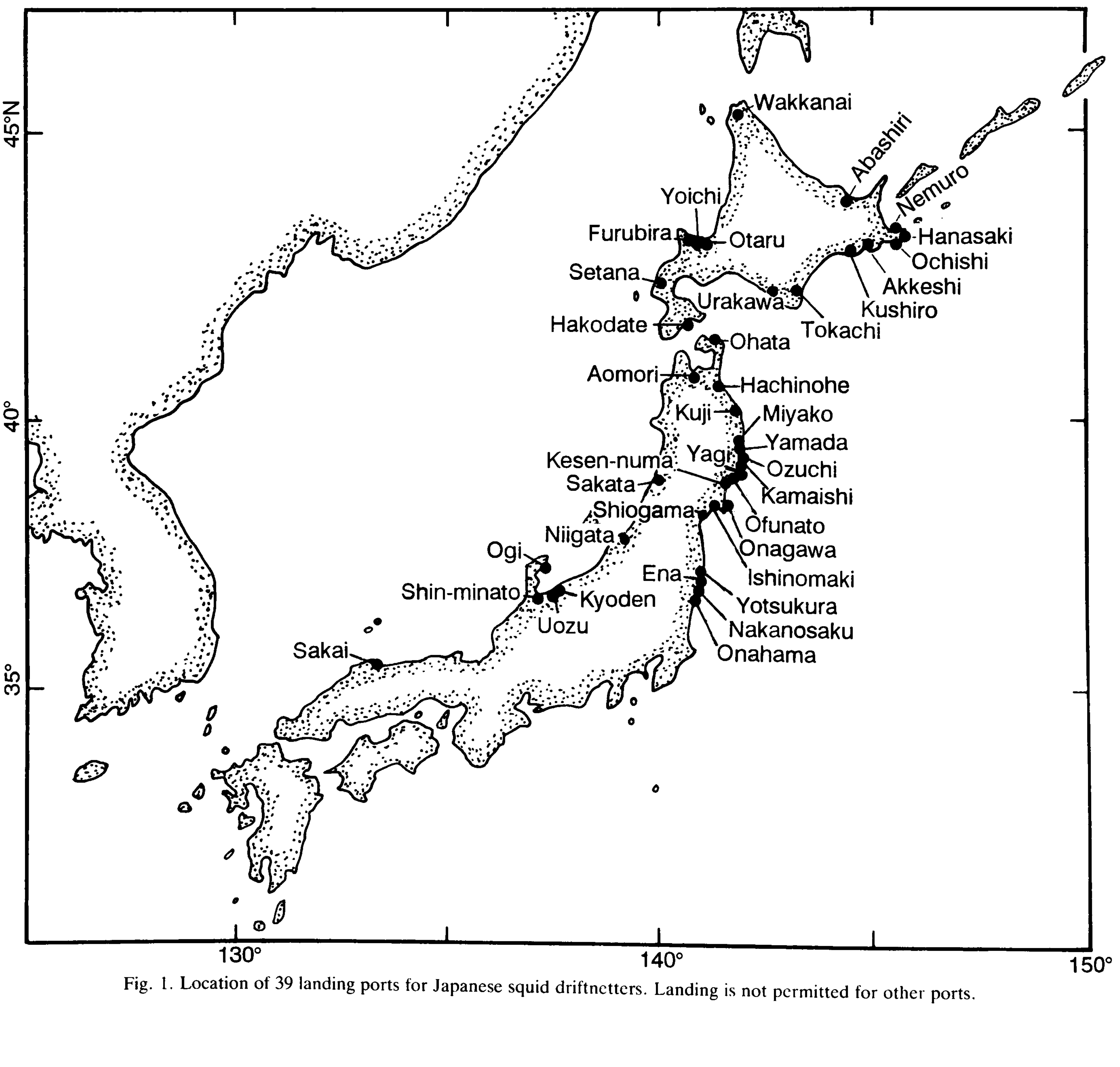

Fig. 1. Location of 39 landing ports for Japanese squid driftnetters. Landing is not permitted for other ports.

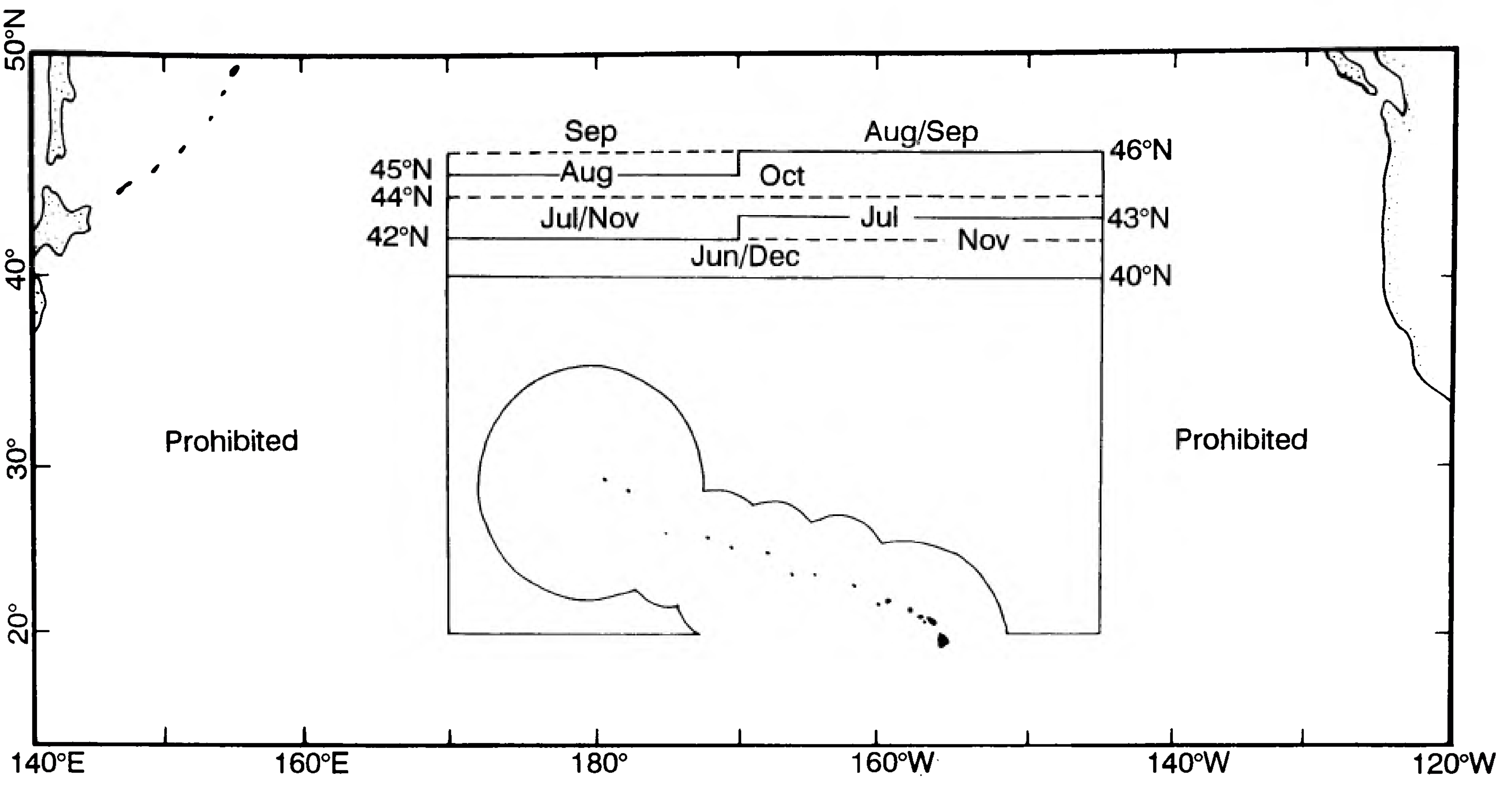

Fig. 2. Japanese squid driftnet fishing area (1989–1992).

Vessels and crew

(a) Type of vessel (Fig. 3)

The Japanese squid driftnetters comprised several different vessel types. They were converted from, or were actually engaged in, other fisheries even during the approved period for the squid driftnet fishery. The other fisheries include salmon driftnet fisheries, tuna fisheries, the Pacific saury fishery, squid jigging fisheries, distant water trawl fisheries, the North Pacific longline and gillnet fishery, and the offshore trawl fishery (Nakata, 1987).

(b) Vessel size and capacity

The vessel length followed a bimodal curve, with larger class vessels measuring 40–60m and smaller class vessels 25–30m. The gross tonnage (GRT) of the 457 licensed vessels in 1990 ranged from 59.5 to 499.9 GRT with modes at 100–150 GRT and 250–350 GRT. The smaller vessels had 100–150m^3 of fish hold capacity and 4–7 tonnes per day freezing capacity, whilst the larger had 350–500m^3 fish hold capacity and a daily freezing capacity of 10–20 tonnes.

(c) Number of licensed vessels

The number of approved vessels by size class since the introduction of the licensing system is shown in Table 1a.

In the 1990 fishing season, 93 of the 457 licensed vessels did not conduct squid driftnet operations. The Ministry of

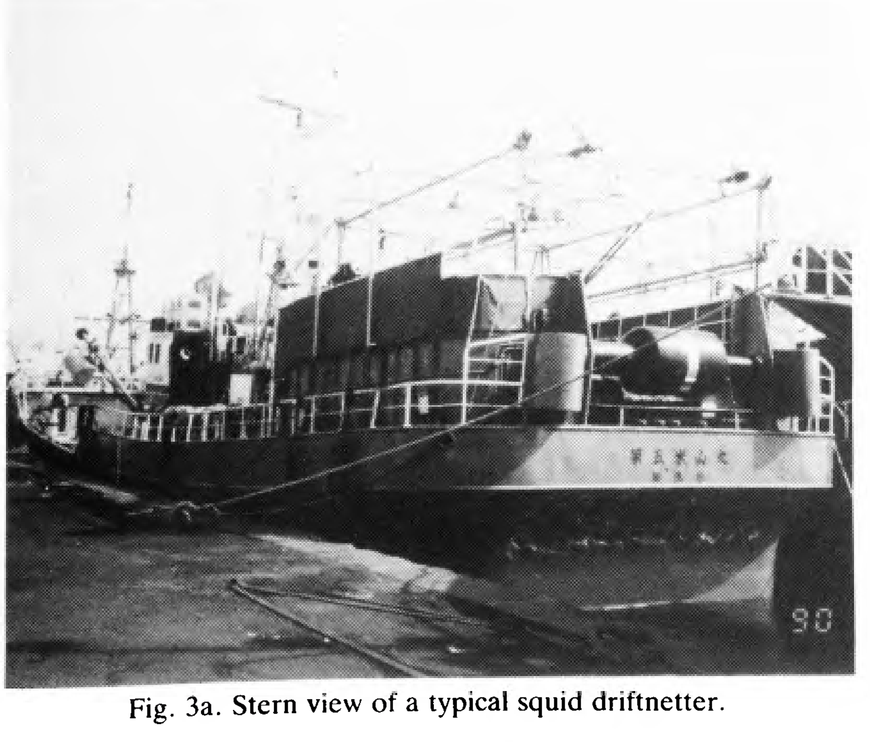

Fig. 3a. Stern view of a typical squid driftnetter.

Fig. 3b. Retrieval operation at main deck.

Table 1a

Number of approved vessels by size class since the introduction of the licensing system.

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991[1]	1992[1]
Small	371	326	285	265	259	237	209	202	196	195	104	80
Large	163	203	230	240	243	255	269	261	264	262	180	151
Total	534	529	515	505	502	492	478	463	460	457	284	231

[1] Only actually operating vessels are included.

Table 1b

Number of licensed Japanese driftnetters by port in 1990.

Prefecture	Port	No.	Prefecture	Port	No.
Aomori	Hachinohe	45	Ibaragi	Hasaki	2
Aomori	Aomori	5	Ibaragi	Hitachi	1
Ehime	Uwajima	2	Ishikawa	Noto	9
Fukushima	Iwaki	36	Ishikawa	Uchiura	25
Hokkaido	Erimo	2	Iwate	Miyako	5
Hokkaido	Matsumae	1	Iwate	Yamada	5
Hokkaido	Wakkanai	14	Iwate	Kamaishi	21
Hokkaido	Esashi	1	Iwate	Ozuchi	4
Hokkaido	Shiriuchi	3	Kagoshima	Kushikino	2
Hokkaido	Hirowo	8	Miyagi	Kesen-numa	20
Hokkaido	Akkeshi	12	Miyagi	Natori	1
Hokkaido	Rumoi	2	Miyagi	Shiogama	29
Hokkaido	Kushiro	27	Miyagi	Ishinomaki	16
Hokkaido	Urakawa	6	Miyagi	Onagawa	1
Hokkaido	Setana	2	Niigata	Niigata	5
Hokkaido	Otaru	9	Shimane	Nishinoshima	1
Hokkaido	Abashiri	3	Shizuoka	Shimizu	2
Hokkaido	Nemuro	53	Shizuoka	Omaezaki	1
Hokkaido	Hakodate	35	Tokyo	Tokyo	4
Hokkaido	Samani	1	Tottori	Sakai	3
Hokkaido	Iwanai	2	Toyama	Uozu	5
Hokkaido	Muroran	2	Toyama	Nyuzen	12
Hokkaido	Monbetsu	4	Toyama	Kurobe	8

Agriculture, Forestry and Fisheries has been reducing the number of licensed vessels for this fishery each year. The number of licensed vessels by home port in 1990 is shown in Table 1b.

(d) Fish handling

The following products were processed on board: (1) whole squid (round); (2) mantle with fins; (3) mantle without fins; (4) mantle without fins and skin; (5) fins; and (6) arms. All products are cleaned, graded, packed in freezing pans (usually 20kg size) and frozen daily.

(e) Vessel crew

The crew size was usually 14–18 including officers. Crew nationality is Japanese.

Gear

(a) Mesh size

The squid driftnet regulations specified a stretched mesh size of 100–135mm. About 90% of the vessels used 110–120mm mesh, which is effective for large flying squid. The 121mm mesh driftnet has the highest efficiency for squid 37–47cm in mantle length (Kubodera and Yoshida, 1981).

(b) Material

An example of a Japanese squid driftnet is shown in Fig. 4. The fishing net is made of nylon monofilament. The corkline is composed of an S-twist rope, a Z-twist rope and

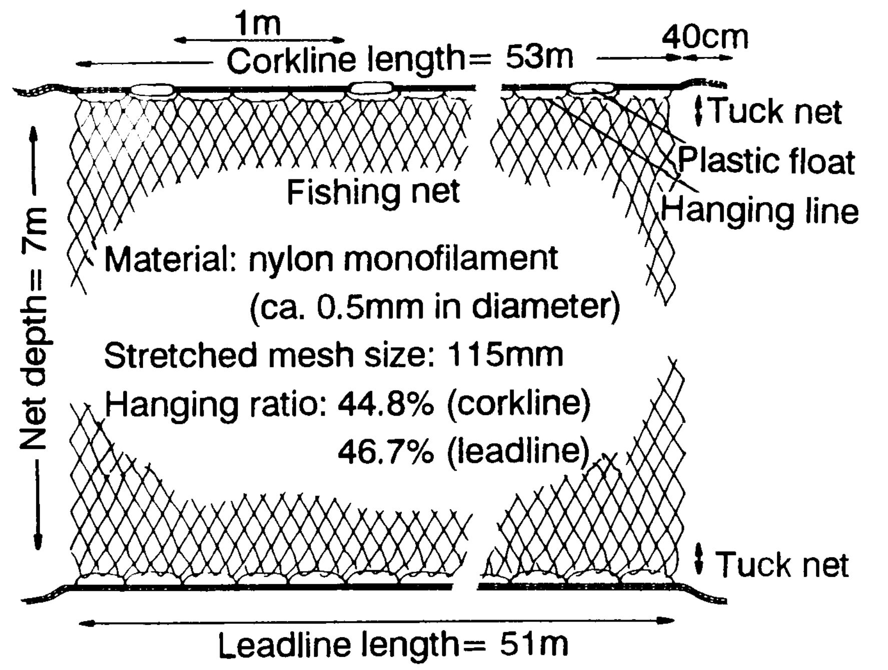

Fig. 4. An example of the construction of a tan of a Japanese squid driftnet.

floats. The leadline is composed of an S-twist rope and Z-twist rope, both of which contain leadlines. The corkline and leadline are made of polypropylene.

(c) Twine size

The diameter of both the corkline and leadline ropes was about 10mm. The filament diameter was about 0.5mm.

(d) Panel length and depth

The corkline length of a panel (tan) ranged from about 30–60m, with a mode at 45–50m. The panel depth at sea was usually 7–10m (8–12m when stretched).

(e) Number of panels carried

Japanese squid driftnetters usually carried 600–1,800 panels or tans per vessel. This included extra net to replace any that was lost or damaged.

(f) Float size and spacing

The length and diameter of a float was about 20cm and 4–5cm respectively. Floats were usually spaced at 1m intervals (Fig. 4). The buoyancy of a float was about 200g.

(g) Beacons

Usually a radio buoy, a light buoy, a plastic buoy and occasionally also a radar buoy was attached to one or both ends of a net section, which consisted of 70–200 tans.

(h) Net-hauling gear

Two hydraulic devices were located on the port main working deck (rarely starboard). The forward device, the 'line-hauler', was used to retrieve the leadline. The other device, about 5–7m aft of the line-hauler, was called the 'ball-roller' and consisted of two rubber balls rotating in opposite directions. The ball-roller retrieved the corkline (Fig. 3 bottom). There was also a pair of ball-rollers above the net pit which was located aft of the vessel; these were used to pull the nets into the net pit, where nets were stored for the next deployment.

(i) Other information

New fishing nets were used at the start of each fishing season, but the corkline and leadline were sometimes re-used. As the season progressed, nets were often torn by the entanglement of large animals such as sharks, billfish and marine mammals, and/or by the crew while removing albacore, pomfret and other fish. Smaller tears were not repaired. Nets with larger holes or tears were replaced during or after the retrieval operation each day. Corklines and leadlines were recycled.

Operations

(a) Usual length of trips

Trips usually lasted from 1–4 months, primarily depending on the amount of catch and the size of the vessel, since the trans-shipment of products is prohibited. Trips by smaller vessels were usually less than 2 months whereas larger vessels were able to cruise up to four months. It took about seven days to sail from Japan to the western border of the fishing grounds (170°E). The average number of operations (net deployments) per vessel per season was about 70.

(b) Usual number of trips per year

The number of trips per fishing season, from June to December, was usually 1–2 for larger vessels and 1–3 for smaller vessels, depending on the other fisheries in which each driftnetter also participated.

(c) Number of panels fished

The average number of tans fished per operation gradually increased from 663 in 1982 to about 1,000 after 1986 (cf. Table 3). These figures are not standardised. The average length of a tan is about 45m.

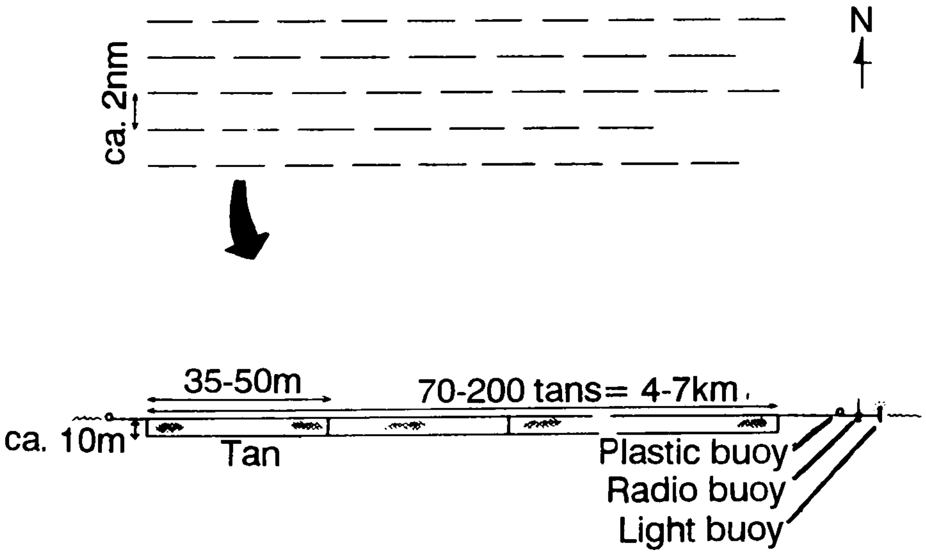

Fig. 5. Hypothetical example of array fishing by five Japanese squid driftnetters, each vessel deploying 7–10 sections from a particular longitude to the East at 2 n.miles distance (top). General construction of a section (bottom).

About 70–200 tans of driftnet were connected to form one net section (Fig. 5). Usually 6–10 sections were set in an operation. Sections are usually set separately with several hundred metres between them (Fig. 5). The distance between sections sometimes expanded to several miles before retrieval due to wind and sea currents. When sea conditions were good, sections were often connected to each other by ropes to make the retrieval operation easier.

(d) Soaking time

Typically, driftnet deployment occurred a few hours before sunset and took 2–4hrs. The net retrieval operation began 2–3hrs before sunrise. It usually took from about 40 minutes to 3hrs to retrieve one net section, depending on the catch and the condition of the nets. The soak time for a section of driftnet varied from 4hrs to more than 15hrs depending on the amount of catch and retrieval direction (from the start of the set or end of the set). In rare cases, nets were left for more than one night, primarily where catches were too large to process (an extended or *tome ami* operation in Japanese terminology).

(e) Usual catches (per operation)

The average catch of flying squid was 3.8–7.9 tonnes per operation during 1983–92 (see below).

(f) Array fishing

To avoid gear conflict between driftnetters, representatives of driftnetters from Japan, Korea and Taiwan agreed on a fishing protocol in 1987. The major items were: (1) vessels operating in proximity will always exchange net deployment information before the start of a set; (2) the vessel must maintain its setting course at 90° or 270° with an allowance of 20°; and (3) the vessel must keep at least 2 n.miles away from neighbouring vessels (Fig. 5).

Economics and history

(a) Price per kilo to fishermen

Table 2 shows the landing and price of the major flying squid products for 1985–91. Unprocessed squid, i.e., whole squid in the round, comprised about one third of the total landed product in the early 1980s. However, more recently the major product became the mantle without the internal organs and cut at the ventral midline (*hiraki*). This shift in processing on board was primarily aimed at saving freezing space and hence enabled a higher total income per cruise. It was enhanced by a higher price for *hiraki* than whole squid.

(b) Market

Flying squid was sold in the domestic Japanese market.

(c) Processing

Flying squid is suitable for processing and cooking, due to its thick and tender mantle as well as its large size. The landed squid products were further processed, mainly into: (1) *roll*, frozen mantle without fins and skin; (2) *ika-kun*, smoked and sliced; or (3) *daruma*, seasoned and dried mantle. *Roll* is sold at retail stores as either frozen mantle or as frozen food with bread-crumbs or flour. Most *daruma* was further processed to make *soft-saki-ika* by tearing it into pieces. The estimated domestic demand for flying squid in 1987 was 72,000 tonnes for *roll*, 20,000 tonnes for smoked squid and 35,000 tonnes for *daruma* (Taya, 1989).

(d) Locations of processors

Squid processors are distributed throughout most of Japan. Major processors for flying squid were located at Hakodate and along the Pacific coast of northern Honshu, from Hachinohe to Onahama (Fig. 1).

Table 2

Landings and price of major flying squid products sold in Japan, 1985-1991 (Japan Squid Driftnet Fishery Association).

Year	1985	1986	1987	1988	1989	1990	1991
Catch (t)							
Whole squid	6,348	3,175	849	287	175	-	-
Nuki[1]	29,915	14,032	16,669	14,492	17,765	18,864	6,698
Hiraki[2]	34,147	33,020	48,076	30,681	36,107	44,099	16,981
Hiraki-mimitori[3]	15,836	15,143	26,564	20,552	22,603	27,845	29,073
Arms[4]	9,228	14,116	12,120	17,052	15,301	12,275	14,612
Fins	2,261	3,608	2,630	2,164	3,143	2,470	3,777
Others	849	3,145	2,454	1,101	741	27	228
Total	98,584	86,239	109,362	86,329	95,835	105,580	71,369
Price (Yen/kg)							
Whole squid	303	304	275	288	190		
Nuki[1]	536	532	295	418	324		
Hiraki[2]	582	565	321	423	381		
Hiraki-mimitori[3]	636	635	371	481	442		
Arms[4]	138	199	187	200	99		
Fins	285	236	147	200	139		
Overall	500	483	310	382	330	353	452

[1] Mantle without internal organs but not cut.
[2] Mantle without internal organs and cut at longitudinal axis.
[3] *Hiraki* without fins.
[4] Arms, tentacles and distal part of head.

(e) Total annual ex-vessel value

The average annual ex-vessel value per vessel ranged from 71 to 124 million Yen during 1981–88.

(f) History of the development of the fishery and trends

Flying squid had been unexploited before the early 1970s, when the catch of Japanese common squid, *Todarodes pacificus*, drastically declined (Osako and Murata, 1983). The flying squid fishery commenced in 1974 with jigging operations off the Pacific coast of Japan. Driftnets were introduced in 1978 and were found to be much more effective than jigging (Osako and Murata, 1983). The number of squid driftnetters was estimated to be over 800 in November 1978 (Murata, 1989). This resulted in a conflict with the existing jigging fishery (Nakata, 1987). To avoid this conflict, the Japanese Government separated the fishing grounds for these fisheries at 170°E in 1979 (Fig. 6). As noted above, the Government established a set of restrictive regulations including a limited entry system for the squid driftnet fishery in 1981 (Nakata, 1987).

Fig. 6 shows the general distribution of the fishing grounds for jigging and driftnets until 1982. The annual

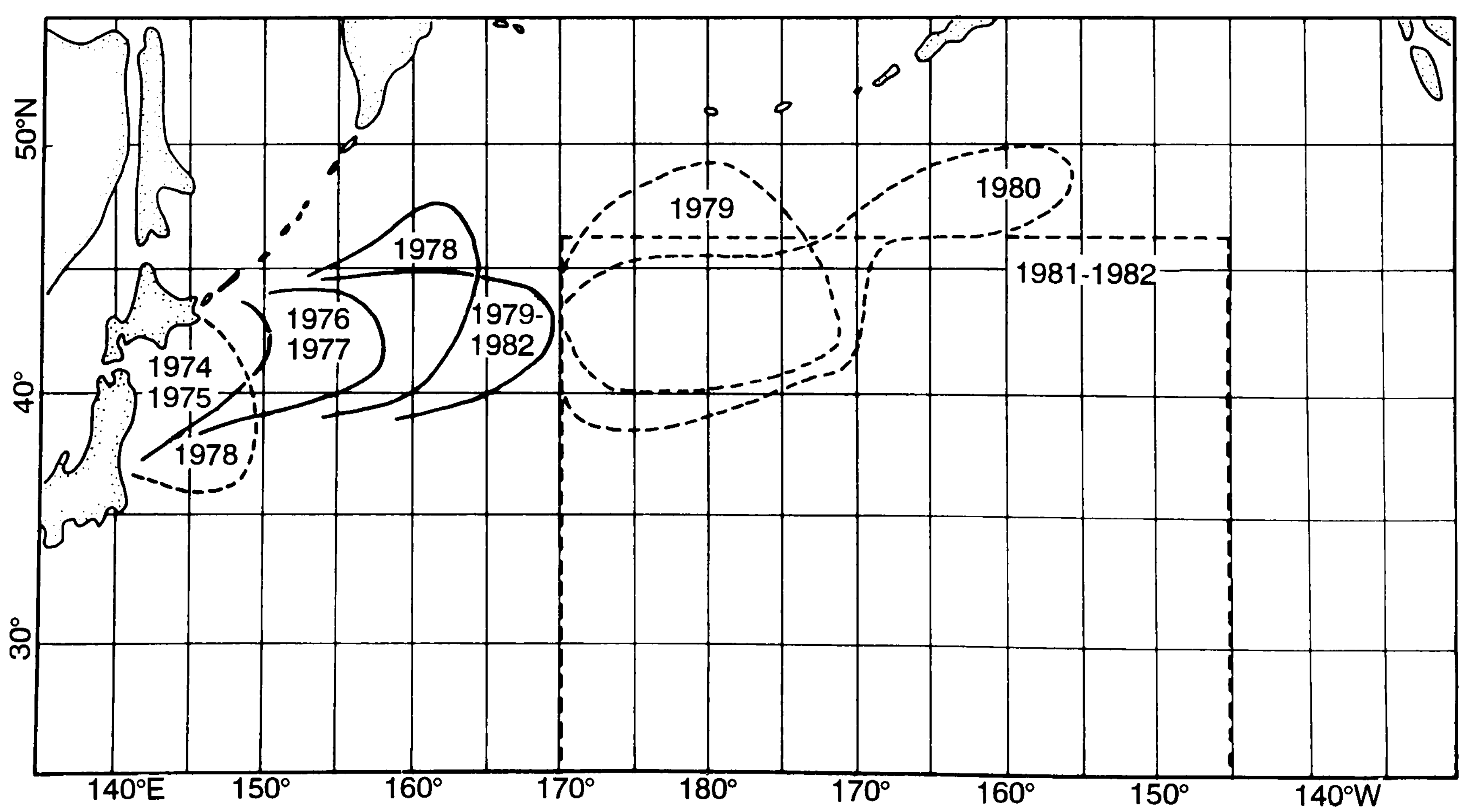

Fig. 6. General distribution of Japanese fishing ground for flying squid during 1978–1982 (after Murata, 1989). Solid line, jig fishery; broken line, driftnet fishery.

Table 3

Annual number of fishing days, deployed tans, catch in round weight, CPUE and landings for the Japanese squid driftnet fishery, 1978-1992.

Year	Fishing day[1]	Deployed tans[3]	Catch[1] (t)	CPUE kg/tan	CPUE t/day	Product landed[2] (t)
1978	[6]	[6]	*ca* 45,000 [4]			
1979	[6]	[6]	*ca* 45,000 [4]			
1980	[6]	[6]	121,585 [4]			76,884 [3]
1981	[6]	[6]	103,163 [4]			61,960 [3]
1982	33,073	21,928,768	158,760	7.2	4.8	100,235
1983	32,685	25,224,746	215,778	8.6	6.6	105,758
1984	32,645	29,251,829	123,719	4.2	3.8	73,991
1985	35,132	34,023,355	197,795	5.8	5.6	98,584
1986	35,549	36,367,294	152,226	4.2	4.3	86,239
1987	29,613	32,017,130	208,319	6.5	7.0	109,362
1988	31,998	36,055,567	157,773	4.4	4.9	86,329
1989	33,646	34,385,032	171,014	5.0	5.1	95,835
1990[5]	23,656	22,769,857	187,660	8.2	7.9	105,580
1991	19,453	21,709,643	101,638	4.7	5.2	71,369
1992	13,775	15,656,091	99,800	6.4	7.3	

[1] Fisheries Agency of Japan (1984, 1985b, 1986, 1987, 1988, 1989a, 1990, 1991, 1992, 1993) for 1982-92.
[2] After The Japan Squid Driftnet Association.
[3] Standardized at 50m per tan for only 1989 and 1990.
[4] By Murata (1989).
[5] Including experimental fishing in May.
[6] No reliable data.

flying squid catch by jigging was about 124,000 tonnes in 1977 and this gradually decreased to about 20,000 tonnes in the late 1980s (Murata, 1989). In spite of the reduction in the number of vessels from over 800 in 1978 to 534 in 1981, the driftnet catch increased rapidly in 1980 and the annual catch fluctuated between 124,000 tonnes and 216,000 tonnes during 1983–90 (Table 3). This presumably resulted from the development of new fishing grounds and from the increased size of vessels. In 1991–92, the total catch decreased to about 100,000 tonnes as fishing effort declined. Based on the catch and number of fishing days, the CPUE (tonnes per day) also fluctuated between 4.3 and 7.9 during 1982–92 with no apparent trend (Table 3).

However, the CPUE (in kg per tan) decreased from over 7 in 1982 and 1983 to 4.2 in 1984 and fluctuated between 4.2 and 8.2 after 1984. A considerable decline in the number of tans in 1990 resulted from (1) a decrease in the number of vessels which actually operated and (2) a good catch of flying squid. There are no CPUE data before 1982 (Mamoru Murata of the Hokkaido National Fisheries Research Institute, pers. comm.).

There has been a similar pattern in the relationship between the monthly number of fishing days and CPUE since 1982 when reliable statistics became available (Fig. 7). The highest monthly fishing effort occurred in August (1982–86) or July (1987–90). The highest CPUE usually occurred in June or July.

The geographic distribution of fishing effort in 1989 is shown in Fig. 8. Fishing effort was mostly confined to the waters between the northern boundary and 38°N and usually within 2–3° of the monthly northern boundary. Fishing effort was bimodal longitudinally from June to October, whereas effort was reduced and concentrated in the waters west of the dateline in November and December. These patterns are similar from 1983 to 1989 (Fisheries Agency of Japan, 1984; 1985a; 1986; 1987; 1988). The surface water temperature on the fishing grounds is usually 13–18°C.

Total landings (by year)

Table 2 shows annual landings by type of product. Table 3 shows annual catches in round weight. Total annual values ranged from 38 to 62 billion Yen during 1981–88 (Ministry of Agriculture Forestry and Fisheries, 1990).

Effort data

The total annual fishing days and the number of tans deployed from 1982 to 1992 are shown in Table 3. The monthly number of fishing days from 1983 to 1990 and the distribution of fishing effort by month and by 1° square are shown in Figs 7 and 8 respectively.

Interactions with cetaceans

(a) Species

Of the 24 cetacean species recorded in the fishing grounds by sighting surveys (Jones, 1988; Miyashita, 1989), at least 18 have been incidentally taken by the Japanese squid driftnet fishery (Tables 4 and 5). The delphinids in the North Pacific can be classified as cold or warm water species based on surface water temperature (Kasuya and Jones, 1984; Miyashita, 1989). Given the water temperature preference of large squid (13–18°C), the three cold water species of Dall's porpoise (*Phocoenoides dalli*), Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) and northern right whale dolphin (*Lissodelphis borealis*), would be expected to be the major bycatch species.

(b) How and when entangled

Amano (1990) observed eight cetacean entanglements and reported that (1) all entanglements occurred in the upper two-thirds of the nets, (2) entanglement was more frequent in the central section among 1,000 tans deployed, but there was no obvious tendency in the horizontal distribution of entanglements within a section comprising 125 tans and (3) entangled body parts were flukes (caudal fin, 3 individuals), head (1 individual) and unknown including complicated entanglements (4 individuals). Snow (1987)

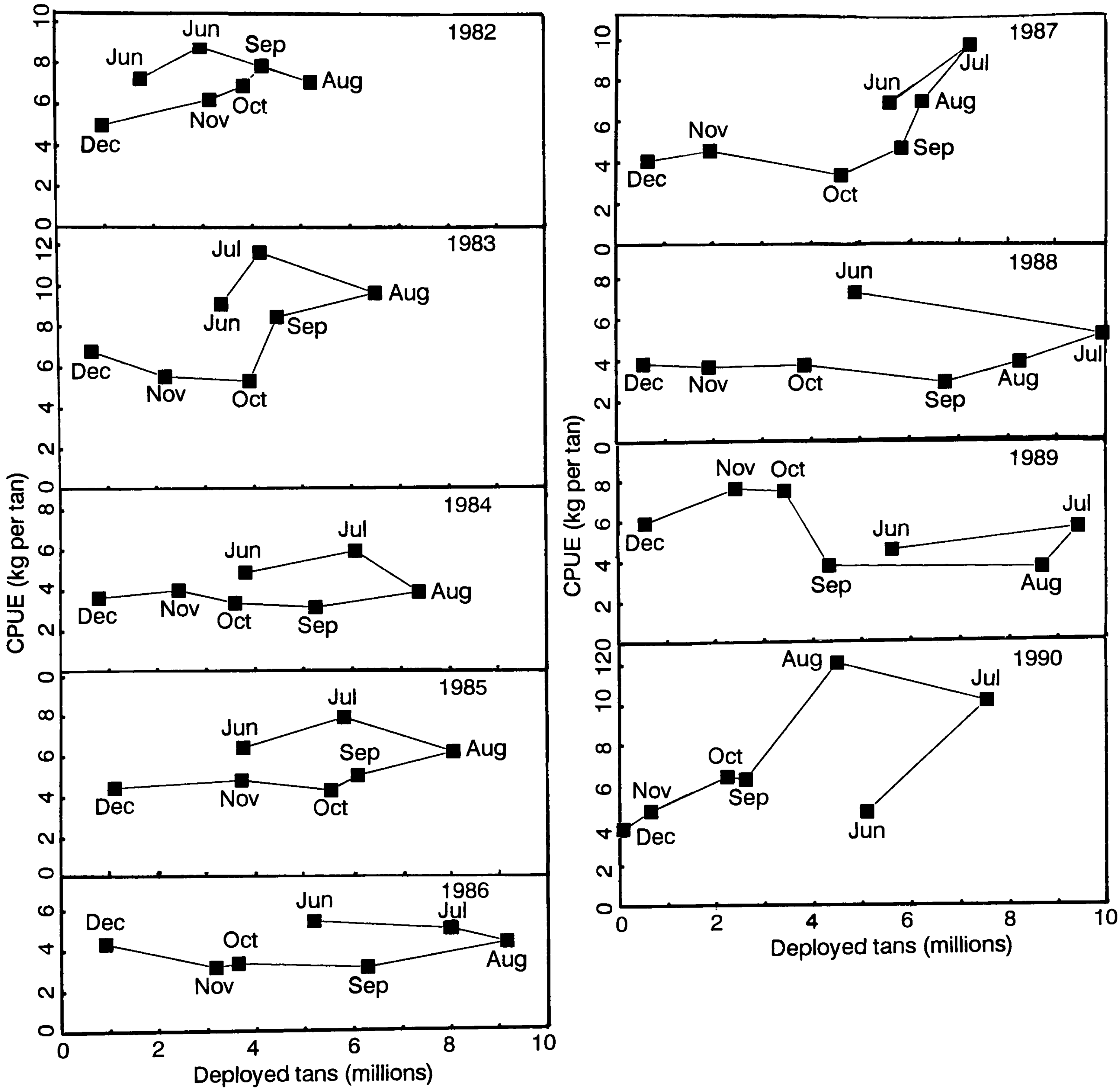

Fig. 7. Relationship between number of fishing days and CPUE (ton/operation) by month, 1982–1990.

and Jones *et al.* (1987) reported a similar tendency in the vertical position of entanglements for Dall's porpoise incidentally taken by the salmon driftnet fishery, i.e., a higher percentage of entanglements in the upper and middle parts than the lower third of the gillnet. Jones *et al.* (1987) reported (1) no difference between the three sections (110 tans each) of the salmon driftnet in the number of Dall's porpoise entangled and (2) higher entanglement rates for areas near the ends of a net section than for the central portion.

Liau and Hwang (1990) reported that marine mammals were more easily caught by large mesh sizes, especially 16, 18 and 20cm mesh, when comparing nine mesh sizes from 6–20cm. Yatsu *et al.* (1994) found a positive relationship between mesh size and cetacean catch rates among 16 different mesh sizes from 33mm to 197mm (Fig. 9) and considered that flukes and beaks (if present) are the primary parts entangled, because fluke lengths or beak girths are similar to the larger mesh sizes.

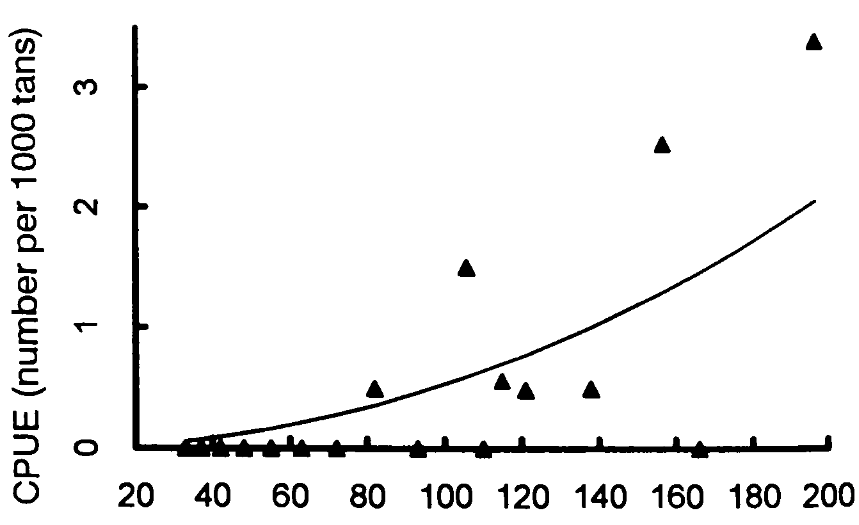

Fig. 9. Relationship between mesh size (M) and cetacean CPUE (Y) obtained from the Japanese squid driftnet research cruises in the North Pacific, 1984–90 (modified from Yatsu *et al.*, 1994). Solid line, $Y=5.29 \times 10^{-5} M^2$.

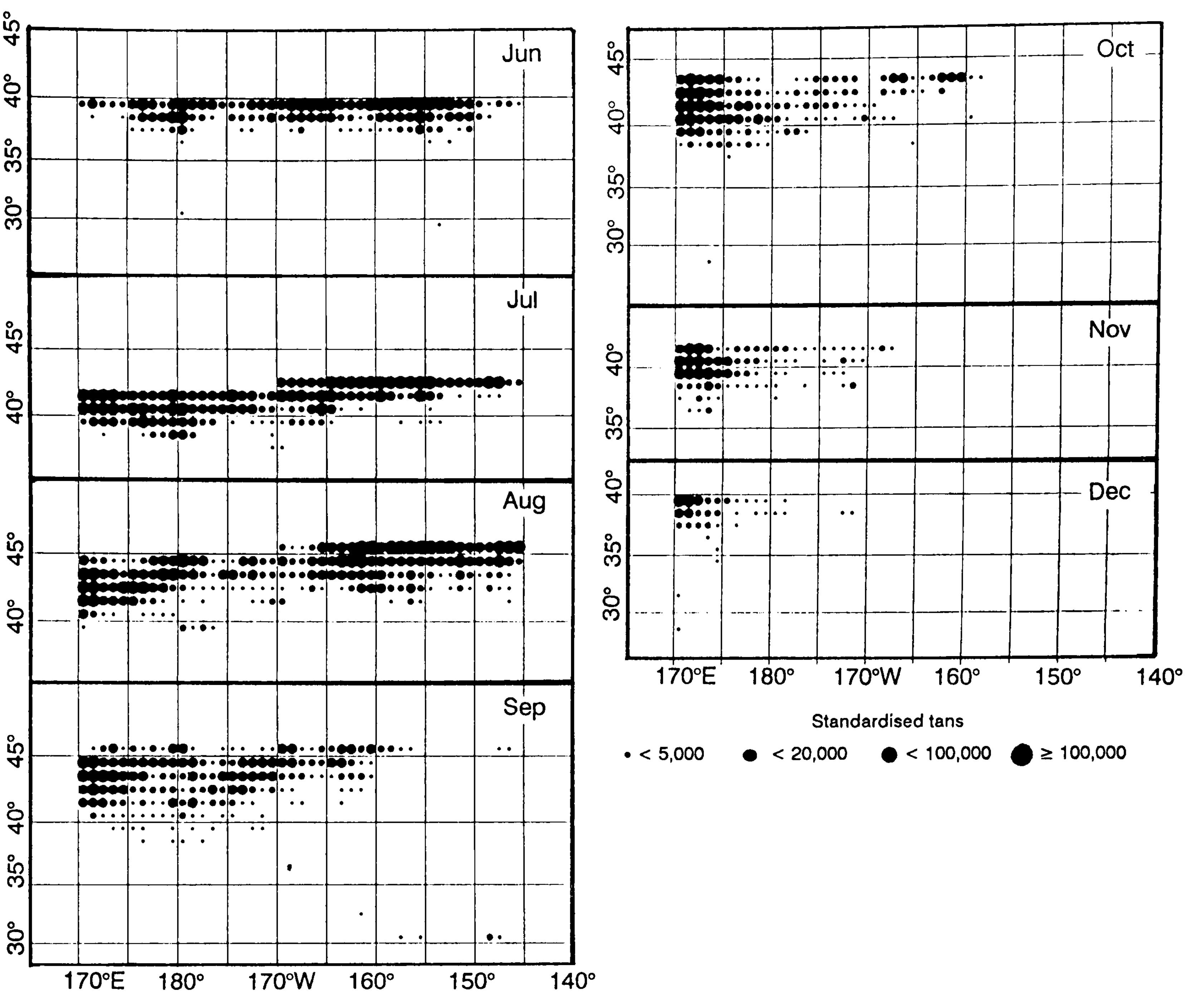

Fig. 8. Geographic distribution of fishing effort in number of days by month by 1°x1° block (latitude x longitude) in 1989 (after Fisheries Agency of Japan, 1990).

Table 4

Observed effort and bycatch of cetaceans for Japanese commercial squid driftnetters. Observations were made on fishing vessels except for 1985. In 1985, retrieval operations were usually observed from a US Coastguard cutter and its motor launch. Tan length standardised at 50m.

Species/effort	1982[1]	1985[3]	1986[7]	1988[2]	1989[4]	1990[8,5]	1990[9,5]	1991[8,6]
Number of operations observed	11	10	30	464	1,402	2,864	2,879	2,659
Number of tans observed				533,618	1,427,225	2,244,400	2,281,896	2,063,965
Observed driftnet length (km)	440	135	1,656	26,681	71,361	112,220	114,095	106,767
Mean observed tan (net) length per operation (km)	40	14	55	58	51	39	40	40
Number of bycatch								
Dall's porpoise	0	0	7	57	141	298	318	311
Northern right whale dolphin	7	0	43	114	455	812	840	939
Pacific white-sided dolphin	0	0	8	77	254	437	459	411
Common dolphin	11 [10]	0	0	5	12	69	69	87
Striped dolphin	0	0	1	0	0	6	6	5
Others/unknown	0	0	0	0	52	41	44	34
Total	18	0	59	253	914	1,663	1,736	1,787
CPUE (No. per 1000 tans)								
Dall's porpoise	0.00	0.00	0.21	0.11	0.10	0.13	0.14	0.15
Northern right whale dolphin	0.80	0.00	1.30	0.21	0.32	0.36	0.37	0.45
Pacific white-sided dolphin	0.00	0.00	0.24	0.14	0.18	0.19	0.20	0.20
Common dolphin	1.25	0.00	0.00	0.01	0.01	0.03	0.03	0.04
Striped dolphin	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
Others/unknown	0.00	0.00	0.00	0.00	0.04	0.02	0.02	0.02
Total	2.05	0.00	1.78	0.47	0.64	0.74	0.76	0.87

[1] Cary and Burgner (1983); [2] Fishery Agency of Japan (1989b); [3] Ignell, Bailey and Joyce (1986); [4] INPFC (1990); [5] INPFC (1991); [6] INPFC (1992); [7] Tsunoda (1989); [8] Excluding extended operations; [9] Including extended operations; [10] Identification in doubt, more likely Pacific white-sided dolphin (Cary and Burgner, 1983).

Table 5

List of cetaceans entangled in squid driftnet and sighted in the Japanese squid driftnet fishing ground, 20-46°N, 170°E-145°W. SST: surface water temperature where cetacean species were sighted (after Miyashita, 1989). Key: 1 = Fisheries Agency of Japan (1989b); 2 = INPFC (1990); 3 = INPFC (1991); 4 = INPFC (1992); 5 = Jones (1988); 6 = Miyashita (1989); 7 = Miyazaki (1986) and 8 = Tsunoda (1989).

English name	Scientific name	Entangled	Sighted	SST (°C)
Dall's porpoise	*Phocoenoides dalli*	2 3 4 1 8	5 6	< 18
Northern right whale dolphin	*Lissodelphis borealis*	2 3 4 1 8	5 6	10-23
Pacific white-sided dolphin	*Lagenorhynchus obliquidens*	2 3 4 1 8	5 6	10-23
Common dolphin	*Delphinus delphis*	2 3 4 1 7	5 6	18-28
Striped dolphin	*Stenella coeruleoalba*	3 4 8	6	18-28
Spotted dolphin	*Stenella attenuata*		6	22-28
Spinner dolphin	*Stenella longirostris*		6	22-25
Bottlenose dolphin	*Tursiops truncatus*	3 4	6	16-28
Risso's dolphin	*Grampus griseus*	3	6	> 22
Short-finned pilot whale	*Globicephala macrorhynchus*	3	6	16-18
False killer whale	*Pseudorca crassidens*	3	6	> 22
Killer whale	*Orcinus orca*		6	16-28
Unidentified dolphin			6	
Sperm whale	*Physeter macrocephalus*	4	5 6	> 12
Pygmy sperm whale	*Kogia breviceps*	3		
Unidentified *Kogia*	*Kogia* sp.	4 7		
Cuvier's beaked whale	*Ziphius cavirostris*	3 4		
Unidentified Ziphiidae			6	
Unidentified *Mesplodon*	*Mesplodon* sp.	3	6	
Unidentified beaked whale		3 4		
Humpback whale	*Megaptera novaeangliae*		5	
Blue whale	*Balaenoptera musculus*		6	14-26
Mink whale	*Balaenoptera acutorostrata*		6	14-23
Sei whale	*Balaenoptera borealis*		5 6	12-23
Bryde's whale	*Balaenoptera edeni*		6	16-28
Fin whale	*Balaenoptera physalus*		5 6	14-23
Unidentified large whale			5 6	
Unidentified medium whale		3 4		
Unidentified small whale		3 4	5 6	
Unidentified black whale		3 4		
Unidentified whale			5 6	
Others/unknown		2 3 4		

Based on observations of bottlenose dolphins in aquaria, Akamatsu *et al.* (1991) concluded that during the daytime, dolphins primarily recognise nets visually and that at night they cannot recognise nets by echolocation sufficiently to avoid them (although see Au, 1994). The soaking time of squid driftnets is usually from 2–3hrs before sunset to several hours after sunrise. Yatsu *et al.* (In press) presented preliminary analysis of the relationship between section number (as an index of soaking time) and CPUE of the major incidentally-caught species. Although the relationships were unstable due to the small sample sizes, the CPUE for the Pacific white-sided dolphin and for the northern right whale dolphin appeared to increase as soak time increased.

(c) How removed

When cetaceans were completely entangled, they were brought aboard and then disentangled. When cetaceans were lightly entangled or too large to bring aboard, they were disentangled outside the vessel by cutting the nets and/or caudal fins and by shaking and pulling.

(d) Proportions of live and dead

The proportion of live cetaceans among total entanglements was 3.6%, 3.1% and 3.5% in 1988, 1989 and 1990 respectively according to observer programme data (Fisheries Agency of Japan, 1989a; b; INPFC, 1990; 1991).

(e) Utilisation of cetacean bycatch

Usually, squid fishermen did not want to dissect cetaceans on board because they believed the blood spoils the quality of squid products. Some incidentally taken cetaceans were sold on the Japanese market, but the amount is thought to be negligible. The landing of cetaceans was prohibited in 1990 to deprive the fishermen of any incentive to kill cetaceans.

(f) Cetacean catch data

Tables 4 and 5 summarise the incidental take of cetaceans reported by scientific observers on board Japanese commercial squid driftnet vessels. The three cold water species accounted for 98% and 93% of the total cetacean take in 1988, and 1989–91 respectively. The monthly geographic distribution of catch rates for these three species is shown in Figs 10–12.

Table 6 shows the estimated total cetacean bycatch for this fishery during the years 1989–1991. To obtain these estimates we used data collected by scientific observers on the Japanese squid driftnet fishery during 1989–1991 (INPFC, 1990; 1991; 1992), catch and effort statistics (Fisheries Agency of Japan, 1990; 1991; 1992) and related information. The 1990 and 1991 observer data included data from extended retrieval sections but excluded data from subsurface net sections and data from the month of May, because only a subsurface experiment was carried out in May. A total of 460 (1989), 364 (1990) and 284 (1991) driftnetters operated in this fishery and each vessel usually

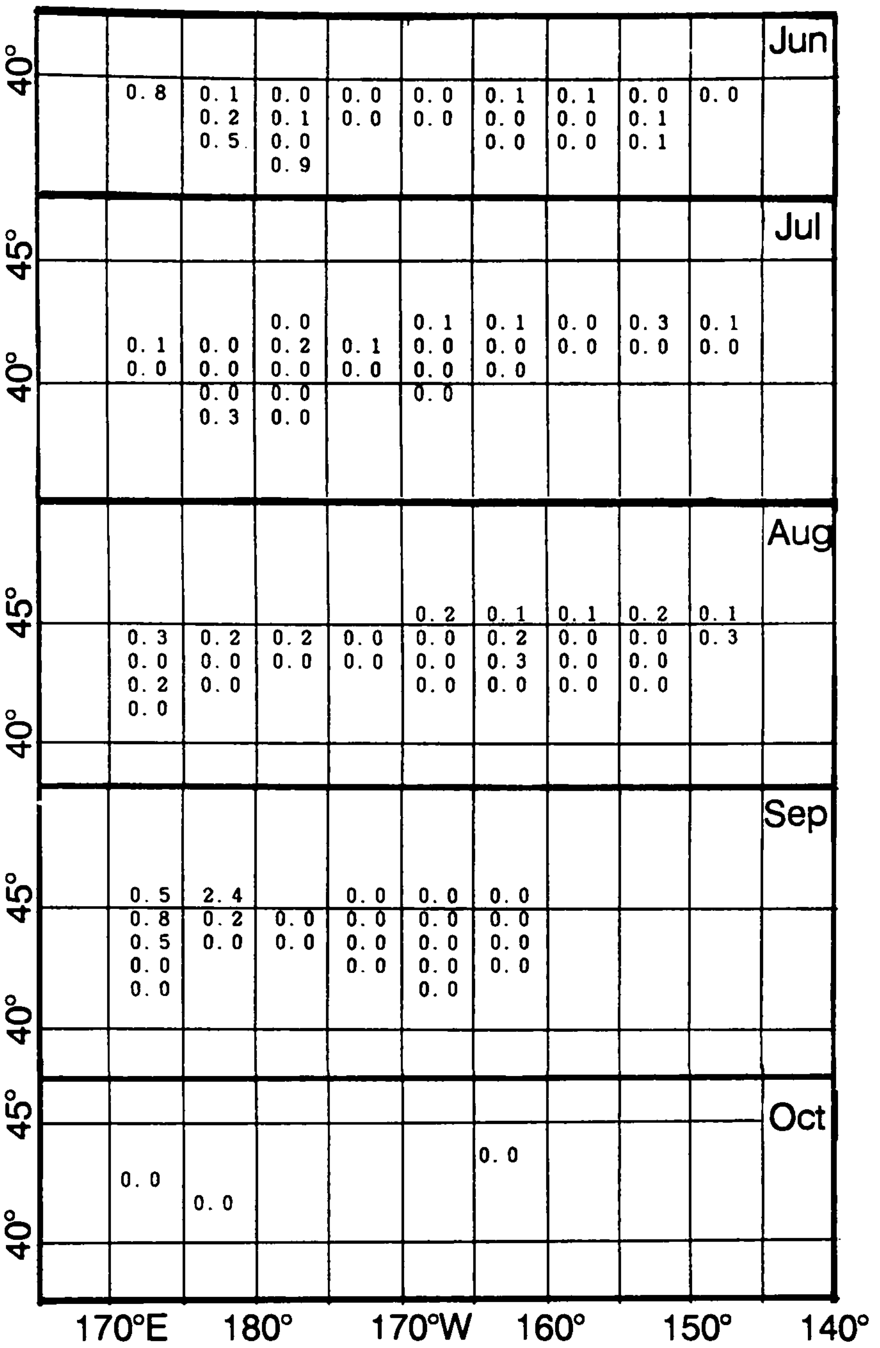

Fig. 10. Catch rate of Dall's porpoises by month by 1x5° block in 1989 calculated from INPFC (1990); no. per 1000 tans.

Table 6

Estimated bycatch of cetaceans for the Japanese squid driftnet fishery in 1989, 1990 and 1991 with approximate 95% confidence intervals.

Species	Estimated bycatch	-2 SD	+2 SD
1989			
Dall's porpoise	3,065	898	5,231
Northern right whale dolphin	12,449	4,706	20,192
Pacific white-sided dolphin	6,154	2,441	9,868
Common dolphin	286	0	914
Other, unidentified cetaceans	1,079	0	3,287
1990			
Dall's porpoise	3,093	2,279	3,907
Northern right whale dolphin	7,909	6,286	9,531
Pacific white-sided dolphin	4,447	3,605	5,289
Common dolphin	562	106	1,017
Other, unidentified cetaceans	624	372	876
1991			
Dall's porpoise	3,204	2,481	3,928
Northern right whale dolphin	9,320	7,417	11,223
Pacific white-sided dolphin	3,784	2,553	5,014
Common dolphin	1,035	350	1,719
Other, unidentified cetaceans	664	307	1,021

made 1–3 cruises during the fishing season. Scientific observers monitored about 3% of cruises in 1989, 12% in 1990 and 13% in 1991.

A scientific observer was placed on one of the cruises for each selected vessel. Although selection of the vessel's

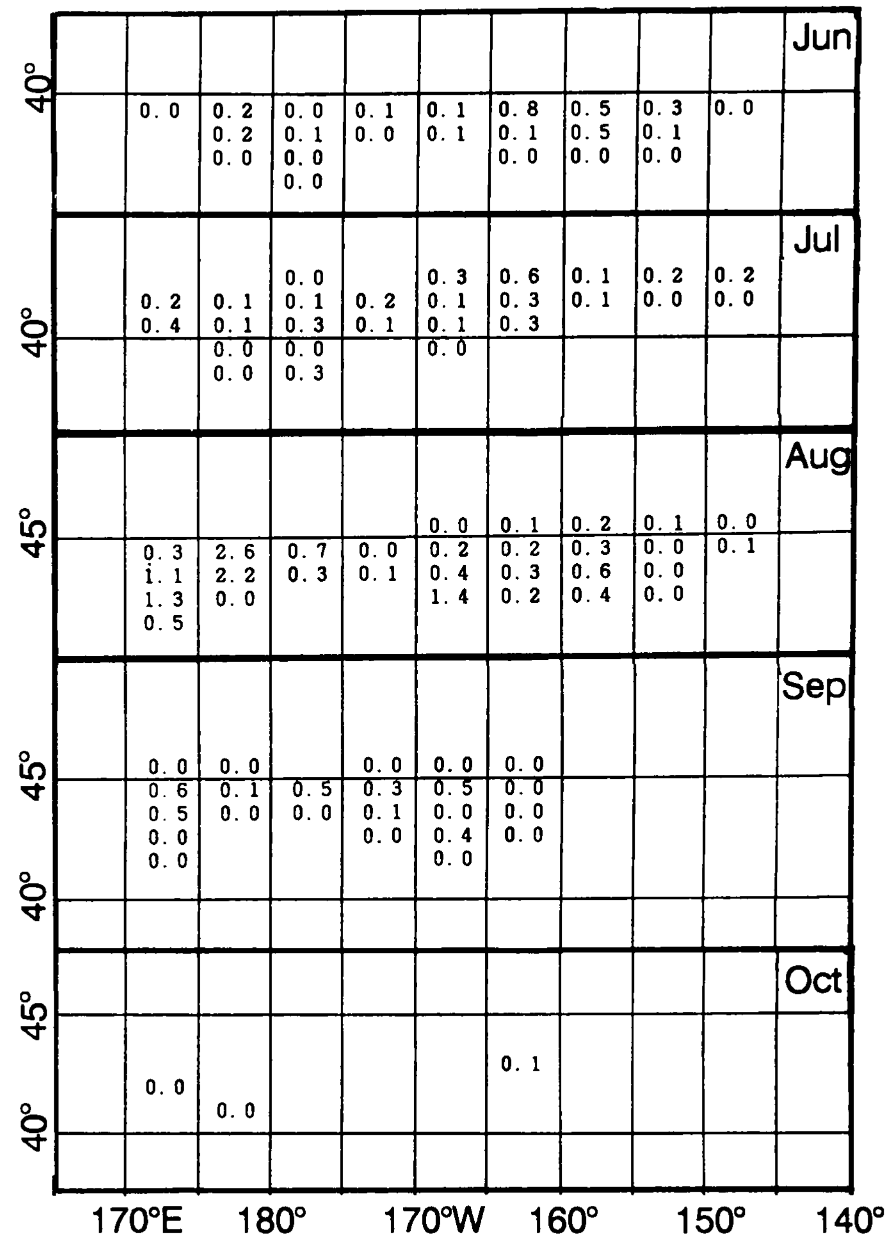

Fig. 11. Catch rate of northern right whale dolphin by month by 1x5° block in 1989 calculated from INPFC (1990); no. per 1000 tans.

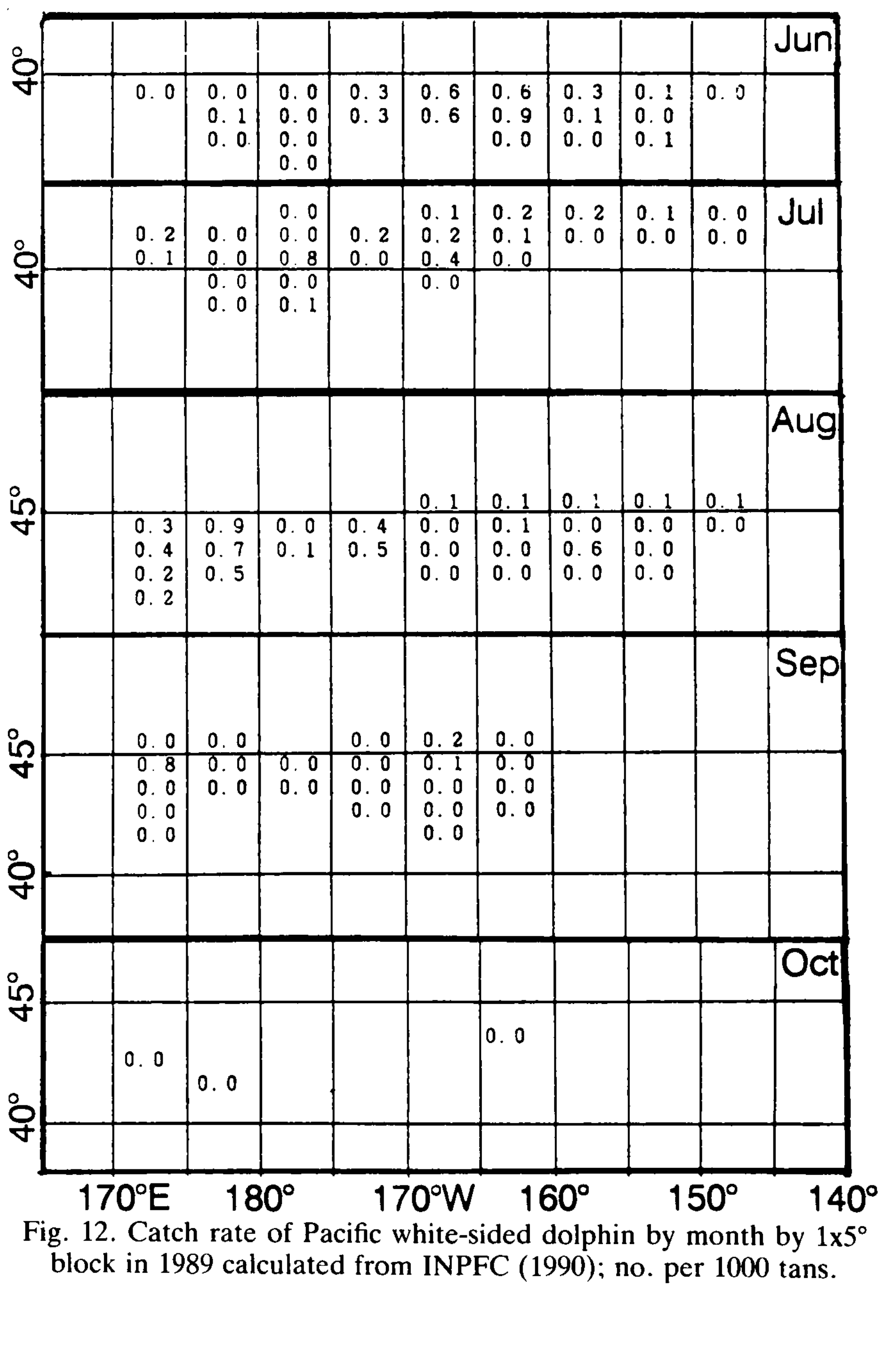

Fig. 12. Catch rate of Pacific white-sided dolphin by month by 1x5° block in 1989 calculated from INPFC (1990); no. per 1000 tans.

cruises was not based on a formal statistical design, we consider that the distribution of monitored operations well represented the total fishing activities in 1990 and 1991 and to some extent in 1989. Observers were instructed to monitor operations for five consecutive days and omit observations on the sixth day. Most of the observations were made on randomly selected 6 or 7 net sections in an operation (INPFC, 1990; 1991, 1992). The catch and effort statistics are based on fishing logbooks submitted by the fishermen.

Since data at the net section level are not available from the 1989 observer programme or from the catch and effort statistics, it is convenient to consider a two-stage sampling plan with cruises as a primary sampling unit and operations as a secondary sampling unit. We also assume that the sampling of observer data was made randomly at cruise and operation levels. Data were not stratified by time or by area.

Estimators of total bycatch ($\hat{Y}$) and its variance $V[\hat{Y}]$ are as follows (Cochran, 1963).

$\hat{Y} = \hat{R}X$ where

$$\hat{R} = \frac{\sum_{i=1}^{n} M_i\bar{y}_i}{\sum_{i=1}^{n} M_i\bar{x}_i} \left(\bar{y}_i = \frac{1}{m_i}\sum_{j=1}^{mi} y_{ij},\ \bar{x}_i = \frac{1}{m_i}\sum_{j=1}^{mi} x_{ij}\right)$$

$$V[\hat{Y}] = \frac{N(N-n)}{n(n-1)}\sum_{i=1}^{n} M_i^2(\bar{y}_i - \hat{R}\bar{x}_i)^2 +$$

$$\frac{N}{n}\sum_{i=1}^{n}\frac{M_i(M_i - m_i)}{m_i(m_i - 1)}\sum_{j=1}^{mi}((y_{ij} - \bar{y}_i) - \hat{R}(x_{ij} - \bar{x}_i))^2$$

where, M_i = number of total operations in i-th cruise
m_i = number of observed operations in i-th cruise
N = number of total cruises (801 in 1989, 643 in 1990, 428 in 1991)
n = number of observed cruises (27 in 1989, 75 in 1990, 55 in 1991)
X = number of total tans (34,385,032 in 1989, 22,636,075 in 1990, 21, 660, 852 in 1991)
x_{ij} = number of observed tans in j-th operation of i-th cruise
y_{ij} = number of observed animals in j-th operation of i-th cruise.

(g) Efforts to reduce the cetacean bycatch
Acoustic and subsurface driftnet experiments have been conducted by Japan (Snow, 1987; Hayase *et al.*, 1990; Hayase and Yatsu, 1993; Hatakeyama *et al.*, 1994). A study of the modification of driftnets in northern Australian waters revealed that neither bead chain nor plastic tubing had a significant effect on dolphin bycatch, whereas a reduction in cetacean catch rates was observed for subsurface nets set 4.5m below the sea surface (Hembree and Harwood, 1987). Snow (1987) and Jones *et al.* (1987) independently evaluated modified salmon driftnets whose acoustic reflectivity was increased by attaching hollow strands of monofilament or plastic blisters. Snow (1987) reported a 3–45% (usually 5–25%) decrease in the incidental take of Dall's porpoise for modified nets, but Jones *et al.* (1987) found no detectable difference between standard and modified nets. Hatakeyama *et al.* (1994) summarise the studies carried out largely, but not exclusively, on the Dall's porpoise.

Experimental fishing by six Japanese commercial squid driftnetters was conducted in May-July 1990 by simultaneously using surface nets and subsurface nets set at 1m or 2m below the sea surface (Hayase *et al.*, 1990). The results suggest that cetacean catch rates in subsurface nets were lower in May, but were statistically inconclusive for June and July, at least in part due to the small number of experiments.

Hayase and Yatsu (1993) also reported a similar fishing experiment using six commercial vessels during June-August 1991. In this experiment, about 400 tans of surface and subsurface nets set at 2m below sea surface were simultaneously used for an operation. Scientific observers monitored 107,844 tans of surface nets and 103,163 tans of subsurface nets. They recorded 12 and 7 Dall's porpoise, 13 and 4 Pacific white-sided dolphin and 50 and 47 northern right whale dolphin for surface and subsurface nets respectively. Although CPUE of subsurface nets for the former two species were somewhat lower than those of surface nets, no statistical differences were detected between them.

(h) Laws and regulations applying to cetaceans
In August 1990, the Government of Japan prohibited the retention and landing of cetaceans taken incidentally by driftnets.

(i) Impacts on cetacean populations
A scientific review on the impacts of large-scale pelagic driftnet fishing on living marine resources of the North Pacific was held from 11–14 June 1991 in Sydney, British Columbia. The following are the major results of the review of five cetaceans actually caught in large quantities by the large-scale pelagic driftnet fisheries and/or species of potential great concern.

(1) NORTHERN RIGHT WHALE DOLPHIN
There has been a decline in the population over the past 10 years due to the impact of the driftnet fishery. The population would continue to decline if current catch rates and levels of effort were maintained.

(2) NORTHERN RIGHT WHALE
The population in the eastern Pacific is thought to be near extinction and is probably no larger than about 50 individuals. Although there is no record of any bycatch in the squid driftnet fishery, any catch will move these whales closer to extinction.

(3) HUMPBACK WHALE
No humpback whale has yet been observed entangled in the large scale driftnet fishery, but concern was expressed about their migration route from the breeding areas around the Ryukyu and Hawaiian Islands to their North Pacific summering area across the driftnet fishing grounds. Japanese vessels do not fish in May in the area of concern.

(4) PACIFIC WHITE-SIDED DOLPHIN
The upper range of the bycatch in all the pelagic driftnet fisheries in the North Pacific is currently about 5% of the stock size and a calculation using the 'worst case' parameter estimates suggested that with high probability the population is near or above the assumed MSY (Maximum Sustainable Yield) level of 60% of the unexploited population size. This species is probably at a high level but is declining as a result of its bycatch.

(5) DALL'S PORPOISE
Most of the driftnet mortality is probably inflicted on three putative stocks (those found south of Kamchatka, south of the Aleutian Islands and in the Central Gulf of Alaska). Given the large size of these stocks, the total takes are not sufficient to cause the combined populations to decline. Although the status of the *truei*-type of this species is of great concern (e.g. IWC, 1992), none are taken incidentally in the Japanese squid driftnet fishery.

DISCUSSION AND RECOMMENDATIONS

The Japanese squid driftnet fishery was important for Japan. About 450 vessels employing about 8,000 fishermen landed approximately 100,000 tonnes of flying squid products equivalent to 40–50 billion Yen annually. The impact of this fishery on cetaceans, however, may have been significant for some stocks or species, especially the northern right whale dolphin. Given the uncertainties surrounding both cetacean population estimates and bycatch levels, it is necessary not only to collect more information to improve our assessments of the status of affected stocks but also to consider methods to reduce incidental takes. The following are possible methods for this purpose (the order does not indicate priority).

(1) Modification of driftnets
Subsurface nets have been found to be effective in reducing cetacean bycatches in some experiments (e.g. Hembree and Harwood, 1987), but the effect in the squid driftnet fishery is still uncertain despite the large-scale experiments in 1990 and 1991. Since small cetaceans in general tend to be entangled in the upper or middle portions of the nets, it is necessary to study the reasons for this difference (e.g., area, species and design of subsurface nets, especially depth and suspension lines). Restriction of mesh size to smaller mesh appears to be effective to reduce cetacean bycatch rates.

(2) Time-area regulations
This method would be effective for the Dall's porpoise, whose spatial distribution is somewhat different from the major squid driftnet fishing grounds. Dall's porpoise were entangled at the surface water temperature of 12–15°C in 1986 and 6–14°C in 1987 (Jones, 1988). A relatively high catch rate for this species was recorded in the northern part of the Japanese fishing grounds (Fig. 10). Closure of the northern part of the current fishing grounds could reduce the incidental take of Dall's porpoise, but, if a shift in fishing effort to the southern area occurred, the incidental take of cetaceans in those regions would increase. The distribution of Pacific white-sided dolphin and northern right whale dolphin, the other major cetaceans incidentally caught by this fishery, largely overlaps with the major fishing grounds (Figs 11–12). The Korean squid driftnet fishery operated in a more southerly area than the Japanese fishery, using smaller mesh sizes (76–115mm; usually 105mm in spring and 86mm in summer and autumn) than the Japanese fishery (Gong *et al.*, 1993). Although the fishing grounds for these fisheries differ considerably from each other in an east-west direction, the cetacean catch rates (all species combined) in 1990 for the Korean fishery (0.17, data from US and Korean observers combined; 0.27, US observers; 0.08 Korean observers; calculated from Park *et al.* (1991)) are considerably smaller than that of the Japanese fishery (0.74 or 0.76; Table 4). The catch rates of the Korean fishery for Dall's porpoise, northern right whale dolphin and Pacific white-sided dolphin are 0.06, 0.12 and 0.08, respectively (data from US observers in Park *et al.* (1991)). These values are less than half of those for the Japanese fishery. Therefore, a combination of smaller mesh sizes and a southward shift of fishing grounds would probably reduce the cetacean catch rates of the Japanese squid driftnet fishery.

(3) Development of alternative fishing techniques
The possibilities and problems associated with squid jigging, mid-water trawling and long-lining as alternative fishing methods have been discussed by the INPFC members. The bycatch rate for jigging is small and limited to fish and squids (Anonymous, 1990). We consider jigging to be the most promising alternative technique because it was successful in obtaining large catches of flying squid (up to 124,000 tonnes in 1977) in the northwestern Pacific (Murata, 1990). However, most of the larger flying squid drop off the jigs due to their weak tentacles (Murata *et al.*, 1981). The Fisheries Agency of Japan has recently begun studies to mitigate the drop-off of large squid by modifying jigs and jigging machines (Yatsu, 1990; Hayase and Yatsu, 1991).

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SC/O90/G55

Regulation of the Japanese High Seas Driftnet Fisheries

Kazuhiko Nagao

Offshore Fisheries Division, The Fisheries Agency Ministry of Agriculture, Forestry and Fisheries
1-2-1 Kasumigaseki, Chiyoda-ku, Tokyo, Japan 100

ABSTRACT

Two different high seas driftnet fisheries were operated by Japanese fishermen: the squid driftnet fishery and the large-mesh driftnet fishery. The squid fishery targeting flying squid started in the North Pacific in 1978. In 1981, the Government of Japan implemented a limited entry licensing system for this fishery, under which various regulations were imposed. The number of licensed vessels has decreased since 1981. In order to minimise the incidental take of salmon, a northern boundary was established based on the distribution data of salmon and flying squid. The large-mesh driftnet fishery targeting tunas and billfish has been conducted in Japanese coastal waters for more than 100 years. Expansion of this fishery to the high seas began around the middle of the 1970s. In 1990, a limited entry licensing system was introduced for this high seas fishery. Japan has been working in cooperation with the USA and Canada to collect detailed scientific data from these two high seas fisheries. Adoption of the UN Resolution in December 1989 has provided the opportunity for Japan to work more closely with other nations on a regional basis to strengthen the management of these fisheries. The Government of Japan decided not to issue licenses for large-scale pelagic driftnet fisheries on or after 1 January 1993 to implement UN General Assembly resolution 46/215.

KEYWORDS: NORTH PACIFIC; FISHERIES; SQUID; FISH; MANAGEMENT

INTRODUCTION

Driftnetting is an effective fishing method for catching flying squid (*Ommastrephes bartrami*). The squid driftnet fishery has become an important Japanese fishery, supplying around 100,000 tons of squid products per year to the Japanese market. The large-mesh driftnet fishery has a relatively long history and plays an important seasonal role for many fishermen. This paper describes the regulations for these high seas fisheries imposed by the Government of Japan.

DESCRIPTION OF REGULATIONS

Squid driftnet fishery

This fishery started in 1978 in the northwestern Pacific and expanded into the high seas of the North Pacific in the following year. It targets on flying squid, which, because of their soft, large bodies cannot be caught efficiently by other fishing methods such as jigging.

In 1981, the Government of Japan introduced a limited entry licensing system for this fishery under which various regulations were imposed. The system and regulations have been reinforced and improved based upon scientific and other relevant information from the fishery.

Under this system, the number of licensed vessels has decreased from 534 in 1981 to 457 in 1990, as the Government has not authorised new entries. In 1991 and 1992, the number of vessels operating was reduced substantially (Table 1).

A northern boundary was established in 1981 to minimise the incidental take of salmonids. In 1989, the northern boundary for July and August was revised based on the available information concerning habitat segregation of salmon and flying squid (Fig. 1).

Major provisions of the regulations

The main measures covered by the regulations are:

(1) limitation of the number of the vessels engaged in the fishery;
(2) geographical and temporal restrictions on the fishing ground, in particular, the establishment of the northern boundary by month;
(3) prohibition of the retention of anadromous species, cetaceans and fur seals taken incidentally;
(4) prohibition of the transfer of catch at sea;
(5) mandatory display of the vessel's name, registration number and license number on its hull to facilitate the identification of the vessel at sea;
(6) mandatory marking on fishing gear for identification;
(7) restrictions on mesh size for squid stock conservation;
(8) mandatory record keeping of Naval Navigational Satellite System (NNSS) data in order to identify operational positions;
(9) mandatory vessel position reports; and
(10) mandatory submission of catch reports to the Government.

Measures taken consistent with the 1989 UN Resolution

In addition to the above regulations, a number of further measures (see below) were taken in accordance with the UN Resolution on gillnetting adopted in 1989.

Table 1

Licensed vessels in the Japanese squid driftnet fishery, 1981-92.

Year:	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Vessels:	534	529	515	505	502	492	478	463	460	457	284*	231*

* Total number of vessels conducting squid driftnet fishing operations during the season.

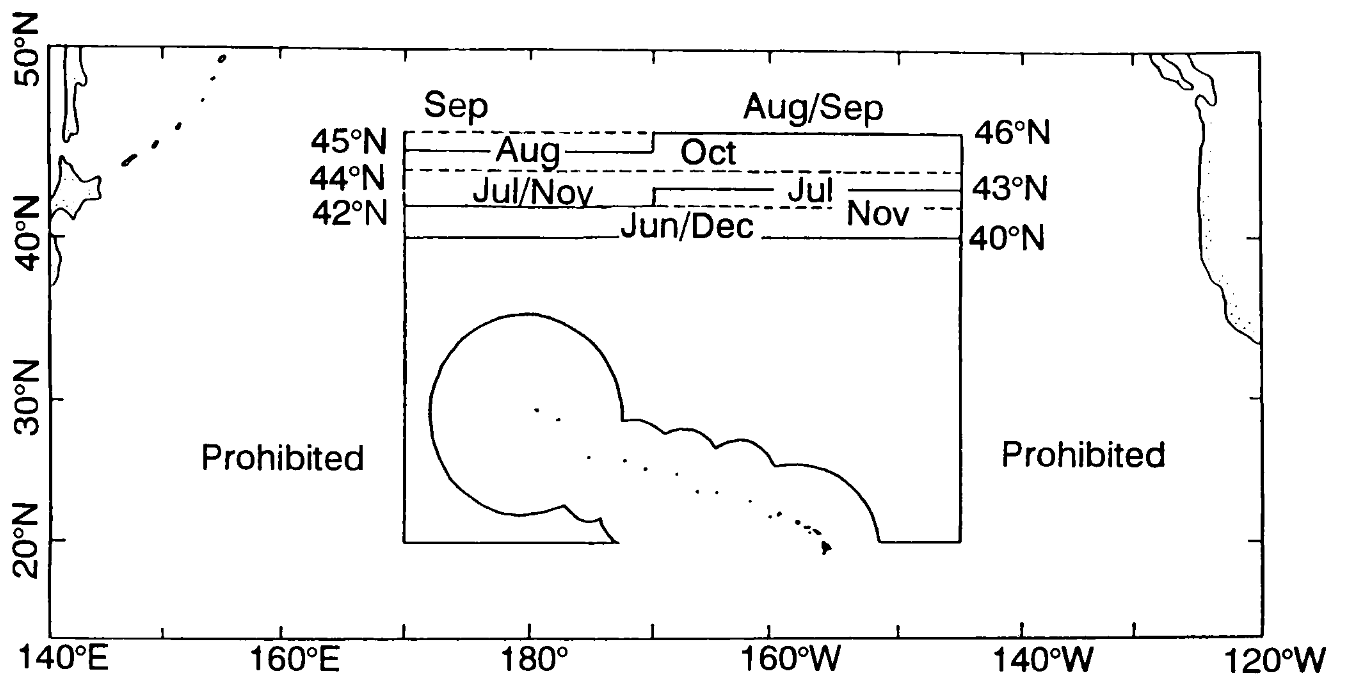

Fig. 1. North Pacific fishing grounds for Japanese squid driftnet fishery.

(1) *Restrictions on the scale of operations and the prohibition of expansion*
The number of vessels licensed in the 1991 fishing season (June-December) was 453 or less, which is a reduction of more than 80 from 1981. In addition, the Government formally prohibited this type of fishing in all areas outside the North Pacific from 15 August 1990.

(2) *Collection and exchange of scientific data*
A scientific observer programme for this fishery was initiated in 1988. In 1989, under agreements with the USA and Canada, a joint pilot scientific observer programme was implemented. Based upon these results, a full scale joint scientific observer programme was agreed and implemented in order to ensure the collection of statistically reliable data upon which conservation and management measures for this fishery might be based. Under the 1990 programme, 74 squid vessel cruises were observed. A similar programme was implemented for the 1991 and 1992 fishing seasons, when 75 cruises and 55 cruises were observed respectively.

(3) *Expansion of scientific survey and research*
Japan has continued to conduct and expand its scientific research on the catch of target species and other marine living resources taken incidentally in this fishery. A number of research vessels have been sent to the fishing grounds since 1984; four vessels conducted research in 1990. The participation of Canadian and US scientists on the Japanese research vessels has been encouraged. Scientists of Japan, Canada and the United States have discussed the relevant research results submitted by Japan to the International North Pacific Fisheries Commission (INPFC) established under the International Convention for the High Seas Fisheries of the North Pacific Ocean (effective 1952).

(4) *Installment of transponders*
From July 1990, under agreements with the USA and Canada, the Government of Japan ordered all squid driftnet fishing vessels to install satellite transmitter equipment (transponders) enabling identification of vessel positions from land on a real time basis. These data are also made available to the Canadian and the US authorities, thus enabling the authorities of the three countries to identify the position of each fishing vessel. In addition to the 1990 scientific observer programme, this enables Canada, the USA and Japan to know the actual location of fishing operations by Japanese fishing vessels. The Japanese enforcement authority can monitor observance of regulations concerning operation areas through the systematic use of this state-of-the-art transponder system and enforcement vessels at sea.

During the 1991 fishing season, the Government of Japan required a mechanical check of the transponders on board each fishing vessel before departure in order to ensure their normal operation during navigation. If a transponder ceases to function normally, the vessel is not allowed to continue fishing.

Large-mesh driftnet fishery
This fishery, which targets on tunas and billfish, has been conducted in Japanese coastal waters for more than 100 years. Expansion of the fishery to the high seas began around the middle of the 1970s. The Government of Japan instituted regulations in 1973 as a means, among other things, of avoiding competition with existing coastal fisheries.

Since August 1989, a vessel registration system has been in force, that requires fishing vessels to submit operation plans before their departure and operation reports after their return. From August 1990, the vessels engaged in large-mesh driftnet fishing on the high seas have been placed under a limited entry licensing system.

Major provisions of the regulations
The main features of the measures implemented under this system are as follows:

(1) limitation of the number of the vessels engaged in the fishery;
(2) geographical and temporal restrictions on the fishing ground (Fig. 2);
(3) prohibition of the retention of anadromous species, cetaceans and fur seals taken incidentally;
(4) prohibition of the transfer of catch at sea;
(5) mandatory display of vessel's name and registration number on its hull to facilitate identification of the vessel at sea;
(6) mandatory marking of fishing gear for identification;
(7) restrictions on mesh size for stock conservation; and
(8) mandatory submission of catch reports to the Government.

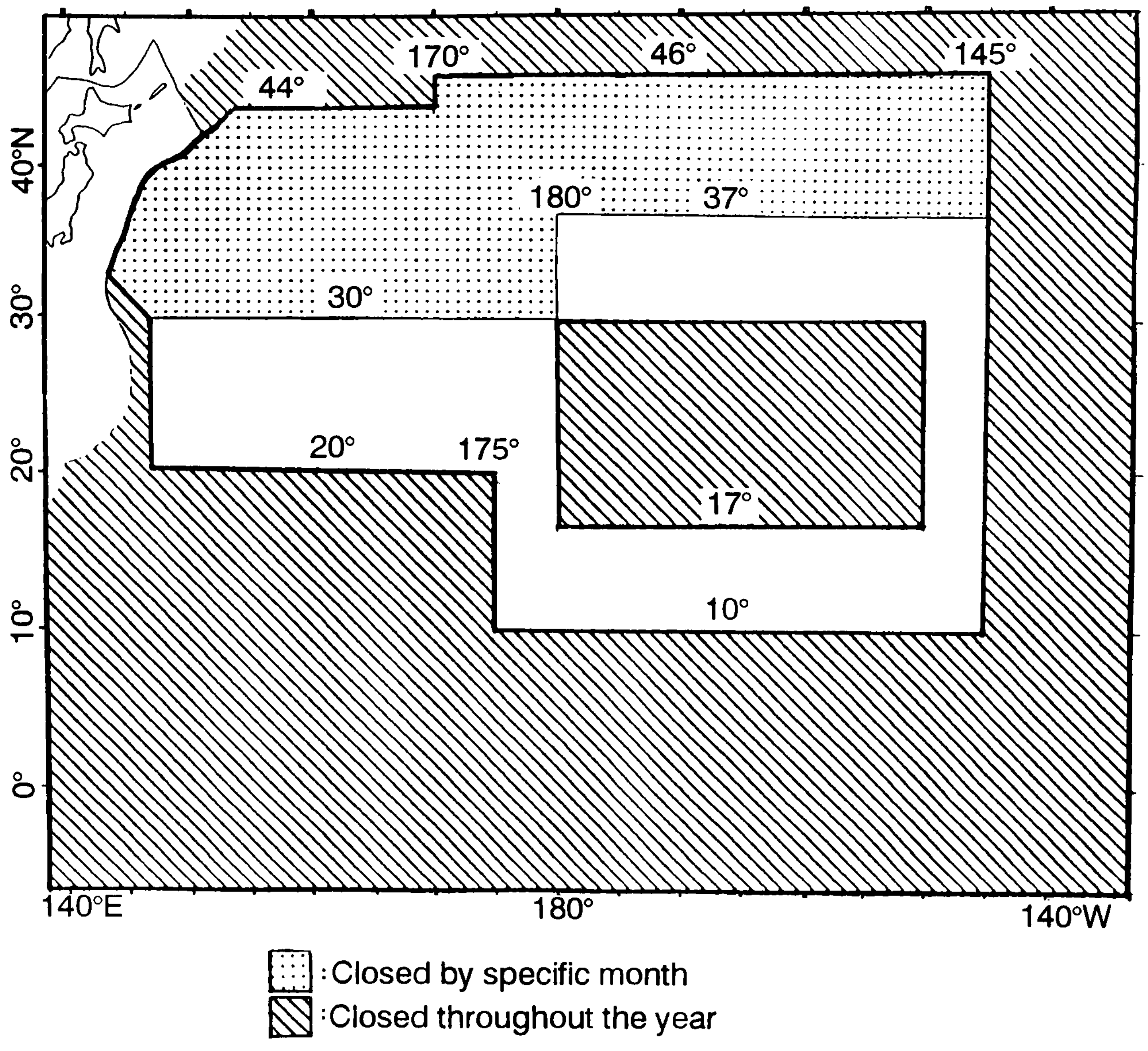

Fig. 2. North Pacific fishing grounds for high-seas large-mesh driftnet fishery.

Measures consistent with the 1989 UN Resolution

(1) *Large-mesh driftnet fishing on the high seas of the North Pacific*

(A) RESTRICTIONS ON THE SCALE OR OPERATIONS AND THE PROHIBITION OF EXPANSION

From August 1990, a limited entry licensing system was introduced. For the period from August 1990 to June 1991, the Fisheries Agency set an upper limit on the number of licensed fishing vessels of 149; 70 licenses were issued.

(B) COLLECTION AND EXCHANGE OF SCIENTIFIC DATA

From 1990, in accordance with agreements with the USA, a joint scientific observer programme for this fishery was initiated. Under this programme, 24 large-mesh driftnet vessel cruises were observed during the 1990/1991 fishing season.

(C) EXPANSION OF SCIENTIFIC SURVEYS AND RESEARCH

In the summer of 1989, the Fisheries Agency conducted a scientific research survey with the participation of a US scientist. Early in 1991, another research vessel was sent to the fishing ground (Fisheries Agency of Japan, 1991; Nakano *et al.*, 1993).

(D) INSTALLMENT OF TRANSPONDERS

From October 1990, in accordance with an agreement with the USA, the Government of Japan ordered all the fishing vessels engaging in this high seas large-mesh driftnet fishery to install transponders enabling the identification of vessel positions on a real time basis.

(2) *Large-mesh driftnet fishing in the South Pacific*

In accordance with the UN Resolution and with due attention to regional characteristics embodied in the Resolution, Japan suspended driftnet fishing in the South Pacific one year in advance of the 1 July 1991 date of cessation stipulated in the UN Resolution.

Japan took this decision taking into account, in particular, the serious concerns of the South Pacific Island countries over driftnet fishing in the region. These countries, whose economic base depends, to a large extent, on marine resources, have strong intentions of developing the albacore fishery for their own economic benefit.

The above measures will be continued until such time as appropriate conservation and management arrangements for South Pacific albacore tuna resources as referred to in the UN Resolution are entered into and appropriate regulatory measures for driftnet fishing are established under such arrangements by the parties concerned.

(3) *Large-mesh driftnet fishing in other areas*

In accordance with the UN Resolution, the Government of Japan took measures (effective 15 August 1990) prohibiting large-mesh driftnet fishing in all waters other than the Pacific Ocean.

Measures consistent with the 1991 UN resolution

The Government of Japan decided not to issue licenses for large-scale pelagic driftnet fisheries on or after 1 January 1993 to implement UN General Assembly resolution 46/215.

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SC/O90/G52

The Japanese Large-Mesh Driftnet Fishery in the Pacific Ocean

Yoh Watanabe

National Research Institute of Far Seas Fisheries, 5–7–1 Orido 5 Chome, Shimizu, Shizuoka 424, Japan

ABSTRACT

The Japanese large-mesh driftnet fishery started in the 19th century in the coastal waters of Japan. The modern large-mesh driftnet fishery began in 1970 and gradually expanded to offshore North Pacific waters. By 1983, it had reached the South Pacific. In 1973, the Government of Japan initiated regulations for this fishery. In 1990, responding to a United Nations resolution, the Government introduced a limited entry system for the high seas North Pacific driftnet fishery and prohibited such operations in all other high seas waters. The number of large-mesh driftnet vessels in 1988 was 459. Most vessels have multiple-type fishing licences. The total annual catch in 1983–88 ranged from 25,000 to 40,000 tonnes. Albacore is the main target species, accounting for about 30% of the total. Skipjack and billfish are also targeted. One panel of net ('tan') ranges from 32–54m in length and from 9–10m in depth. Mesh size varies between 151 and 210mm, with 170–180mm being the most common for albacore. The nets are constructed of nylon multistranded monofilament or nylon multifilament. The nets are set before sunset and hauling begins at midnight. The number of net panels used varies, from a few hundred for small vessels to 1,000–1,300 for large vessels. In the North Pacific, the fishing season lasts all year, with a peak from February to April. In the South Pacific, the fishery operated only during the austral summer. The fishing grounds have included a broad region extending from the Japanese 200-mile limit to north of Hawaii in the North Pacific and the Tasman Sea and waters east of New Zealand in the South Pacific. Driftnet surveys by research vessels in the North Pacific recorded bycatches of several cetacean species, including striped dolphins, common dolphins and northern right whale dolphins. The Japan Marine Fishery Resource Research Centre carried out experiments aimed at reducing bycatches by using subsurface driftnets in the South Pacific and obtained positive results. Japan, the USA and Canada agreed to initiate a joint scientific observer programme to collect biological information on the Japanese large-mesh fishery in the North Pacific during the 1990 fishing season. The Government of Japan decided not to issue licenses for large-scale pelagic fisheries on or after 1 January 1993 in response to the 1991 UN Resolution.

KEYWORDS: INCIDENTAL CAPTURE; NORTH PACIFIC; SOUTH PACIFIC; SWORDFISH; STRIPED MARLIN; BLUE MARLIN; SHORTBILL SPEARFISH; BLUEFIN TUNA; ALBACORE; BIGEYE TUNA; YELLOWFIN TUNA; SKIPJACK; SALMON SHARK; POMFRET; SLENDER TUNA; NORTHERN RIGHT WHALE DOLPHIN; COMMON DOLPHIN; PACIFIC WHITE-SIDED DOLPHIN; STRIPED DOLPHIN; BOTTLENOSE DOLPHIN; RISSO'S DOLPHIN; PANTROPICAL SPOTTED DOLPHIN; PYGMY KILLER WHALE; SHORT-FINNED PILOT WHALE; FALSE KILLER WHALE; PYGMY SPERM WHALE; SOUTHERN BOTTLENOSE WHALE; ARNOUX'S BEAKED WHALE; ZIPHIIDAE

INTRODUCTION

The Japanese large-mesh driftnet fishery, called *oome-ami* or *oome-nagasiami* and officially registered as the 'marlin and others drift gillnet fishery', is one of two large-scale Japanese driftnet fisheries; the other is the squid driftnet fishery. Until August 1989, the large-mesh fishery operated under a free-entry system regulated by the Government of Japan. Since that time, the system has changed to a registration system for vessels larger than 10 gross tonnes (GRT). These vessels are required to submit operational schedules, catch-and-effort statistics and other information. The Government applied a limited entry system outside the Japanese 200-mile fishing zone in August 1990 (Nagao, 1994). In response to UN General Assembly Resolution 46/215, the Government decided not to issue licenses for lage scale pelagic driftnet fisheries on or after 1 January 1993.

DESCRIPTION OF THE FISHERY

History of development and current trends

The fishery has a long history, dating back more than 100 years. A prototype fishery using driftnets to catch bluefin tuna began off the Pacific coast of Japan in the 1840s. In those days fishing vessels were small and limited their operations to coastal waters (Kando, 1990). The modern large-mesh fishery developed during the 1970s. During this period, the main fishing grounds were off Sanriku District and off the Boso Peninsula (Sasaki, 1974). The fishing area was extended to include other coastal as well as offshore waters of Japan. The number of targeted species also expanded to include marlins, swordfish and other species of tuna. In the early 1980s in a quest for albacore, the vessels increased in size and the fishing grounds expanded to the east in the North Pacific. In 1982, total catch of this fishery was over 40,000 metric tonnes (Table 1). Because of a desire to operate year round, 17 driftnetters entered the high seas areas of the South Pacific in the 1983/84 southern summer season to search for new fishing grounds. Subsequently, about 20 vessels operated in the South Pacific each summer until 1988/89, when 64 Japanese driftnetters and approximately the same number of Taiwanese fishing vessels fished in the region. At the same time and in the same region, the USA and New Zealand rapidly increased their troll catches of albacore. The South Pacific nations were concerned about the condition of the albacore stock and the impacts of the driftnet fishery on the marine ecosystem. Owing to this concern, the Japanese Government limited the number of driftnetters in the region to 19 in the 1989/90 season and ended the fishery completely before the 1990/91 season.

Vessels and crew

The numbers of vessels operating in the fishery from 1973 to 1988 are shown in Table 1. These numbers exclude small vessels (<10GRT) which operate only in the coastal waters of Japan. Following the 1978–1982 increase, the number of vessels gradually dropped, from 717 in 1982 to 459 in 1988. Table 2 shows the number of vessels by size and the types of fishing licenses held in 1988. Most vessels over 50 GRT had multiple licenses, e.g., squid driftnet, salmon driftnet, etc. Vessels operating large-mesh nets throughout the year comprised less than 10% of the total.

The number of crewmen per vessel is less than 20, with 15–16 being typical for a large vessel (over 200 GRT) operating on the high seas.

Gear

Fig. 1 shows the general specifications of a Japanese large-mesh driftnet. The length of one panel or 'tan' (the minimum unit) ranged from 32–54m in length after shrinkage and from 9–10m in stretched depth (6–7m fishing depth). Mesh size varied among vessels and according to the target species, from 151–210mm stretched mesh (for albacore, mesh of 170–180mm was commonly used and for marlin, 200mm). The number of vessels by mesh size is shown in Table 3. Large mesh (over 190mm) was common for vessels of less than 200 GRT. Net shrinkage in the water ranged from 50–60%. The nets were constructed of the recently developed nylon multi-stranded monofilament or nylon multifilament. About 100 'tan' linked together formed a section, or *hari*. Various numbers of these sections, usually less than 10, were deployed unconnected to each other in a single operation. Each section was equipped with a radio buoy and a light buoy at the hauling end and an orange buoy at the terminal end. The amount of net used varied with the size of the vessel; 1,000–1,300 'tan' were used by large vessels working on the high seas, whereas a few hundred were used by vessels of less than 50 GRT.

Operations

Setting of the net usually began in the afternoon and was completed before sunset. This took 2–4 hours. The net was cast from the stern. Retrieval started at midnight and was completed in the morning. The nets, therefore, were deployed at the surface (surface to 6–7m) for about 5–15 hours. The entire set was usually made in a straight line, with each *hari* separated from its neighbours by a gap of about 50–200m. Sometimes the nets were set in a curved line due to bad weather, direction of currents, adjacent operations by other vessels, etc. Typical sea-surface temperatures were 15–23°C; 18–19° is most suitable for albacore.

The duration of a trip depended on the size of the vessel and the distance to the fishing grounds. The number of trips during a year is shown in Table 4. A trip commonly lasted 20–40 days for a 100 GRT vessel and 40–140 for a vessel of more than 200 GRT. The average number of trips, travelling days and operating days for vessels of over 200 GRT are shown in Table 5. Most large vessels spent one trip per year in the large-mesh fishery.

Areas and seasons of operations

Fig. 2 shows the fishing grounds by quarter of the year. In January the fishery began off Japan and gradually extended to the east. In February and March, the grounds extended into the area north of the Hawaiian Islands. Skipjack was the main catch in this quarter. Then the grounds shifted westwards for albacore. Most large vessels changed to squid driftnetting in May, when squid landings were the largest of the year (Table 6). The fishing grounds off Japan are occupied by mid- and small-sized vessels from June to December. Some large vessels (>200 GRT) formerly went to the South Pacific grounds in November or December after the squid season, to catch albacore during the austral summer.

Table 1

Catches of Japanese large-mesh driftnet fishery, in metric tonnes by species, 1973-1988 (compiled from landing reports submitted by prefectures).

Year	No. of boats	Catches in metric tonnes					
		Marlin	Tuna	Albacore	Skipjack	Others	Total
1973	501	5,239	220		429	2,595	8,483
1974	380	5,079	587		370	2,022	8,057
1975	351	11,432	780		469	2,711	15,394
1976	396	8,912	2,168		708	5,019	16,807
1977	314	8,851	2,558		1,377	5,937	18,723
1978	292	10,050	6,582		1,965	6,904	25,501
1979	394	4,986	5,388		1,014	12,683	24,071
1980	457	8,050	6,049		1,273	17,777	33,149
1981	559	7,524	17,585	16,825	2,828	5,601	33,537
1982	717	4,603	19,079	17,217	7,940	12,884	44,505
1993	620	4,587	10,123	8,307	5,883	17,294	37,887
1984	547	4,216	12,086	10,776	6,810	10,638	33,750
1985	470	6,259	14,939	12,894	4,521	5,921	31,640
1986	474	8,301	12,184	7,269	8,785	7,200	36,469
1987	460	4,532	8,006	7,221	7,733	4,798	25,070
1988	459	5,124	15,623	15,132	13,038	6,299	40,083

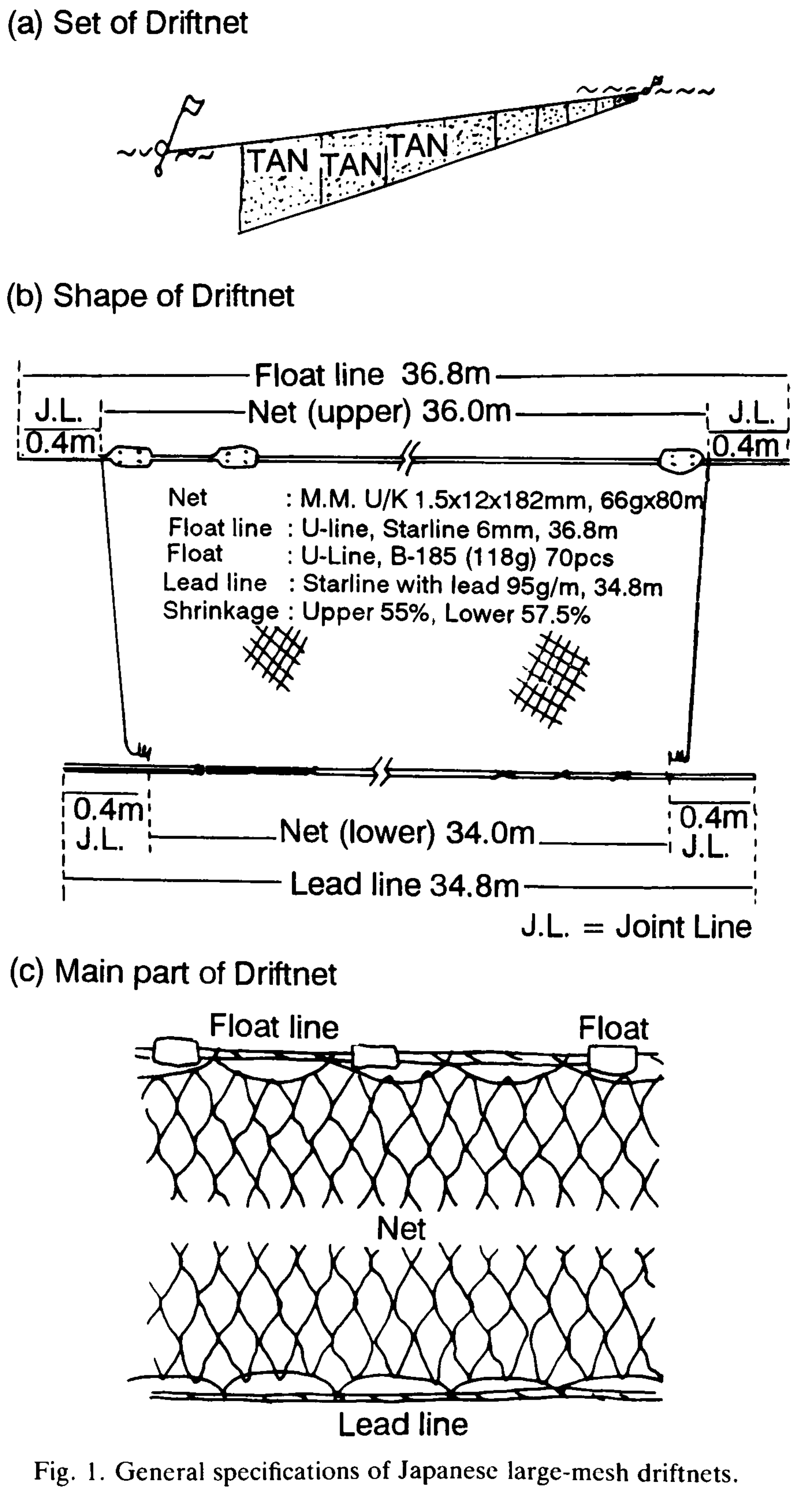

Fig. 1. General specifications of Japanese large-mesh driftnets.

Table 2

Number of large-mesh driftnet fishing vessels by size and kinds and number of fishing licenses held by large-mesh fishing vessels in 1988 (compiled from landing reports submitted by prefectures).

Size of vessel (GRT)	10-49	50-99	100-199	200-299	300-399	400-499	Total
No. of large-mesh driftnet vessels registered	134	74	133	55	38	25	459
Kinds of fishing licenses:							
Squid drift gillnet	**	39	58	47	32	21	197
Salmon drift gillnet	**	36	58	-	-	-	94
Tuna longline and pole-and-line	**	20	55	2	-	-	77
Saury stick-held dip net	**	28	63	-	-	-	91
Squid angling	**	9	15	1	2	8	35
NPO long line and gillnet*	**	-	-	1	1	4	6
Off-shore trawl	**	1	4	-	-	-	5
Others	**	1	1	2	-	-	4
Sub-total	**	134	254	53	35	33	509

* North Pacific Ocean longline and gillnet.
** No information.

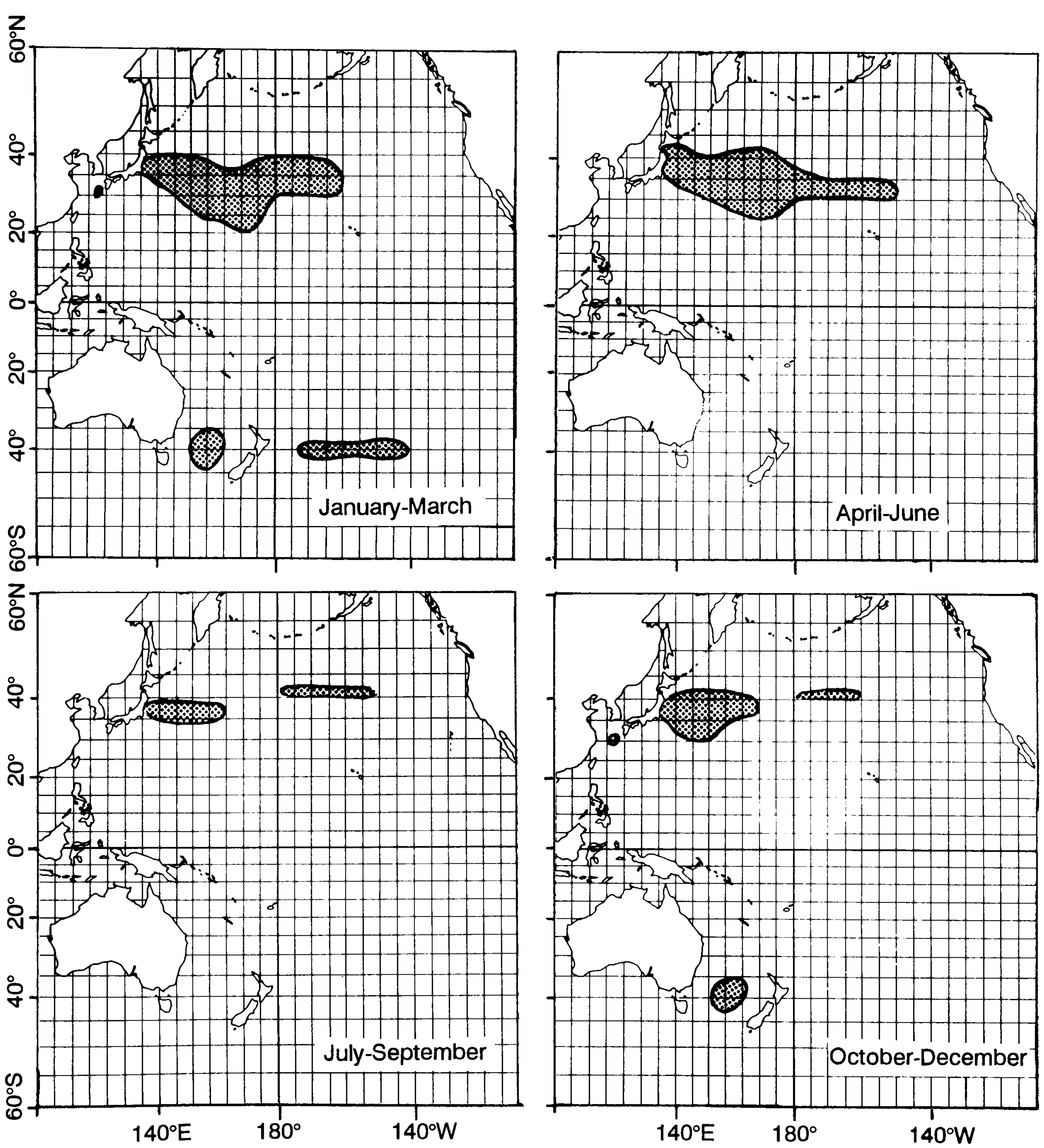

Fig. 2. Quarterly distribution of fishing grounds for the Japanese large-mesh driftnet fishery in 1988.

Table 3

Number of fishing boats by mesh size used and GRT in 1988 (compiled from landing reports submitted by prefectures).

Mesh size (mm)/ Size of boat (GRT)	151-155	156-160	161-165	166-170	171-175	176-180	181-185	186-190	191-195	196-200	201-	n.d.
50-99	6	4	3	3	1	36	3	2		1	7	8
100-199	8	9	9	11	2	66	7	3	3	2		13
200-299	2	4	4	12	1	20	5					7
300-399	2	1	4	4	1	17	1	2				6
400-499	5	2	2	3		7	3				1	2
Total	23	20	22	33	5	146	19	7	3	3	8	36

Table 4

Number of fishing boats by length of voyage and GRT in 1988 (compiled from landing reports submitted by prefectures).

Voyage days/ Size of boat (GRT)	-20	21-40	41-60	61-80	81-100	101-120	121-140	141-
50- 99	25	23	12	4	3	1	1	4
100-199	46	57	16	8	1	3		2
200-299	2	4	13	13	4	4	6	8
300-399	4	8	3	6	7	1	1	8
400-499	2	10	5	2	4		1	1

Table 5

Mean effort of fishing boats (over 50GRT), 1981-1988 (compiled from landing reports submitted by prefectures).

	Per boat			Per trip	
Year	No. of trip	Trip day	Operation day	Trip day	Operation day
1981	2.8	72.8	46.0	26.2	16.6
1982	2.0	67.9	42.2	34.7	21.6
1983	1.6	53.8	34.0	33.7	21.3
1984	1.6	50.9	32.0	31.1	19.5
1985	1.7	50.0	32.1	29.5	18.9
1986	1.8	52.1	33.5	28.8	18.5
1987	1.9	51.3	32.5	27.2	17.2
1988	1.9	53.1	34.1	27.4	17.5

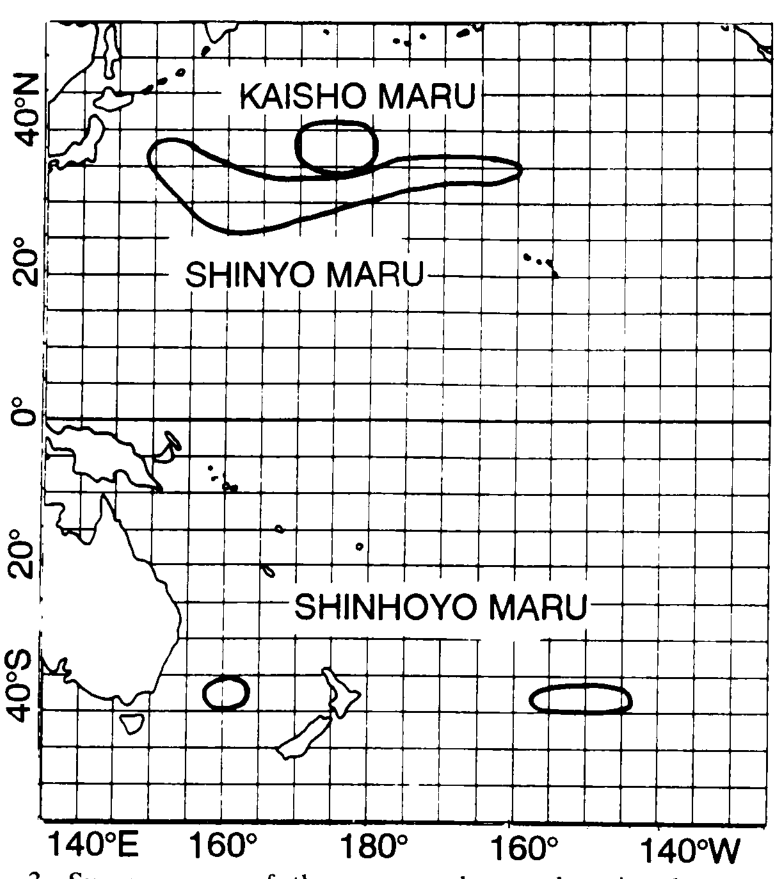

Fig. 3. Survey areas of three research vessels using large-mesh driftnets (Data presented in Table 9).

Target species

The target species have changed over time. In the first period, when the fleet operated near Japan, marlins and swordfish were targeted, with a mesh size of about 200mm. In the early 1980s, with the expansion of the fishery, the emphasis changed to albacore. More recently, the catch of skipjack was about the same as that of albacore (Table 1). Table 7 shows examples of the species composition of catches. The albacore catch in the South Pacific was relatively higher than in the North Pacific, whereas the reverse was true for skipjack.

Total landings and ports

Annual catches are shown in Table 1. These data were compiled using landing reports submitted to the Fisheries Agency of Japan (FAJ) by the prefectures where the vessels landed their catches. Some catches by vessels of less than 10 GRT may be included in these statistics. The total annual catch ranged from 25,000 to 40,000 tonnes in the 1980s; the albacore component fluctuated between 7,200 and 17,200 tonnes.

Landings at the major ports in 1988 are shown in Table 8. Fish caught in the East China Sea are landed at Nagasaki.Catches from other regions are landed mainly at ports on the Pacific coast from Hokkaido south to Chiba Prefecture; largest landings are at Kesennuma, Shiogama, Hachinohe and Ishinomaki. The albacore and skipjack are quick-frozen on board and processed into canned products ashore. Catches in coastal waters are iced in the hold and sold as raw fish in the market.

Regulations (*and see Nagao, 1994*)

The Government of Japan introduced certain regulatory measures for the fishery in 1973 by issuing a ministerial ordinance and a notice. These were designed to regulate the fishery and to solve conflicts with other coastal fisheries and with pole-and-line and longline fisheries for tuna and skipjack. In 1982, in order to avoid potential incidental catches of salmon in the North Pacific area closures were implemented, similar to those for the squid driftnet fishery. In addition to these national regulations, various other regulatory measures were implemented by prefectural governments to solve conflicts among coastal fisheries, other driftnet fisheries and this fishery. These regulations included limiting the number of vessels and time area restrictions. In 1989, the Government enforced a new registration system for this fishery which included required submission of catch reports. Responding to the 1989 resolution on high seas large-scale pelagic driftnetting by the United Nations, the Government introduced a limited entry system for this fishery on the high seas of the North Pacific in order to strengthen control and to gather scientific information. The number of licensed vessels was reduced from previous seasons. The fishery was prohibited in high seas waters other than in the North Pacific from August 1990. In August 1990, the Government prohibited retention and landing of cetaceans, even those taken incidentally in driftnets. Finally, in response to the 1991 UN Resolution, the Government stopped large-scale driftnet fishing after January 1993.

Cetacean bycatches

Survey cruises

It is known that cetaceans are incidentally caught in driftnets. Following a request by the Japanese Government, some of the fishermen in the large-mesh fishery volunteered to submit bycatch reports. However, the severe problems of species identification for both seabirds and cetaceans in these data make them unsuitable for scientific analysis. Therefore, in this paper, data from survey cruises conducted by two organisations using large-mesh driftnets on the commercial fishing grounds (Fig. 3 and Table 9) are considered. The Japan Marine Fishery Resource Research Centre (JAMARC) collected catch and by-catch data for two fishing surveys in the North and South Pacific. In the North Pacific, a total of 186 surveys for a Pacific pomfret assessment were conducted in a large area from 22–47°N and 148°E-133°W from April 1982 to February 1983. The analysis here is limited to the 51 surveys carried out in the area of the commercial fishery during the fishing season. Nine species of cetaceans were incidentally caught during these surveys: striped dolphins (*Stenella coeruleoalba*), northern right whale dolphins (*Lissodelphis borealis*) and common dolphins (*Delphinus delphis*) made up 37%, 29% and 21% of the total, respectively. Most of the entangled cetaceans suffocated, but two unidentified medium-sized whales escaped during net hauling near the vessel. In addition, a southern bottlenose whale (*Hyperoodon planifrons*) was cut free from the net by the crew but probably did not survive, because it sank with the net wrapped around it.

In 1989, the FAJ conducted a survey cruise with a chartered large-mesh driftnetter in the North Pacific. One Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) and an adult female pygmy sperm whale (*Kogia breviceps*) and calf were captured and died during this survey (Table 9). Bycatches in the driftnet fisheries in the North Pacific are more fully discussed in Hobbs and Jones (1993).

Experiments to reduce entanglement

JAMARC carried out an exploratory cruise with a driftnet research vessel in the South Pacific from November 1989 to March 1990. During this cruise, 42 experimental operations were carried out using standard surface nets and subsurface nets (2m below the surface) in order to determine whether a subsurface net would allow cetaceans to pass and reduce their entanglement. The results of these experiments are shown in Table 10. The CPUE (fish per 1,000 'tan') for was higher for albacore for the subsurface net but lower for skipjack. About one tenth as many cetaceans were caught in the subsurface nets as in the surface nets. No turtles or seabirds were caught in the subsurface nets. Following these encouraging results, seven Japanese commercial squid driftnetters used the subsurface net in the North Pacific in 1990 (Hayase and Watanabe, 1990). However, the search to find gear and practices that retain the benefits of driftnets to the fishermen but reduce bycatches remains (e.g. Dawson, 1994; Goodson *et al.*, 1994; IWC, 1994).

Table 6

Monthly landing by species in 1988 (compiled from landing reports submitted by prefectures).

	Catches in metric tonnes					
Month	Marlin	Tuna	Albacore	Skipjack	Others	Total
January	82	387	348	77	128	675
February	264	2,965	2,924	345	208	3,780
March	474	2,162	2,109	746	455	3,837
April	713	1,427	1,369	4,261	1,666	8,067
May	691	2,609	2,549	4,633	1,439	9,372
June	108	2,976	2,866	831	677	4,592
July	387	1,342	1,293	252	320	2,301
August	865	315	276	371	363	1,914
September	628	219	204	350	211	1,408
October	426	269	261	256	203	1,154
November	344	513	506	702	472	2,030
December	144	439	427	214	157	953
Total	5,124	15,623	15,132	13,038	6,299	40,083

Table 7

Species composition of catches by four Japanese large-mesh driftnetters operating in the Pacific Ocean, 1989-1990.

Area:	North Pacific						South Pacific	
Sample boat	A		B		C		D	
(GRT)	(299)		(274)		(200)		(443)	
Fishing ground	29-32N 165E-164W		29-31N 158-177E		29-32N 149-162E		Tasman Sea	
Period of operation	Jan-Apr 1990		Feb-Apr 1990		Apr 1990		Dec 1989-Feb 1990	
Species	No. %	Wt. %	No. %	Wt. %	No. %	Wt. %	No. %	Wt. %
Swordfish	0.4	5.7	1.9	16.7	0.1	0.3	0.1	1.4
Striped marlin	0.4	4.4	0.1	1.1	0.3	3.1	0.1	2.3
Blue marlin	0.0	0.8	0.0	0.1			0.0	0.5
Shortbill spearfish			0.2	0.3			0.2	0.5
Bluefin tuna	0.0	0.0						
Albacore	6.7	7.8	8.5	12.3	8.2	12.1	60.1	65.0
Bigeye tuna	0.1	0.3	0.2	0.6	0.2	0.6	0.0	0.0
Yellowfin tuna	0.0	0.3	0.1	0.2	0.1	0.0	0.0	0.1
Skipjack	53.1	33.3	66.6	48.7	24.8	24.4	39.4	29.4
Salmon shark	0.1	0.7	0.0	0.0			0.1	0.7
Pomfret	39.2	26.5			25.7	n.d.		
Slender tuna							n.d.	0.2
Others	n.d.	20.1	21.8	19.3	39.8	59.5		
No. of fish	30,159		27,443		1,684		61,608	
Catches (kg)	189,397		160,386		6,030		342,381	

Table 8

Landings in metric tonne by species, by main driftnet landing port in 1988. This Table was compiled by landing reports submitted from prefectures and only includes those ports with landings of over 100 tonnes.

		Catches in metric tonnes					
Name of prefecture	Name of port	Marlin	Tuna	Albacore	Skipjack	Others	Total
Hokkaido	Kushiro	237	702	554	631	306	1,876
	Tokachi	99	0	0	37	42	177
	Hakodate	74	861	861	676	188	1,799
Aomori	Hachinohe	191	1,851	1,822	1,514	413	3,969
Iwate	Miyako	313	80	66	68	175	636
	Kamaishi	115	159	124	60	80	414
	Yagi	53	346	341	262	87	748
Miyagi	Kesennuma	1,939	3,201	3,154	4,929	2,330	12,399
	Onagawa	197	761	749	752	360	2,071
	Ishinomaki	261	1,547	1,522	1,130	431	3,369
	Shiogama	1,058	4,775	4,718	2,274	1,284	9,391
Fukushima	Ena	57	182	178	254	58	551
	Onahama	51	703	687	149	75	977
	Nakanosaku	6	201	200	149	35	392
Chiba	Choshi	198	149	52	109	375	831
Nagasaki	Nagasaki	230	0	0	15	2	246
Total catch (tonnes)		5,124	15,623	15,132	13,038	6,299	40,083
Total amount (million Japanese yen)		2,985	3,464	3,207	1,668	1,248	9,366

Table 9

Occurrences of cetaceans taken by large mesh driftnet survey cruises in the Pacific Ocean.

Area:	North Pacific		South Pacific
Type of survey	Pacific pomfret resources survey	Driftnet fishery survey	Driftnet new fishing ground
Name of vessel	*Shinyo maru*	*Kaisho maru*	*Shinhoyo maru*
Organiser	JAMARC	FAJ	JAMARC
Period	Apr 1982-Feb 1983	July 1989	Nov 1989-Mar 1990
Survey area	26-39N 148E-160W	35-40N 172-178E	34-39S 155E-144W
Surface water temperature	14-22C	15-25C	18-21C
Mesh size (mm)	150,160,170,180	180	178
Number of operations	51	15	75
Number of net (tan)	42,059	4,200	66,538
Species			
Northern right whale dolphin	22	-	-
Common dolphin	16	-	97
Pacific white-sided dolphin	1	1	-
Striped dolphin	28	-	17
Bottlenose dolphin	1	-	3
Risso's dolphin	4	-	-
Pantropical spotted dolphin	2	-	-
Pygmy killer whale	1	-	-
Short-finned pilot whale	-	-	1
False killer whale	-	-	1
Pygmy sperm whale	-	2	-
Southern bottlenose whale	-	-	2
Arnoux's beaked whale	-	-	1
Ziphiidae	1	-	-
Unidentified whale (medium sized)	-	-	2
Total	76	3	124

Table 10

Results of bycatch reduction experiment by JAMARC, November 1989 - March 1990, Tasman Sea. CPUE: No. of fish/1,000 tans.

Type	Standard surface		Experiment subsurface	
No. of operations	42		42	
Total net used (tan)	57,940		6,898	
	No.	CPUE	No.	CPUE
Albacore	30,917	534	4,446	645
Skipjack	13,282	229	772	112
Swordfish	104	2	15	2
Striped marlin	33	1	3	0
Blue shark	229	4	28	4
Mako shark	104	2	14	2
Dolphin and whale	123	2	1	0
Sea turtles	4	0	0	
Sea birds	4	0	0	

IMPACT OF DRIFTNET CATCHES ON MARINE RESOURCES

North Pacific

Albacore

This stock has been fished by various surface fisheries, including pole-and-line fishing, trolling, longlining and driftnetting. Only in recent years have concerns about the status of the stock been expressed. The North Pacific Albacore Workshop held in 1989 recognised that the stock is in poorer condition than was previously thought (Bartoo and Watanabe, 1989). Because the total catch by large-mesh and squid driftnet fisheries by Japan, Korea and Taiwan is assumed to have been higher than the catch by other surface fisheries (i.e. the Japanese pole-and-line fishery and the US troll fishery), fishing mortality from the driftnet fisheries is expected to have had an impact. However, the actual impact is not yet known, partly due to incomplete catch and effort statistics. Japanese and US scientists are undertaking a joint stock assessment that will take into account the driftnet fisheries.

Skipjack and bluefin tuna

Driftnet catches for these species are small compared with those of the pole-and-line and purse seine fisheries and thus the impact of the driftnet catches should be small.

Marlins and swordfish

The North Pacific stock of striped marlin has been fished by longline and driftnet. The driftnet share has been increasing, and became comparable with the longline share after the mid-1980s. Suzuki (1989) inferred that the overall fishing impact on the northern stock has not been high enough to be a dominant factor in changing stock size. Swordfish are captured more by longline than by driftnet. The Pacific swordfish stock is thought to be relatively healthy (Bartoo and Coan, 1989) and thus the driftnet fishery appears to have had no appreciable impact on the population size.

Marine mammals

In the 1980s there was little information on the population size and general biology of most species of marine mammals affected and the size of the incidental catches that the impact of the driftnet fishery on these species is difficult to quantify. As noted above, in surveys using large-mesh driftnets several species of cetaceans were caught and killed. Thus, it was reasonable to expect that the stocks of marine mammals were affected by the fishery. Under agreements for observation of the Japanese driftnet operations, Japan, the USA and Canada began collecting by-catch information in the large-mesh fishery during the 1990 season. Scientific observers were deployed on 24 vessels from September 1990 to April 1991. These and other data are discussed in Hobbs and Jones (1993) who found that the northern right whale dolphin (*Lissodelphis borealis*) appeared to be the most depleted cetacean species.

Seabirds

There is almost no documented information on incidental catches of seabirds by large-mesh driftnets. According to the results of interviews of fishermen by the author, the catches are smaller than in squid driftnetting. The above-mentioned cooperative observer programme will also collect data on bird catches.

South Pacific

Albacore

Catches of southern-stock albacore by Asian large-mesh driftnetters increased greatly in the 1988/89 season but decreased drastically in the following season. The 1989/90 catch was about the same as the combined US-New Zealand troller catch. Due to the lack of biological information and incomplete statistics, there have been no assessments of the impact of driftnet fishing on the stock. The National Research Institute of Far Seas Fisheries (NRIFSF) carried out a scientific survey of albacore drop-out during net retrieval in driftnet operations in the Tasman Sea in November-December 1989. The drop-out ratio was 7.3% (Watanabe, 1990).

Skipjack

Catches are so small that the impact must be negligible.

Southern bluefin tuna

There have been no records of catch of this species in driftnet operations in the Tasman Sea. In the waters east of New Zealand, large bluefin tuna were caught sporadically. The catches by other than Japanese driftnets are unknown. It is thus not possible to assess the impact of the driftnet fisheries on this species.

Marlins and swordfish

Driftnet catches have been very small compared with longline catches and probably have negligible impact.

Marine mammals

Especially high mortality of cetaceans was recorded by the JAMARC survey in the Tasman Sea (Table 10). Japan suspended its fishery there from the 1990/91 season.

Seabirds

According to the JAMARC survey, incidental catch of seabirds was quite small. The impact is likely less than that of longline fisheries and takes by New Zealand and Australian native peoples.

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A Brief Review of Stock Identity in Small Marine Cetaceans in Relation to Assessment of Driftnet Mortality in the North Pacific[1]

William F. Perrin and Robert L. Brownell, Jr.
Southwest Fisheries Science Center, La Jolla, California, USA

ABSTRACT

Dolphins of several species are killed incidentally in driftnet fisheries on the high seas in the North Pacific. Information on stock identity, necessary for assessment and management of the dolphin populations, is lacking. The review of such information for other species and populations for which it is available indicates that further research may uncover stock divisions in the fishery region, although uniformity of habitat over the large region can be construed to suggest that such divisions may be absent.

KEYWORDS: REVIEW; STOCK IDENTITY; SMALL CETACEANS-GENERAL; MANAGEMENT; FRANCISCANA; WHITE WHALE; NARWHAL; HARBOUR PORPOISE; VAQUITA; FINLESS PORPOISE; INDO-PACIFIC HUMP-BACKED DOLPHIN; TUCUXI; DUSKY DOLPHIN; PACIFIC WHITE-SIDED DOLPHIN; WHITE-BEAKED DOLPHIN; ATLANTIC WHITE-SIDED DOLPHIN; BOTTLENOSE DOLPHIN; ATLANTIC SPOTTED DOLPHIN; PANTROPICAL SPOTTED DOLPHIN; SPINNER DOLPHIN; STRIPED DOLPHIN; COMMON DOLPHIN; IRRAWADDY DOLPHIN; COMMERSON'S DOLPHIN; FALSE KILLER WHALE; KILLER WHALE; LONG-FINNED PILOT WHALE; SHORT-FINNED PILOT WHALE; BAIRD'S BEAKED WHALE

INTRODUCTION

The several pelagic driftnet fisheries in the North Pacific kill small cetaceans incidentally (Northridge, 1991; INPFC, 1992a; b; IWC, 1992; Jones *et al.*, 1992; Hobbs and Jones, 1993). The major species in this bycatch are the northern right whale dolphin (*Lissodelphis borealis*), striped dolphin (*Stenella coeruleoalba*), common dolphin (*Delphinus delphis*), Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) and Dall's porpoise (*Phocoenoides dalli*). Several other species are taken in relatively small numbers. In order to assess the impact of these kills, the stocks involved must be identified, or, lacking that, some judgement must be made about how far to divide up the range of the species for purposes of management. However, little or nothing is known about the stock structure or even the distribution of most of the species in the region. The purpose of this brief review is to summarise what is known about the stock identity of small marine cetaceans in the North Pacific and in other regions, and to use this to attempt to deduce hypotheses for the likely stock structure of the affected species in the areas of the driftnet fisheries.

The term 'stock' is defined here to mean any existing or potential management unit comprised of a single breeding population and includes entities recognised as subspecies, geographical forms or isolated populations (the assumption being that geographic isolation implies some degree of genetic isolation).

In this paper we do not attempt to review the rationale or analyses upon which the decisions for stock identity were based. Such a review, along the lines suggested by Dizon *et al.* (1992a), is in order but is beyond the scope of this paper.

One or more stocks (in the sense defined above) have been identified for 19 of the 62 small marine cetaceans (Table 1). Information indicating the possible existence of more than one population is available for another seven species. For the remaining thirty-six species nothing is known of geographical variation or stock structure. Species accounts follow for the twenty-six species in the first two categories.

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SPECIES ACCOUNTS

Franciscana (*Pontoporia blainvillei*)

The franciscana inhabits the coastal waters of southern Brazil, Uruguay and northern Argentina. The results of multivariate analyses of skull measurements of specimens stranded or killed in gillnet fisheries indicate that the dolphins from the northern part of the range off Brazil differ slightly from those from farther to the south off southern Brazil, Uruguay and Argentina in cranial proportions (Pinedo, 1991). Whether this means the existence of a morphological cline or separate populations will not be known until material from more intermediate localities has been examined. The overall study is based on several hundred specimens, although the sample of intact adult skulls of known sex is much smaller.

White whale (*Delphinapterus leucas*)

This species lives in subArctic and Arctic waters of North America, Asia and Europe (Klinowska, 1991). Most of the populations migrate between summering and wintering grounds; the summer months are spent in shallow estuaries and near-shore waters and the winter months in deeper coastal and ice-edge waters. Some populations on the periphery of the range at lower latitudes (e.g. the St. Lawrence Estuary in Canada and Cook Inlet in Alaska) are resident year round. Animals from several summering grounds winter in the same area.

The present model used in management in Canada and the USA is that the summering populations represent discrete stocks that mingle with but probably do not breed with animals on the wintering grounds from other summering grounds. This conservative hypothesis (from the perspective of conservation) is supported by a

Table 1

Status of information on stock structure of small marine cetaceans. The three categories used: no information available ('None'); some relevant information available but no stocks identified ('Some'); at least one stock delineated ('Stocks'). The last category includes those species (*Phocoena sinus* and *Cephalorhynchus hectori*) for which there is known to be only a single small and local population.

Species	None	Some	Stocks	Species	None	Some	Stocks
Pontoporia blainvillei		X		*Cephalorhynchus commersonii*			X
Delphinapterus leucas			X	*Cephalorhynchus eutropia*	X		
Monodon monoceros			X	*Cephalorhynchus heavisidii*	X		
Phocoena phocoena			X	*Cephalorhynchus hectori*			X
Phocoena spinipinnis	X			*Peponocephala electra*	X		
Phocoena sinus			X	*Feresa attenuata*	X		
Neophocaena phocaenoides			X	*Pseudorca crassidens*	X		
Australophocaena dioptrica	X			*Orcinus orca*			X
Phocoenoides dalli			X	*Globicephala melas*			X
Steno bredanensis	X			*Globicephala macrorhynchus*			X
Sousa chinensis		X		*Tasmacetus shepherdi*	X		
Sousa teuszii	X			*Berardius bairdii*			X
Sotalia fluviatilis			X	*Berardius arnuxii*	X		
Lagenorhynchus albirostris		X		*Mesoplodon pacificus*	X		
Lagenorhynchus acutus		X		*Mesoplodon bidens*	X		
Lagenorhynchus obscurus			X	*Mesoplodon densirostris*	X		
Lagenorhynchus obliquidens		X		*Mesoplodon europaeus*	X		
Lagenorhynchus cruciger	X			*Mesoplodon layardii*	X		
Lagenorhynchus australis	X			*Mesoplodon hectori*	X		
Grampus griseus	X			*Mesoplodon grayi*	X		
Tursiops truncatus			X	*Mesoplodon stejnegeri*	X		
Stenella frontalis		X		*Mesoplodon bowdoini*	X		
Stenella attenuata			X	*Mesoplodon mirus*	X		
Stenella longirostris			X	*Mesoplodon gingkodens*			
Stenella clymene	X			*Mesoplodon carlhubbsi*	X		
Stenella coeruleoalba			X	*Mesoplodon peruvianus*	X		
Delphinus delphis			X	*Ziphius cavirostris*	X		
Lagenodelphis hosei	X			*Hyperoodon ampullatus*	X		
Lissodelphis borealis	X			*Hyperoodon planifrons*	X		
Lissodelphis peronii	X			*Kogia breviceps*	X		
Orcaella brevirostris		X		*Kogia simus*	X		

traditional use of summering grounds by individual whales and independent responses to exploitation by at least some of the summering populations (IWC, 1980; Finley *et al.*, 1982; Reeves and Mitchell, 1987; Hazard, 1988).

Some morphological differences have been found between white whales from different areas in Canada (Sergeant and Brodie, 1969; Finley *et al.*, 1982), although later comparisons of Russian specimens from different summering grounds did not yield differences (Ognetov, 1981; Ognetov and Potelov, 1982). Doidge (1991) confirmed the existence of size differences between whales from Hudson Bay and those from Alaska, West Greenland, the St. Lawrence River and the MacKenzie Delta. The morphological studies were based on several hundred specimens.

Preliminary results of the use of mitochondrial DNA markers to distinguish white whale stocks indicate that whales in eastern Hudson Bay are distinct from those in the Mackenzie Delta and also suggest that they are distinct from those in western Hudson Bay, Cumberland Sound and Jones Sound (Helbig *et al.*, 1989). These studies are continuing.

Frost and Lowry (1991), on distributional grounds, recognised three provisional stocks in western Alaska and one shared with Canada. Seven stocks are provisionally recognised in Canada and five in Russia (IWC, 1992).

Although much remains to be done in delineating the populations, and opinions have changed as more data were collected, at least 16 stocks have been provisionally recognised (Reeves and Mitchell, 1987; Hazard, 1988; Helbig *et al.*, 1989; Richard *et al.*, 1990; Frost and Lowry, 1991; Klinowska, 1991; IWC, 1992).

Narwhal (*Monodon monoceros*)

Stock divisions for this Arctic species have been based on distribution and migration; no morphological or genetic studies have been carried out, and it is not known if there is site fidelity. Three stocks were tentatively recognised in 1980 (IWC, 1980; Klinowska, 1991): Davis Strait-Baffin Bay, Foxe Basin and East Greenland-Spitzbergen. The affinities of animals in northwestern European and eastern Siberian waters are unknown. More recently, within the overall aggregation that winters in Davis Strait-Baffin Bay, the Canadian Government has recognised three management units: one summering in northwest Greenland, one in northwestern Hudson Bay, and one in the Canadian High Arctic (Strong, 1988).

Harbour porpoise (*Phocoena phocoena*)

The harbour porpoise is primarily a coastal species, although recent surveys have revealed that it is more common in offshore waters than previously believed (IWC, 1990). It inhabits the temperate coastal waters of Europe, West Africa, North America and Asia and the Black Sea (Klinowska, 1991).

The Black Sea population is totally isolated (Gaskin, 1984), but stock structure elsewhere is less clear. Gaskin (1984) postulated 18 stocks based primarily on distributional patterns: one Black Sea; one African; eight European; two Greenlandic; three along the eastern coast of North America; two along the US west coast and Canada/Alaska; and one in Japan. Average morphological differences exist among porpoises from the Black Sea, Mediterranean and eastern North Atlantic; the North Atlantic animals are largest and the Black Sea animals smallest (Perrin, 1984). The porpoises along the coast of West Africa have larger skulls than those to the north in European waters (Fraser, 1958); this may indicate isolation. Within the eastern North Atlantic, non-metrical cranial analyses and isoenzyme studies suggest the existence of at least two populations (IWC, 1991a). In the western North Atlantic, four populations have been postulated: West Greenland; Newfoundland and Labrador; Gulf of St. Lawrence; and Bay of Fundy-Gulf of Maine. However, recent studies of mtDNA do not support the absence of gene flow among at least three of these (MMI, 1992), and alternative hypotheses of three populations and of one population have been adopted for purposes of management.

In a recent study based on cranial morphometric and non-metrical characters for several hundred skulls, Yurick and Gaskin (1987) demonstrated separation between eastern Pacific, western Atlantic and eastern Atlantic series. Sample-size limitations prevented confident finer comparisons, but the data suggested segregation of Dutch, Baltic and eastern English (North Sea) animals. In a similar study, Amano and Miyazaki (1992) found 'good differences' between eastern and western Pacific porpoises as well as between those from the North Pacific and North Atlantic. They concluded that distant populations are well differentiated morphologically and that this indicates little if any gene flow. Rosel (1992) confirmed this general picture, based on the analysis of mitochondrial DNA sequence data; she found no evidence of gene flow among North Pacific, North Atlantic and Black Sea populations.

In the eastern Pacific, the results of examination of pesticide levels indicate that harbour porpoises from Central California do not mingle extensively with those in Oregon and Washington (Calambokidis and Barlow, 1991), but analyses of mitochondrial DNA suggest the possibility of some gene flow or seasonal mixing between these areas (Rosel, 1992).

Vaquita (*Phocoena sinus*)
The vaquita is endemic to the upper portion of the Gulf of California; there is only one population. It has the smallest geographic range of any marine cetacean (Brownell, 1986; IWC, 1990).

Finless porpoise (*Neophocaena phocaenoides*)
A freshwater race of this species inhabits the Yangtze River; it is morphologically and physiologically different from the marine form found in adjacent coastal waters and specimens from India (Fraser, 1966; Gao Anli, 1991). Pilleri and Gihr (1972; 1980) compared the riverine form with specimens from Pakistan and described a new species *N. asiaeorientalis* based on the Yangtze material. Pilleri and Chen (1980) discussed differences between the two putative species. Pilleri and Gihr (1975) described yet another species, *N. sunameri*, from Japan. These species have not been accepted, because the morphological differences between the various series of specimens are average rather than distinct (Honacki *et al.*, 1982). Gao (1991) concluded, based on morphological and genetic studies, that 5–6 populations should be recognised: (1) South Asia; (2) South China Sea; (3) Yellow Sea; (4) Yangtze River; and (5) Japan (probably two populations, on eastern and western coasts). He proposed that three subspecies be recognised: *N. p. phocoenoides* (southern Asia and South China Sea); *N. p. sunameri* (Yellow Sea and Japan); and *N. p. asiaeorientalis* (Yangtze River). His morphological analyses were based on 218 specimens.

Dall's porpoise (*Phocoenoides dalli*)
Dall's porpoise is a pelagic animal of the North Pacific. It is found off the coasts of the USA, Canada, USSR, Korea and Japan. Stock structure in this species has been under intensive study in recent years because of large directed and incidental kills, mainly in the central and western North Pacific.

There is evidence for several stocks. Two colour morphs occur: the *truei*-type and the *dalli*-type; these are found in sharply different frequencies in different areas and were formerly recognised as separate species. Despite the striking dimorphism, however, isozyme studies indicate gene flow between the two forms (Shimura and Numachi, 1987). Osteological studies of several hundred specimens from the eastern North Pacific, Bering Sea and southern fisheries conservation zone of the USA were inconclusive (Walker and Sinclair, 1990), but geographic variation in parasite loads (Walker, 1990) and in pollutant levels (Subramanian *et al.*, 1986) and patterns of migration and breeding areas as determined from sightings of mother-calf pairs (Yoshioka *et al.*, 1990) suggest the existence of at least six stocks of *dalli*-type porpoise and one of *truei*-type associated with the main calving grounds (IWC, 1990; Miyashita, in press). However, there is some uncertainty about the existence of a separate eastern Pacific stock and the eastern boundary of a stock in the Bering Sea.

Indo-pacific hump-backed dolphin (*Sousa chinensis*)
This species inhabits shallow coastal waters and estuaries from China throughout Southeast Asia to the northern coasts of Australia and west along the coasts of the Indian Ocean (including the Persian Gulf and the Red Sea) to southern South Africa (Klinowska, 1991). It is highly variable geographically in external shape, size and colouration. Pilleri and Gihr (1980) recognised four species: *S. plumbea* from the east coast of Africa, Red Sea, Persian Gulf, India, Burma and Thailand; *S. lentiginosa* from the same regions; *S. chinensis* from the coast of southern China; and *S. borneensis* from Sarawak in Borneo and northern Australia. Most workers now only recognise a single species (Honacki *et al.*, 1982). The long coastal range and the level of variation suggest that many local breeding populations exist, but the specimens and data that would allow rigorous examination of this hypothesis have not yet been collected.

Tucuxi (*Sotalia fluviatilis*)
A dwarf riverine race of the tucuxi was formerly considered a separate species (Honacki *et al.*, 1982). The larger marine form is distributed in estuaries and shallow bays along the east coast of South America from the Caribbean to Paraná in Brazil (Borobia *et al.*, 1991). Fewer than 100 osteological specimens are available for study. These are sufficient to demonstrate separation between the riverine and marine forms (Borobia and Sergeant, 1989) but not adequate for examining geographical variation and stock structure of the marine form within its very long coastal range.

Dusky dolphin (*Lagenorhynchus obscurus*)
This species inhabits temperate and cold-temperate waters adjacent to all the land masses and island groups in the Southern Hemisphere (Klinowska, 1991). The range is apparently discontinuous, with populations in the waters of New Zealand, South America (Chile, Peru, Argentina and Falkland Islands) and South Africa. Van Waerebeek (1992) examined 415 skulls and concluded that the

populations in Peru, southwestern Africa and New Zealand, at least, are morphologically distinct; samples from other regions (e.g. Peru versus Chile) were too small to allow firm conclusions.

Pacific white-sided dolphin (*Lagenorhynchus obliquidens*)
The Pacific white-sided dolphin occupies temperate waters extending from Baja California in the eastern Pacific across the top of the central North Pacific below the Aleutian Islands and south to Taiwan (Leatherwood *et al.*, 1984). Separate eastern and western Pacific stocks have been proposed because of a supposed region of very low density in the upper central North Pacific (Klinowska, 1991), but more recent surveys have shown apparent continuous distribution across the North Pacific (Miyashita, 1991; Stacey and Baird, 1991). A study of geographical variation based on 243 specimens demonstrated differences between samples from Baja California and from farther north along the west coast of North America (Walker *et al.*, 1986), indicating the possible existence of separate northern temperate and southern temperate stocks in this region. In the western Pacific, specimens from the Sea of Japan are larger than those from the Pacific coast of Japan; cranial differences also exist (based on 86 specimens; Miyazaki and Shikano, 1989).

Given the results of the limited studies to date, there would seem to be a potential for the existence of additional stocks in the northwestern and north-central North Pacific, although considerations of oceanography and continuity of distribution in the region must be taken into account (see Discussion).

Miyashita (1991) noted that there was little variation in sea surface temperatures in the range of the species across the North Pacific in the driftnet fishing region. He estimated population size for the region in two segments (between 150°E and 170°W and between 170°W and 125°W). However, he stated that the division was tentative and had 'nothing to do with a possible stock boundary'. He used the same divisions to estimate abundance of the northern right whale dolphin, *Lissodelphis borealis*.

White-beaked dolphin (*Lagenorhynchus albirostris*)
This species is endemic to the North Atlantic. Based on analysis of 62 skulls, Mikkelsen (1991) concluded that separate populations exist on the western and eastern sides of the Atlantic.

Atlantic white-sided dolphin (*Lagenorhynchus acutus*)
Mikkelsen (1991) also examined skulls (123) of this species, also endemic to the North Atlantic. She found statistically significant differences between samples from the two sides of the North Atlantic, although the level of significance is lower than in the case of *L. albirostris*. She concluded that this may reflect the more pelagic habitat of *L. acutus*.

Bottlenose dolphin (*Tursiops truncatus*)
This has long been considered a coastal species, but recent studies have shown it to occur in large numbers far offshore in some regions, e.g. the eastern tropical Pacific (Scott and Chivers, 1990). It occurs in all temperate and tropical coastal waters.

The bottlenose dolphin is a highly variable species; at least 20 nominal species have been described (Mead and Potter, 1990). Typically, any particular region supports both inshore and offshore forms. This has been demonstrated for the eastern North Pacific (Walker, 1981), Peru (Van Waerebeek *et al.*, 1990), South Africa (Ross, 1984), and the US east coast (Hersh, 1990). The pattern is complicated by the apparent existence of tropical and temperate forms in the western Pacific and Indian Oceans (Zhou, 1987; Ross and Cockcroft, 1990); these may overlap in distribution, with one being more inshore than the other in the region of overlap. Animals in the Mediterranean are larger than those in the Black Sea and smaller than those in the eastern North Atlantic, suggesting separate stocks in these three areas (Perrin, 1984).

The potential for existence of additional unrecognised stock divisions for this species is high.

Atlantic spotted dolphin (*Stenella frontalis*)
This species inhabits coastal waters (usually deeper than 200m) from New England to Argentina in the western Atlantic and from Cape Verde to the Gulf of Guinea in the eastern Atlantic (Perrin *et al.*, 1987). It also occurs far offshore in the mid-tropical Atlantic and in the Gulfstream at least as far east as the Azores. It is highly variable geographically in size, colour pattern and cranial characters (Perrin *et al.*, 1987).

The available specimens are not sufficient for establishing firm stock boundaries, but samples from the US east coast, the Caribbean, Africa, the Gulfstream and the mid-tropical Atlantic are sufficiently different morphologically to suggest that animals in these five regions should be managed as separate stocks. The specimen coverage is especially poor for Central America, South America south of the Caribbean, and Africa, and the emergence of additional stock divisions should be expected as specimens and results of sighting surveys accumulate.

Pantropical spotted dolphin (*Stenella attenuata*)
The pantropical spotted dolphin occurs around the world in tropical waters (Perrin *et al.*, 1987; Perrin and Hohn, 1994). It has been studied most intensively in the eastern tropical Pacific, where large numbers are killed in the tuna purse-seine fishery; the available specimens run into the high hundreds. Three stocks are currently recognised in this region for purposes of management: a coastal form (the subspecies *S. attenuata graffmani*), that ranges from Mexico to Peru, and 'northeastern' and 'western/southern' offshore stocks (Perrin *et al.*, 1985; 1994a; Dizon *et al.*, 1992b). In addition, specimens from Hawaii differ morphologically from those from the eastern tropical Pacific.

Material from other parts of the Pacific and the Indian and Atlantic Oceans is still too limited to support more than very tentative conclusions concerning geographical variation involving these areas (e.g. that the few available specimens from the Atlantic suggest that large coastal forms may also exist in the western North Atlantic and Africa), but it is to be expected that more stock divisions will be discovered as information accumulates (Perrin *et al.*, 1987).

Spinner dolphin (*Stenella longirostris*)
This dolphin is pantropical in distribution and occurs both in coastal waters and on the high seas. It is killed in large numbers in the tuna purse seine fishery in the eastern tropical Pacific and has been intensively studied there. The available material consists of several hundred specimens. Three subspecies have been reported (Perrin, 1990): *S. l. longirostris*, *S. l. centroamericana* (a coastal form) and *S. l.*

orientalis (a more offshore form). The last two correspond to the 'Central American spinner' (formerly Costa Rican spinner) and 'eastern spinner' management units (Perrin *et al.*, 1985). Studies of DNA (Dizon *et al.*, 1992a), external shape and colouration (Perrin *et al.*, 1991) and cranial variation (Douglas *et al.*, 1992) have demonstrated that the current 'whitebelly spinner' management unit constitutes a broad zone of hybridisation or intergradation between *S. l. orientalis* and *S. l. longirostris* to the west.

The species has not been as well studied elsewhere. A dwarf form in the Gulf of Thailand may deserve subspecific designation (Perrin *et al.*, 1989). A distinctive form may also exist in the Gulf of Aden (Robineau and Rose, 1983). It is likely that eventually several more stocks will be recognised.

Striped dolphin (*Stenella coeruleoalba*)
The striped dolphin inhabits tropical and warm-temperate waters around the world (Wilson *et al.*, 1987; Perrin *et al.*, 1994b). It is found in both coastal waters and on the high seas. As for the other tropical dolphins, its known range is likely to expand greatly as knowledge accumulates about the cetacean faunas of South America, Africa and tropical Asia. There are geographical gaps in the locality records, but it is too early to know whether these represent discontinuities in the range or inadequate coverage. For example, there are very few records from the eastern North Pacific, but the range may be continuous across the temperate central North Pacific; it is known to extend from Japan east to at least 155°W (INPFC, 1992b).

Geographical variation in morphology or genetic characters has not been investigated. In the eastern tropical Pacific, two stocks were formerly designated based on a band of very low density between 10° and 15°N: the 'northern striped dolphin' and 'southern striped dolphin' (Perrin *et al.*, 1985), but recently these were pooled because of accumulation of sightings in the supposed gap (Dizon *et al.*, 1992b). Judging from the pattern of pronounced geographical variation in the other dolphins of this genus, it should be expected that numerous stock divisions will emerge as more material becomes available.

Common dolphin (*Delphinus delphis*)
This species is found worldwide in tropical and temperate waters, both along coasts and far offshore (Klinowska, 1991). There are several distinct forms which have been described variously as subspecies, species, races or geographical forms. The species needs to be thoroughly revised, but until this year the name *Delphinus delphis* has been used to include all forms (see below).

The species has been most intensively studied in the eastern Pacific, and several forms have been described there based on morphology and distribution (Perrin *et al.*, 1985). These include the Baja Neritic, Northern, Central and Southern Common Dolphin stocks and a tentative Guerrero Common Dolphin stock. The Baja Neritic and Northern forms are sympatric in Baja California and California waters, but the former occurs very close to shore and the latter more offshore. Recent studies of large series of adult specimens of the two forms have found them to be distinct in several characters (Heyning and Perrin, 1994); the 'long-beaked' is now considered a separate species, *D. capensis*. A comparison of mtDNA sequences indicates an absence of gene flow between the two forms and a closer genetic relationship between the offshore form and common dolphins in the Black Sea than between the two eastern Pacific forms (Rosel, 1992). A similar pattern is emerging on the coast of Peru (pers. comm. from J.C. Reyes, 1990). There are also indications of distinct forms in the Mediterranean, Black Sea and eastern North Atlantic (Perrin, 1984). Two forms exist in the Indian Ocean, one with a very long beak described by van Bree and Gallagher (1978) as *Delphinus tropicalis* and the other more similar to common dolphins elsewhere.

It is clear that dozens of common dolphin stocks may eventually be recognised. The affinities of common dolphins in the areas of the driftnet fisheries in the central North Pacific are unknown, but given their distance from previously studied populations, it is unlikely that they will prove to belong to a currently recognised stock.

Irrawaddy dolphin (*Orcaella brevirostris*)
In some areas this species is confined to fresh water (Marsh *et al.*, 1989). Its range extends from Australia through Southeast Asia to the east coast of India. Given the shallow estuarine and coastal habitat of the Irrawaddy dolphin, it is likely that isolated marine breeding populations exist as well. Geographical variation in morphology and genetics has not been studied.

Commerson's dolphin (*Cephalorhynchus commersonii*)
The range of this species includes the coasts of Argentina, Chilean Tierra del Fuego, the Falkland Islands, Kerguelen Islands, and South Georgia (Brown, 1988; Goodall *et al.*, 1988). The Kerguelen population is morphologically distinct and perhaps deserves subspecific designation (Robineau and De Buffrenil, 1985; Robineau, 1986).

False killer whale (*Pseudorca crassidens*)
The false killer whale inhabits oceanic tropical and warm-temperate waters worldwide. Kitchener *et al.* (1990) found substantial differences among series of skulls from Australia, South Africa and Scotland and suggested that there are a number of disjunct regional populations rather than a global panmictic population as hypothesised by Purves and Pilleri (1978).

Killer whale (*Orcinus orca*)
The killer whale is cosmopolitan, occurring from polar ice to equatorial seas. It has most often been observed in coastal waters (within 800km of land) but also ranges the high seas (Heyning and Dahlheim, 1988). Its stock structure has been investigated in some regions and is complex. Some breeding groups are migratory and others are resident. Long-term studies have shown little or no movement between groups of the two different types in the same region or between 'communities' of the resident type (Bigg *et al.*, 1990).

Two nominal species have been described from the Antarctic: a dwarf form *O. nanus* (Mikhalev *et al.*, 1981) and an ice dwelling form *O. glacialis* (Berzin and Vladimirov, 1982). However, morphological differences between these forms and other Antarctic killer whales are modal, and most workers consider them to be subspecific forms. In any case, they are likely to represent different stocks.

Heyning and Brownell (1990) found differences in total length between killer whales from the Northern and Southern Hemispheres but no differences between whales from the North Pacific and North Atlantic.

The pattern of isolated breeding stocks may be very fine-grained. In recent DNA studies, Hoelzel (1989; 1990) compared six putative populations from the Northeast Pacific, Iceland, Denmark and Argentina and found marked genetic differences between two sympatric Puget Sound populations (resident and transient), comparable to those found between the samples from different oceans. He also concluded that the level of inbreeding suggested by the data implies that the effective population size of local populations is very low and that conservation policy in any region should take into account the possibile existence of independent sympatric stocks.

Long-finned pilot whale (*Globicephala melas*)
This species is found in cold temperate waters of the North Atlantic and the Southern Hemisphere. The populations in the two hemispheres are geographically isolated from each other; the Southern Hemisphere form has been variously known as *G. edwardii* or *G. m. edwardii* (Klinowska, 1991). The species occurred in northern Japanese waters in historical times but is now extinct there (Kasuya *et al.*, 1988). Morphological and genetic studies of geographical variation have been limited but are increasing (e.g. Amos *et al.*, 1991; Aguilar *et al.*, 1993; Andersen, 1993). As yet there is little firm evidence for the existence of multiple discrete stocks in the North Atlantic. Parasite data from Canada, the Faroe Islands and the western Mediterranean suggest that individual pilot whales do not routinely move between these regions (IWC, 1990). Bloch and Lastein (1992) compared external measurements of pilot whales from Newfoundland and the Faroes and concluded that they came from different populations. However, this conclusion must be considered tentative, because the measurements were not taken by the same investigators in the two areas and were separated by 30 years or more in time. Additional studies based on larger samples from the various regions and on monitoring of movements are needed.

Short-finned pilot whale (*Globicephala macrorhynchus*)
The short-finned pilot whale occurs pantropically and in warm temperate waters of the eastern and western North Pacific. Stock structure has been studied only in the northwestern Pacific, where the whale is taken in directed harpoon and drive fisheries. Studies of distribution, morphology and isozymes have revealed that two genetically isolated populations occur there, a northern form and a southern form (Kasuya *et al.*, 1988; Wada, 1988). There is some disagreement as to the taxonomic level that should be accorded these two forms (Kasuya and Tai, 1993; Miyazaki and Amano, 1994). They occupy waters with different oceanographic regimes, delimited by the southern front of the cold Oyashio Current and the northern front of the warm Kuroshio Current. The two forms are presently managed as separate units. Similar investigations in other regions would probably uncover additional stock divisions (Kasuya and Tai, 1993).

Baird's beaked whale (*Berardius bairdii*)
This large beaked whale is a deep-diving species limited to the North Pacific. In the western North Pacific, patterns of distribution and migration suggest that separate populations inhabit the Sea of Japan, Sea of Okhotsk and the open western Pacific (IWC, 1989). The relation of these to the whales in the eastern North Pacific is unknown. Morphological or genetic analyses have not been carried out for any regions.

DISCUSSION

In almost every case where large sample sizes have been analysed, geographical variation has been found. Based on the patterns of geographical variation in other regions and in other delphinid and phocoenid species, further stock divisions should be expected for at least some of the small cetaceans involved in the driftnet fisheries in the North Pacific.

The results of recent research (e.g. Kasuya *et al.*, 1988; Reilly, 1990; Reilly and Fiedler, 1990) have indicated that geographical populations of pelagic small cetaceans are associated with water masses and currents and that fronts of various kinds often demarcate the boundaries between them. This should be taken into account when evaluating the stock structure in the North Pacific. In the region of the high seas gillnet fisheries, oceanographic conditions are rather uniform over very great distances (Miyashita, in press); this is a countervailing factor consistent with the notion that stock divisions may not exist for some of the impacted species in the region, e.g. the Pacific white-sided and northern right whale dolphins.

The successful examinations of geographic variation in morphology have been based on large samples of specimens, usually more than 100. Where such samples exist or can be collected, they should be examined. However, newer molecular approaches to geographical genetics in cetaceans, such as those used by Hoelzel (1990), Baker *et al.* (1990), Rosel (1992) and Dizon *et al.* (1992b), may make possible adequate analyses based on smaller series of specimens and should be further explored (see IWC, 1991b).

Other promising approaches are the uses of parasite species and loads (e.g. as in Walker, 1990, for *Phocoenoides dalli*). This requires collection of large samples of parasites and life history data in the field but not osteological specimens, which are much more difficult and costly to collect, prepare and house. Consistent methods must be used in such studies if results are to be compared.

The use of contaminant profiles (as by Calambokidis and Barlow, 1991, for *Phocoena phocoena*) also has considerable promise. It cannot determine genetic differences but can provide inferences about the lifetime movements of individual animals. Here again, as for parasite studies, consistency in methodology is extremely important (Aguilar, 1987).

Finally, as stressed by several authors (e.g. Donovan, 1991), the question of 'stock' identity in a management context cannot be divorced from the overall management strategy adopted. The nature of the management procedure will determine the definition of 'stock' (biological versus management) and thus the nature of the evidence required.

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Eastern North Pacific

SC/O90/G28

A Review of Cetacean and Pinniped Mortality in Coastal Fisheries Along the West Coast of the USA and Canada and the East Coast of the Russian Federation

Jay Barlow

Southwest Fisheries Science Center, P.O. Box 271, La Jolla, CA 92038, USA

Robin W. Baird

Department of Biological Sciences, Simon Fraser University, Burnaby, British Columbia, Canada V5A 1S6

John E. Heyning

Natural History Museum of Los Angeles County, 900 Exposition Blvd., Los Angeles, CA 90007, USA

Kate Wynne

Marine Advisory Program, University of Alaska, 900 Trident Way, Kodiak, AK 99615, USA

Albert M. Manville, II

Defenders of Wildlife, 1244 19th Street, N.W., Washington, D.C. 20036, USA

Lloyd F. Lowry

Alaska Department of Fish and Game, 1300 College Road, Fairbanks, AK 99701, USA

Doyle Hanan

California Department of Fish and Game, 8604 La Jolla Shores Drive, La Jolla, CA 92037, USA

John Sease

National Marine Fisheries Service, P.O. Box 21668, Juneau, Alaska 99802, USA

Vladimir N. Burkanov

Kamchatka Institute of Ecology and Nature Management, Russian Academy of Sciences, Prospekt Ribakov 19/A, Petropavlovsk-Kamchatsky, Russian Federation 683024

ABSTRACT

Many passive net fisheries exist along the Pacific coastlines of the USA (California, Oregon, Washington and Alaska), Canada (British Columbia) and the Russian Federation. Some incidental marine mammal mortality occurs in almost all of these fisheries. In this report, we examine 14 of the fisheries from this region that cause marine mammal mortality. The reviews include: (1) a discussion of the relevant laws pertaining to marine mammal mortality in fisheries in each of the three countries, (2) a brief synopsis of the target species and the area and method of operation for the fishery, (3) information on the economic importance of the fishery and the size of recent catches and (4) any available information on the levels of take of cetacean and pinniped species. Less complete, sometimes anecdotal information is provided for a number of other fisheries in this area. For the vast majority of all coastal fisheries along the North Pacific rim, insufficient information is available to determine whether the fisheries are having a negative impact on the species of marine mammals that live in this area. Based on our findings for this area, we make four recommendations for the gathering of additional information to evaluate the significance of fishery mortality on marine mammal populations and to help minimize its impact.

KEYWORDS: NORTH PACIFIC; INCIDENTAL CAPTURE; FISHERIES; MANAGEMENT; GRAY WHALE; COMMON DOLPHIN; MINKE WHALE; NORTHERN RIGHT WHALE DOLPHIN; SHORT-FINNED PILOT WHALE; RISSO'S DOLPHIN; BOTTLENOSE DOLPHIN; SPERM WHALE; DALL'S PORPOISE; PYGMY SPERM WHALE; PACIFIC WHITE-SIDED DOLPHIN; KILLER WHALE; HUBBS' BEAKED WHALE; CUVIER'S BEAKED WHALE; WHITE WHALE; SEALS.

INTRODUCTION

Increasing international attention is being focused on the problem of incidental mortality of marine mammals in gillnets and other fishing gear. Evaluating the significance of this problem has been hampered by a lack of information regarding (1) which marine mammals are being taking in which fisheries, (2) how many marine mammals are being taken and (3) the size of the marine mammal populations. Rarely is complete information available for all three. In this review we will attempt to provide information on the first of the above categories. We limit ourselves largely to gillnets and other passive fishing gear. We will concentrate on cetaceans caught in the coastal fisheries of the western USA, western Canada and eastern Russia, and will provide quantitative estimates of kill rates where available. Where available, we will also provide information on mortality of pinnipeds and sea otters. In very few cases has the total marine mammal mortality been estimated. In even fewer cases have cetacean population sizes been estimated. Clearly we are a long way from being able to evaluate the significance of marine mammal mortality in fisheries.

Cetacean mortality in passive fishing gear is largely limited to gillnets. Gillnets are commonly classified as set nets (nets that are anchored to the bottom) and driftnets (nets that are free-floating). Both types of nets can be fished at the surface or in mid-water. Only set nets are commonly fished at the bottom. Within the general category of gillnets we include trammel nets, suspendered gillnets and other entangling nets. We will also consider traps and discarded fishing gear (including gillnets and trawl nets) as passive fishing gear.

For consistency and comparability, we have converted units of measure to a common system. We use metric measures of length and mass and US dollars for the value of fish catches. Some small errors may be introduced by these conversions. For consistency, information on fisheries will be presented in geographical order starting with southern California and proceeding counter-clockwise around the Pacific rim to southeastern Russia. A list of common and scientific names used in this report is given in the Appendix.

The fisheries to be considered in detail are given in Table 1 and their approximate locations are shown in Fig. 1. We specifically exclude the North Pacific high-seas driftnet fisheries for squid, tuna and salmon which are covered in separate reports (Hayase *et al.*, 1990; Nagao, 1994; Watanabe, 1994; Yatsu, 1994).

Table 1

Fisheries considered in detail in this report.

(A)	the driftnet fishery for sharks and swordfish off California
(B)	the setnet fisheries off California
(C)	the gillnet fishery for salmon in Washington state
(D)	the driftnet fishery for salmon off British Columbia
(E)	a Canadian-sponsored experimental driftnet fishery for flying squid in western Canadian waters and adjacent international waters
(F)	the salmon setnet fishery in Yakutat and driftnet fishery in southeastern Alaska
(G)	the setnet and driftnet fisheries for salmon in the Copper River Delta and Prince William Sound, Alaska
(H)	the driftnet fishery for salmon in Cook Inlet, Alaska
(I)	the setnet and driftnet fisheries for salmon off Kodiak, South Unimak, and the Alaska Peninsula
(J)	the pollock trawl fishery in the Bering Sea/Gulf of Alaska
(K)	the setnet and driftnet fishery for salmon in Bristol Bay, Alaska
(L)	the setnet fisheries in northern Alaska
(M)	the driftnet fishery for salmon off eastern Russia
(N)	the trapnet fishery for salmon off eastern Russia

LEGAL FRAMEWORK

In the USA, all marine mammals are managed under the Marine Mammal Protection Act (MMPA) of 1972 (as subsequently amended). Prior to 1988, incidental mortality in fisheries was permitted if the populations could be shown to be within a range of 'optimum sustainable population' size (OSP). OSP was interpreted to be a population size between the maximum net productivity level and the environmental carrying capacity. However, OSP has not been determined for most of the cetacean species in US coastal waters. In the 1988 amendments to the MMPA, a special exemption program eliminated the OSP requirement for a 5-year period, during which studies were to be undertaken to assess the status of marine mammal populations and the levels of incidental taking in fisheries. Any fisherman receiving a certificate of exemption was allowed to take marine mammals incidental to their fishing activities regardless of the population's OSP status (although still subject to provisions of the Endangered Species Act). The 1994 amendments to the MMPA established a protocol for setting limits on the maximum allowable takes from each marine mammal population to be in place by January 1995.

Both the 1988 and 1994 amendments provided for an observer program to monitor marine mammal mortality in those fisheries with the highest take rates. The US National Marine Fisheries Service (NMFS) has administered these observer programs, either directly or through contracts.

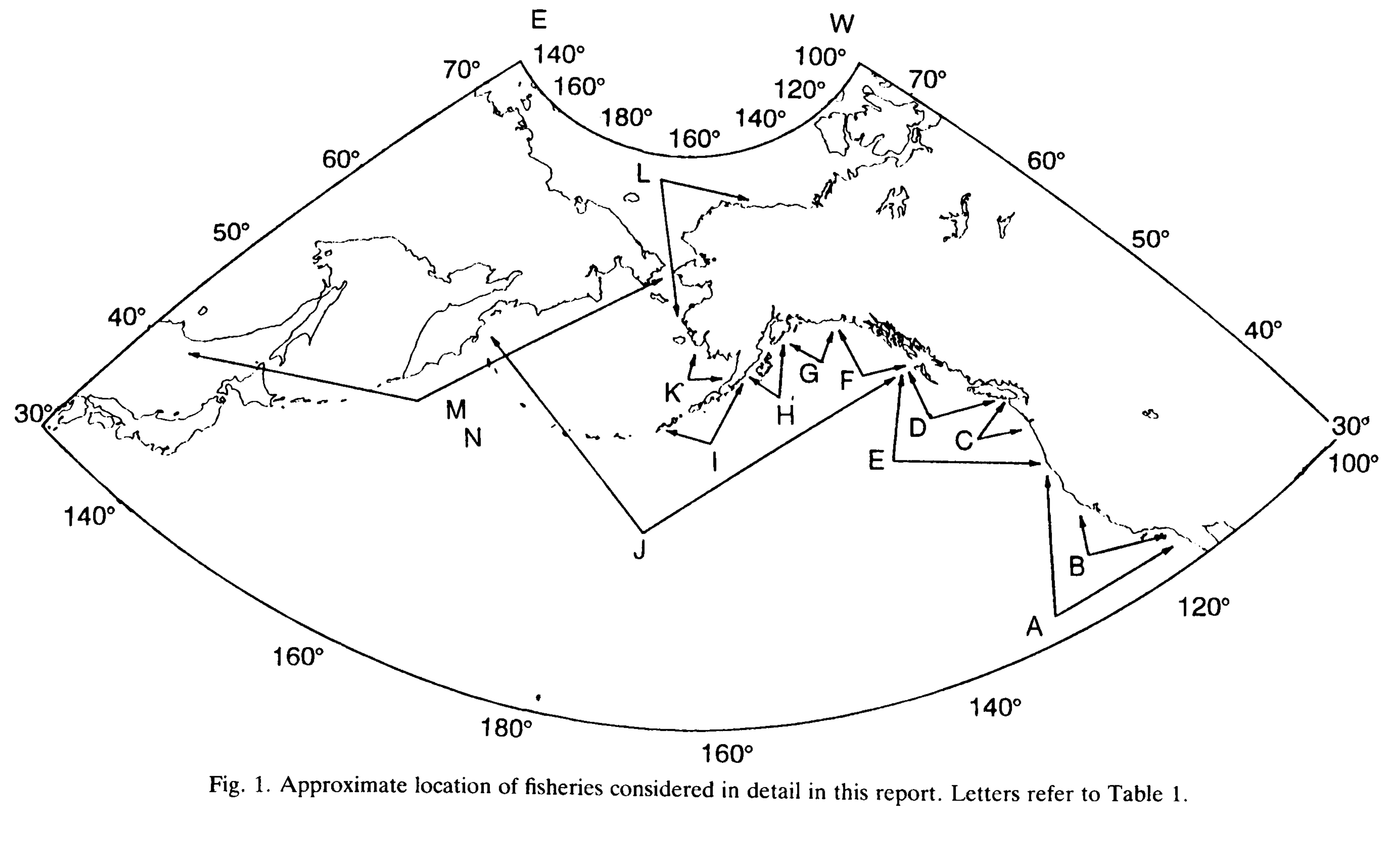

Fig. 1. Approximate location of fisheries considered in detail in this report. Letters refer to Table 1.

In addition, fishermen are required to submit 'logbook' reports detailing all takes of marine mammals in all fisheries that have greater than a 'remote' likelihood of killing marine mammals.

In Canada, marine mammals are protected from all but aboriginal hunting by the 1993 Marine Mammal Regulations of the Fisheries Act of Canada of 1867. Aboriginal hunting can be undertaken for most species without a licence, but only for food, social or ceremonial purposes. Disturbance of marine mammals under these regulations is prohibited, but no definition of 'disturbance' is given. In the case of incidental catches, fishermen are neither encouraged nor required to report catches. When catches are reported, no action is taken.

In the fisheries economic zone of the former USSR, rules stated that incidental catches (including marine mammals) were limited to a maximum of 8% of the total catch by numbers of individuals. If the combined numbers of non-target fish and marine mammals exceeded 8% of the total catch, fishermen were required to move to another area. Fishermen were not punished for incidental catches of cetaceans, but were required to document in their fishing logs the incidental catch of all marine mammal species. In fact, these data were never reported by fishermen or fisheries agencies.

SYNOPSIS OF THE FISHERIES

(A) California driftnet fishery for sharks and swordfish

The driftnet fishery for pelagic sharks began off southern California about 1977 (Hanan *et al.*, 1993). Initially, swordfish were caught incidentally and regulations limited swordfish to no more than 25% of the total catch (Miller *et al.*, 1983). This regulation was later modified and fishermen now fish for both sharks and swordfish (subject to seasonal and area closures) (Hanan *et al.*, 1993). Marine mammal mortality in California gillnets was first documented by Miller (1981). A gillnet observation program was initiated by the California Department of Fish and Game (CDFG) to evaluate the level of marine mammal bycatch in this fishery; this program was discontinued in the late 1980s. A NMFS observation program was initiated in June 1990 and continues today.

Primary ports

The primary ports are San Diego and San Pedro, CA.

Target species

The target species are swordfish, thresher shark, mako (bonito) shark and opah.

Area of operation

The area of operation comprises offshore waters from the Mexican border to Washington, within the US EEZ, principally encompassing sea mounts, escarpments and banks of the continental shelf. The fishery expanded from California to offshore Oregon and Washington, but landings were prohibited in Oregon and Washington due to high incidental catches of marine mammals.

Vessels and crew

Vessels are typically 9–23m long and are made of steel, fiberglass or wood. There are approximately 235 permitted vessels statewide. Of these, currently only about 150 permits are active. Fish are typically held on ice or in brine spray, but a few boats have refrigeration. Crews are typically 2–6 US fishermen.

Gear specifications

Monofilament and 3-strand nylon gillnets are used, with a stretched mesh size of 46–61cm (with an average of 48cm). Nets range from 915–1,830m long by 50–100 meshes deep (mean depth is 40m with a range of 27–62m). The top of the net is typically fished 5–27m below the surface. Surface floats are 30cm in diameter and are spaced 18m apart. The ends of the nets are marked with light beacons and a 25cm radar reflector. Nets are hauled with net reels.

Operations

Trips are typically 1–14 days long and may not end in the same port they begin. Vessels fish one net per night and stay attached to the net. Nets are set in water depths of 122–610m and are free to drift. Nets are set 2hrs before sunset and must be completely hauled by 2hrs after sunrise. Retrieval time is typically 2–4hrs. The fleet typically follows the highest concentrations of fish. The fishery is closed within 75 miles of the coast during the gray whale migration.

Economics and history

The ex-vessel prices range from $4–10/kg for swordfish, $2–4/kg for shark and $0.50/kg for opah. Fish are sold fresh or frozen in the domestic market. The total values of the landings were approximately $5,000,000 for swordfish and $2,000,000 for sharks circa 1990. The fishery developed in the late 1970s, peaked in the 1980s and is now declining.

Total landings

Total landings in 1990 were 680 tonnes of swordfish and 370 tonnes of shark (Hanan *et al.*, 1993).

Effort data

Effort decreased from about 10,000 net pulls per year in the mid 1980s to about 5,000 in recent years (Table 2).

Interactions with cetaceans

Marine mammal mortality was monitored in the mid-1980s by a CDFG observer program and since 1990 by a NMFS observer program. Entangled species included gray whales, short-beaked common dolphins, minke whales, northern right whale dolphins, short-finned pilot whales, Risso's dolphins, bottlenose dolphins, sperm whales, beaked whales, Dall's porpoise, pygmy sperm whales and Pacific white-sided dolphins (Table 2). Evidence of entanglement was also found on beach-cast specimens of short and long-beaked common dolphins, bottlenose dolphins, Risso's dolphins, Pacific white-sided dolphins, killer whales, a Hubbs' beaked whale and a Cuvier's beaked whale (Heyning *et al.*, 1994). Total annual mortality for cetaceans was not estimated by CDFG due to insufficient sample size, but observed mortality is summarized in Table 2. Using data from the CDFG driftnet observation program and extrapolating to the 99% of sets that were unobserved, Heyning and Lewis (1990) provided a rough estimate that 441 rorqual whales were taken in driftnets between 1980–85 with an annual take of about 73 rorquals. If animals are small, they are brought aboard, but whales are usually cut out at the water line. Entangled cetaceans are usually dead, but one minke whale and one sperm whale were released alive. Table 2 provides observed and estimated total mortality from the 1990–93 NMFS Observer Program.

Table 2

Observed and estimated fishing effort and marine mammal mortality in California's drift gillnet fishery for swordfish and sharks from the 1980 to 1986 CDFG observer program (Miller *et al.*, 1983; Diamond *et al.*, 1987; Hanan *et al.*,1988; Hanan and Diamond, 1989; Konno, in press) and the 1990 to 1993 NMFS observer program (Lennert *et al.*, 1994; Perkins *et al.*, 1992; Julian, 1993; 1994). Missing data indicate no available estimates.

	Observation period								
From	4/80	4/83	4/84	4/85	4/86	7/90	1/91	1/92	1/93
To	3/83	3/84	3/85	3/86	3/87	12/90	12/91	12/92	12/93
Effort									
Est. no. net pulls	14,140	11,000	9,700	10,000	10,330	4,078	4,752	4,504	6,599
No. observed net pulls	226	71	44	66	0	181	470	595	728
% observed net pulls	1.6%	0.6%	0.5%	0.7%	0.0%	4.4%	9.9%	13.2%	11.0%
Observed marine mammal mortality									
Unid beaked whale	0	0	0	2	-	0	0	3	0
Common dolphin	0	0	3	7	-	9	44	47	28
Minke whale	0	0	1	0 [1]	-	0	0	0	0
Northern right whale dolphin	0	0	0	1	-	0	7	15	7
Short-finned pilot whale	2	0	0	0	-	1	0	1	11
Pac. white-sided dolphin	1	0	0	0	-	3	5	3	2
Dall's porpoise	0	0	0	0	-	1	2	1	9
Risso's dolphin	-	-	-	-	-	0	5	5	4
Cuvier's beaked whale	-	-	-	-	-	0	0	6	3
Mesoplodont beaked whale	-	-	-	-	-	1	0	3	0
Bottlenose dolphin	-	-	-	-	-	0	0	3	0
Sperm whale	-	-	-	-	-	0	0	3	3 [3]
Pygmy sperm whale	-	-	-	-	-	0	0	0	1
California sea lion	82	6	1	1	-	4	4	9	12
Harbor seal	0	0	0	1	-	1	0	0	0
Elephant seal	0	2	0	2	-	4	13	15	14
Steller sea lion	-	-	-	-	-	0	0	1	0
Estimated marine mammal mortality									
Unid. beaked whale	-	-	-	-	-	0	0	23	0
Common dolphin	-	-	-	-	-	203	373	356	207
Minke whale	-	-	-	-	-	0	0	0	0
Northern right whale dolphin	-	-	-	-	-	0	59	15	52
Short-finned pilot whale	-	-	-	-	-	23	0	8	81
Pac. white-sided dolphin	-	-	-	-	-	68	42	23	15
Dall's porpoise	-	-	-	-	-	23	17	8	67
Risso's dolphin	-	-	-	-	-	0	42	38	30
Cuvier's beaked whale	-	-	-	-	-	0	0	45	22
Mesoplodont beaked whale	-	-	-	-	-	23	0	23	0
Bottlenose dolphin	-	-	-	-	-	0	0	23	0
Sperm whale	-	-	-	-	-	0	0	23	22
Pygmy sperm whale	-	-	-	-	-	0	0	0	7
California sea lion	5,130 [2]	917	232	157	129	90	34	68	89
Harbor seal	0	0	0	158	90	23	0	0	0
Elephant seal	-	-	-	-	-	90	110	114	103
Steller sea lion	-	-	-	-	-	0	0	8	0

[1] One minke whale was caught and released alive.
[2] 1980-82 California sea lion kill was extrapolated from observed mortality and given percentage of observed sets.
[3] One sperm whale was released alive.

Pinniped bycatches and other information

Pinniped mortality information is also given in Table 2. California sea lions and elephant seals were the most common pinnipeds taken. Populations of sea lions, harbor seals and elephant seals are growing in California, despite fishery mortality.

Discussion

Reliable population estimates are now available for most of the cetacean species that are taken in this fishery (Barlow, In press). The estimated annual take rates exceed 2% of the population for several species and may not be sustainable.

(B) California set net fisheries

In California, halibut fishing with gillnets increased dramatically in the 1970s and early 1980s (Methot, 1983; Barlow, 1987). These increases were accompanied by a concurrent increase in the rate at which harbor porpoises (Szczepaniak and Webber, 1985) and seabirds (Salzman, 1989) washed ashore in the vicinity of San Francisco. Similarly, a set net fishery for angel sharks developed in southern California in the 1970s and 1980s. CDFG began observing set gillnets in central and southern California and confirmed that marine mammals were being entangled in the halibut fishery, as well as in fisheries for sharks and white seabass (Miller *et al.*, 1983). The CDFG observer program was largely discontinued in the late 1980s and was supplanted in 1990 by a mandatory NMFS observation program in the set net fisheries for halibut and angel sharks. Set net fisheries for white seabass, yellow tail, soupfin shark, white croaker, bonito and flying fish are not observed regularly.

Primary ports
The primary ports are San Diego, Oceanside, Dana Point, San Pedro, Port Hueneme, Ventura, Santa Barbara, Port San Luis, Morro Bay, Monterey, Moss Landing, Half Moon Bay, San Francisco and Bodega Bay.

Target species
The target species are halibut, angel shark and white seabass.

Area of operation
The area of operation comprises near-shore mainland and insular areas from the Russian River to the Mexican border, typically in waters less than 55m deep.

Vessels and crew
Vessels are 4–12m in length and made from wood or fiberglass. The fleet size is limited to 200 permits, 134 of which were active in 1993. Fish are typically kept on ice and are often landed each day. Crews consist of 1–3 US fishermen.

Gear specifications
Nets are monofilament, twisted monofilament or multifilament nylon with stretched mesh sizes of 20–21cm. Panels are typically 275–366m long by 20 meshes deep. Nets are floated with either a buoyant cork line or with 5cm corks every 1 or 2m. Nets are typically marked at each end with a float or with a pole and flag. Nets are hauled by hand or with a hydraulic net reel.

Operations
Trips range from 1 day (most common along the mainland) to 1 week (most common at the Channel Islands). Fishermen often fish 3–5 separate 1-panel nets. Nets are set in waters less than 91m and usually less than 55m deep. Nets are set along the bottom and are tended in the early morning. Net retrieval takes 1–2hrs. Soak times are usually 24–48hrs. Typical catches are 3–10 halibut or 10–20 angel sharks per net.

Economics and history
Ex-vessel prices range from $5/kg for halibut to $1/kg for angel sharks. Fish is sold domestically, either fresh or frozen. The net values of the landings were $2,750,000 for halibut and $2,600 for angel shark circa 1990. The set net fishery in California developed first for white seabass. This fish stock is now severely depleted in California (Methot, 1983). Set net fishing for halibut expanded in the 1970s and was followed by development of the angel shark fishery.

Total landings
Total landings in 1989 were 545 tonnes of halibut and 1 tonne of angel shark.

Effort data
In California, the number of net sets has decreased from approximately 39,000 annually in the mid-1980s to approximately 16,000 in recent years (Table 3). Much of this reduction in effort is attributed to area closures to protect marine mammals, sea birds and sport fisheries.

Interactions with cetaceans
Harbor porpoises, gray whales, Pacific white-sided dolphins, common dolphins and possibly bottlenose dolphins have been observed entangled in set nets in California. Harbor porpoise mortality in the central California halibut fishery was estimated as approximately 200–300 per year in 1983–87 and has averaged about 40 per year since 1987 (Table 3). Accurate estimates have not been made for 1989, but the minimum mortality was 53 harbor porpoises in this fishery: 38 observed deaths plus 15 stranded animals with gillnet marks (Jefferson *et al.*, 1994). One harbor porpoise was observed caught in a white croaker gillnet out of the 200 net-pulls that were observed off central California (Hanan, unpublished data). Earlier reports also mentioned the entanglement of six harbor porpoises in white seabass gillnets near Morro Bay, California. Although white seabass is no longer common in that area (Methot, 1983), Barlow (1987) speculates that harbor porpoises in central California could have been depleted by the large-scale seabass gillnet fishery in the 1950s. Gray whale mortality has been estimated as less than 10 per year, mostly occurring in southern California (Heyning and Dahlheim, In press). Heyning and Lewis (1990) document 65 records of the entanglement of baleen whales in southern California waters during the 1980s, most of which are attributed to gray whales entangled in this set net fishery. Gray whales appear most likely to be entangled in nets that are set at headlands during their northbound migration. Dead cetaceans are either brought aboard or are cut out of the nets at the water line. Live entangled gray whales typically take the net with them. Some gray whales have been freed by the removal of netting and attached lines.

Time and area closures have reduced the total level of fishing effort in the harbor porpoise range and presumably the level of incidental take. Current legislation will close waters inshore of 55m throughout the sea otter range, approximately from Waddell Creek to Point Sal. In California, a gillnet ballot initiative passed in November 1990 will result in a buy-out of set nets and the elimination of gillnet fishing within 3 n.miles of the mainland and 1 n.mile of any island in southern California by 1994. Preliminary data indicate that some fishing continues in deeper waters. Efforts have been made to reduce whale mortality by use of break-away panels, increased bridle strength and anchor weight, and decreased cork-line strength.

Local populations of harbor porpoises may have been reduced to less than 50% of their pre-fishery abundance in central California (Barlow, 1987; Barlow and Hanan, 1994). The gray whale population is continuing to increase (IWC, 1993; Buckland and Breiwick, In press).

Pinniped bycatches and other information
California sea lion mortality in this fishery has been approximately 2,000–4,000 per year and the harbor seal mortality has been 500–2,000 per year (Table 3). Populations of both species (and elephant seals) are growing in California despite this fishery mortality.

Discussion
Good information is available on the abundance and status of all species of cetaceans and pinnipeds in California waters. In fact, information on the impact of fishing mortality on marine mammal populations may be better for this fishery than for any other gillnet fishery.

Table 3

Observed and estimated fishing effort and marine mammal mortality in California's set gillnet fisheries for halibut and angel sharks from the 1983 to 1988 CDFG observer program (Diamond and Hanan, 1986; Hanan *et al.*, 1986; Hanan *et al.*, 1987; Hanan *et al.*, 1988; Hanan and Diamond, 1989; Konno, in press) and the 1990 to 1993 NMFS observer program (Lennert *et al.*, 1994; Perkins *et al.*, 1992; Julian, 1993; 1994). Missing data indicate no available estimates.

	Observation period								
From To	4/83 3/84	4/84 3/85	4/85 3/86	4/86 3/87	4/87 3/88	7/90 12/90	1/91 12/91	1/92 12/92	1/93 12/93
Effort									
Est. no. net pulls	26,210	37,155	39,104	39,497	29,623	8,070	22,300	16,900	16,300
Effort in days	-	-	-	-	-	3,041	7,089	5,468	5,380
No. observed net pulls	962	1,723	1,499	2,107	978	406	2,231	2,155	2,641
% observed net pulls	3.7%	4.6%	3.8%	5.3%	3.3%	5.0%	10.0%	12.8%	16.2%
Observed marine mammal mortality									
Harbor porpoise	14	19	33	16	13	4	5	6	2
Common dolphin	-	-	-	-	-	0	0	2	0
California sea lion	76	69	84	90	174	67	149	340	239
Harbor seal	31	66	148	103	156	30	43	93	71
Northern elephant seal	-	-	-	-	-	13	3	7	11
Southern sea otters	-	-	-	-	-	3	0	0	0
Estimated marine mammal mortality									
Harbor porpoise	303	226	227	197	34	44	38	44	12
Common dolphin	-	-	-	-	-	0	0	17	0
California sea lion	3,427	2,244	2,207	4,288	2,722	847	1,858	3,255	1,984
Harbor seal	834	1,138	1,886	2,028	903	392	559	1,136	480
Northern elephant seal	-	-	-	-	-	144	26	51	71
Southern sea otters	-	-	-	-	-	33	0	0	0

(C) Washington gillnet fisheries for salmon

Gillnets are used to catch salmon in Washington state by both Native Americans and non-native commercial fishermen. By treaty, half the surplus salmon production is allocated to Native Americans. Set nets are used by the Makah tribe in western Washington (Gearin *et al.*, 1990; 1994). The incidental take of harbor porpoises in this fishery was recognized after unusually large numbers of porpoise were found dead on beaches of the Olympic National Park (Kajimura, 1990). In 1988–89, a cooperative study was initiated between NMFS and the Makah Tribal Fisheries Management Division to study the magnitude of harbor porpoise mortality in this fishery and the size of the affected populations (Kajimura, 1990; Gearin *et al.*, 1990; 1994). Another gillnet fishery for salmon by Native Americans takes place from Semiahmoo Bay, Washington. Incidental mortality of cetaceans has been recorded in this fishery (Baird and Guenther, 1994), but little information is available.

The non-native salmon allocation is divided among sport fishing and commercial fishing. The latter includes trolling, purse seining and gillnetting which have not been covered by observer programs.

Primary ports

The primary ports are Neah Bay, Sekiu and Semiahmoo Bay (Native Americans) and Seattle, Grays Harbor, and Willapa Bay (commercial).

Target species

The target species are chinook salmon (Makah tribe) and all salmon species (non-native commercial).

Area of operation

The area of the Makah fishery is along the northwest coast of Washington state in the Pacific Ocean and in the Strait of Juan de Fuca east to the Sekiu River and including Neah Bay. The non-native commercial fishery is in the Strait of Juan de Fuca and Puget Sound, Columbia River, Grays Harbor and Willapa Bay.

Vessels and crew

The Makah fishing vessels are small, 5–7m skiffs crewed by 1–3 US fishermen (Native Americans only). The current fleet size is 6–10 boats. In the non-native commercial fishery, approximately 600 vessels fish in the Columbia River, Grays Harbor and Willapa Bay, and, although 1,146 vessels were issued gillnet permits to fish in Puget Sound in 1990, the actual number fishing is somewhat less than this. The size of commercial vessels is probably similar to those in Prince Williams Sound, Alaska (see G below) given that many vessels there also fish in Puget Sound (Wynne, unpublished data).

Gear specifications

In the Makah fishery, monofilament and multifilament nylon nets are used with a stretch mesh size of 19–22cm and a maximum length of 183m. Nets are up to 100 meshes deep. In the non-native commercial fishery, nets are 230–550m long (typically 550m), 30–180 meshes deep and have mesh sizes of 13–22cm (net configurations vary with species and area).

Operations

In the Makah fishery, nets are set along the bottom in water depths of 11–18m and are anchored at both ends. Fishermen can fish a maximum of three 183m nets. The fishing season is from 1 May to 15 September with maximum effort in July and August. Nets are usually tended each day, but are typically not picked up or moved. Soak times can exceed 48hrs due to adverse weather. In the non-native fishery, driftnets are used.

Economics and history
In the 1950s, the Makah fishery was conducted primarily in Mukkaw Bay. The effort at that time was about 10 boats with as many as 6 nets per boat and catch rates were up to 75–100 fish per night. The fishery expanded in area in the 1970s.

The non-native fishery has declined consistently since 1974, when the number of gillnet licenses in Puget Sound peaked at approximately 2,000.

Total landings
In the Makah fishery, total landings were 6,404 and 1,690 chinook salmon, respectively for 1988 and 1989. For the non-native fishery in 1991, total landings from Puget Sound were 182,040 chum, 68,702 coho, 15,771 chinook, 174,147 pink and 417,526 sockeye salmon.

Effort data
The estimated effort in the Makah fishery was 2,600 net-days in 1988 and 1,342 net-days in 1989. There are no data for the non-native fishery.

Interactions with cetaceans
The most common cetacean/fishery interaction is with harbor porpoises. Gaskin (1984) reported that in 1972, Ken Balcomb found carcasses of 19 harbor porpoises (many with net marks) on the coast of Washington, possibly killed in a salmon gillnet fishery. An observer program was begun in 1988 to monitor marine mammal bycatch in the Makah fishery. Incidental take included at least 102 harbor porpoises in 1988, 23 in 1989 and 13 in 1990 (Gearin *et al.*, 1994). The take in 1988 was thought to be abnormally high. Studies of body temperature revealed that at least some harbor porpoises entangled during daylight hours. One minke whale was also taken in 1988. Harbor porpoises were used by Native Americans for subsistence purposes. A mandatory observer program is currently monitoring marine mammal mortality in the Makah fishery, but not in the non-native commercial fishery.

Less is known about cetacean mortality in the non-native gillnet fishery. Everitt *et al.* (1979) note Dall's porpoise captures in both salmon gillnets and seines in the San Juan Islands. Flaherty and Stark (1982) note one incident of harbor porpoise mortality in a gillnet in southern Puget Sound. Osborne *et al.* (1988) also note that both harbor and Dall's porpoises are killed in salmon gillnets in Puget Sound and the San Juan Islands. Ken Balcomb (pers. comm.) has noted an increase in harbor porpoise strandings coincident with the occurrence of salmon gillnet vessels in the San Juan Islands.

The population of harbor porpoises in Washington was estimated as 9,800 (SE 4,300) in 1984 (Barlow, 1988). Subsequent surveys of northern Washington (in the immediate area of the fishery) indicated a local abundance of only 634 harbor porpoises (Calambokidis *et al.*, 1993). Harbor porpoise stock structure in this area is not well understood.

Pinniped bycatches and other information
Fishermen reported that 24 harbor seals and 1 sea otter were also taken in 1989.

Discussion
The impact of fishery mortality on harbor porpoises in this area is likely to depend strongly on porpoise stock structure. If porpoise movement between the fishing areas and the southwestern coast of Washington is limited, incidental fishing mortality could severely deplete local harbor porpoise populations. There is a need for more information on porpoise stock structure and movement patterns and for updated estimates of porpoise abundance in surrounding areas.

(D) British Columbia driftnet fishery for salmon
The salmon driftnet fishery in British Columbia has been in operation for most of the century. Fishing occurs primarily in inshore waters. Levels of take of small cetaceans and one species of large whale have been estimated for this fishery by Stacey *et al.* (1990) and Baird *et al.* (In press), respectively. Prior to these recent estimates, evidence of marine mammal bycatch came from opportunistic observations or reports by fisheries officers or fishermen. No formal observation program has been undertaken.

Primary ports
The primary ports are Vancouver and Prince Rupert.

Target species
The primary target species are sockeye, chum, pink, coho and chinook salmon.

Area of operation
Gillnet fishing is permitted in inshore waters of British Columbia, in statistical reporting areas 1–29, which are shoreward of a so called 'surfline'. Regulations may vary between statistical areas.

Vessels and crew
Vessels range from 6–21m in length, with an average of 10.2m for gillnet vessels and 11.6m for gillnet/troll combination vessels. Both bowpicker and sternpicker designs are used. Fishing is controlled by a limited entry system. In 1989 there were 3,230 license holders for gillnet fishing, of which 2,540 held combination gillnet/troll licenses. Most license holders fish every season. Fish are kept in refrigerated seawater or on ice. The crew of 1–5 are Canadian.

Gear specifications
A multifilament nylon net is used with stretched mesh sizes of 10–22cm, with an average mesh of 13cm. Mesh size varies depending on the fish species and local regulations. Except for Area 20, regulations allow panel lengths between 135–375m and net depths of 60 meshes. In Area 20, the maximum size is 550m length and 90 meshes depth. Each vessel fishes only one panel. Floats are approximately 9 x 14cm and are tied to a mixed nylon and polypropylene cork line. Typically the cork line is tied every 1.2m to a 'weed' line, from which the net is hung. The weed line is 6mm polypropylene. The net is tied approximately every 20cm to the weed line. A lead line attached to the bottom of the net is usually about 55m longer than the net and consists of a lead core with a nylon cover, weighing approximately 1 pound per fathom (about 0.25kg per metre). During daylight all nets must be marked at both ends with a plain orange or colored iridescent buoy not less than 125cm in circumference. From one hour after sunset to one hour before sunrise, net ends must be marked with a lantern giving a steady white light. No flashing lights may be used.

Operations
Fishermen remain in attendance of their nets at all times. Fishing occurs from early June to mid September and from early October to the end of November. During this time, only a limited number of fishing openings will take place. Each opening is typically for a specific run of a specific species of salmon, and the length of an opening depends on the catch of that species and on the incidental catch of species which require protection, such as chinook salmon. Openings range from 12hrs to 4 days in length. Nets are typically set in waters less than 183m in depth and are suspended from the surface. Nets are not anchored; set nets are prohibited by regulations. Gillnets cannot be used to enclose an area. Fishing usually occurs from dusk to dawn and soak times vary between 1.5–5.0hrs. Fishing times depend on the length of the opening, the time of day that the opening begins and tidal conditions.

Economics and history
Salmon is used for both domestic consumption and export. Most of the catch is canned. Pearse (1982) reviews the history and management of fisheries on the BC coast. The fishery is presently a limited-entry fishery with a relatively constant number of permits. Between 1979–1988, gillnet catches of salmon have fluctuated between 21,100 and 26,130 tonnes. Total payments to fishermen have also fluctuated but have generally increased. Between 1951 and 1988, the percentage of the total salmon catch taken by gillnets has decreased relative to other gear types, from about 40% in the 1950s to about 25% in the 1980s. Over the same time, total salmon landings have remained relatively constant. It is not known if total gillnet effort has also decreased.

Total landings
In 1988, 19,204 tonnes of salmon were taken by gillnets, including 8,966 tonnes of chum and 7,591 tonnes of sockeye salmon. The salmon fishery (including all gear types) is Canada's most valuable fishery, with an annual landed catch value in excess of $275 million in recent years.

Effort data
In 1988, the fishing effort totalled 54,770 net-days. This effort was concentrated in the periods 26 June to 30 July (25,035 days fished), 31 July to 27 August (14,028 days fished) and 25 September to 29 October (10,738 days fished).

Interactions with cetaceans
Species known to have been caught in or involved in collisions with salmon gillnet gear include harbor porpoises, Dall's porpoises, Pacific white-sided dolphins, killer whales, gray whales and humpback whales (Pike and MacAskie, 1969; Goodman, 1984; Jefferson, 1987; Langelier *et al.*, 1990; M. Bigg, unpublished data; R. Baird, unpublished data). Stacey *et al.* (1990) estimated that at least 55 harbor porpoises, Dall's porpoises and Pacific white-sided dolphins collide with gillnets each year and that between 53–62% die as a result. However, numerous biases in the methods used to derive these estimates suggest that these estimates under-represent actual numbers of gear collisions and thus total mortality. Baird *et al.* (In press) estimate that 11 gray whales collide with gillnet gear each year and that 6.3% are killed. There are only two records of humpback whale entanglement in gillnets and the fate of those animals is not known. Cetaceans are generally discarded, but in responding to a questionnaire survey (Stacey *et al.*, 1990), one fisherman reported consuming caught porpoises.

Virtually nothing is known about the local populations of the two species which appear to be most frequently taken (harbor and Dall's porpoise) and thus evaluating fishery impacts is impossible. Cowan (1988) noted that harbor porpoise populations in British Columbia could be decreasing due to mortality in gillnet fisheries. Gaskin (1992) recommended to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) that the British Columbia population of harbor porpoises be listed as 'threatened', but the Committee did not so designate the population due to insufficient information. Populations are increasing for gray whales (Buckland and Breiwick, In press) and killer whales (Olesiuk *et al.*, 1990), so takes presumably are having a small impact.

Discussion
Research into bycatches in British Columbia has been limited but has shown the presence of some levels of incidental mortality. More research is needed to determine species taken, mortality level, areas of high catches and other details.

The salmon fishery is regulated by statistical area (and sub-areas), and the length and time of openings are also regulated. Since the abundance or density of small cetaceans probably varies along the coast, it may be possible to reduce bycatches in specific areas by closures or restriction of specific localized salmon fisheries. However, for such regulations to be feasible, additional detailed information on population size and movements is necessary.

(E) Western Canadian driftnet fishery for neon flying squid
This experimental fishery (now discontinued) was undertaken to evaluate the economic viability of using large-scale drift gillnets to catch flying squid off British Columbia (BC) and in adjacent international waters. Although an early report did not refer to marine mammal mortality (Bernard, 1981), later reports confirmed that marine mammals were caught each year (Jamieson and Heritage, 1987). The study concluded that commercially exploitable densities of flying squid did exist off BC, but that bycatch problems would probably have to be resolved before a commercial fishery could begin (Jamieson and Heritage, 1988).

Target species
The experimental fishery only targeted neon flying squid.

Area of operation
Fishing generally took place in Canadian and international waters from northern BC (approximately 54°N) to southern Oregon (approximately 42°N), between 50–300 miles off the BC coast and 200–300 miles off the US coast.

Vessels and crew
Five vessels were used, ranging from 22–55m: one Canadian tuna vessel, two Japanese squid vessels and two Canadian freezer blackcod trap vessels. Two vessels fished in 1980 and 1983, one in 1985, three in 1986, and two in 1987. Crews ranged from 7–27 and were Canadian and Japanese.

Gear specifications
Eight-gauge nylon monofilament nets were used with stretched mesh sizes of 11–12cm. On the Japanese vessels, panels were 48–50m long and 8.5m deep. On one of the

Canadian vessels, two panel lengths were used: 100 and 200m, both being 7.2m deep. The average net length fished by the Japanese vessels was about 45km and net lengths for the three Canadian vessels were about 19, 12 and 4km. Float information is only available for one of the Japanese vessels. It used 220g floats at approximately 1m intervals along a 5mm polypropylene float line. Radio buoys were set at the ends of each group of panels.

Operations

Fishing occurred from mid June through early September. The Japanese vessels remained in the fishing area the entire period, whereas the Canadian vessels left periodically to unload catches. Fishing occurred outside the 1,830m depth contour to minimize bycatch of salmon. On the Japanese vessels, 220–250 panels were set in calm weather and 110–125 panels in rough weather. Nets were suspended from the surface and were free to drift. Nets were pulled at first light after soak times of approximately 12hrs. The Japanese vessels could retrieve an average of 3.8km of net per hour. The Japanese vessels averaged 232kg of squid per km of net per night.

Economics and history

The fishery was concluded to be economically feasible but was discontinued largely due to the high levels of marine mammal bycatch found in the small experimental fishery.

Total landings

Squid landings in 1987 were greater than 1,500 tonnes (Jamieson and Heritage, 1988).

Effort data

Effort was reported as 1,474, 2,475, 4,307 and 4,417km net-nights in 1983, 1985, 1986 and 1987, respectively (Jamieson and Heritage, 1988).

Interactions with cetaceans

Species taken included Dall's porpoise, northern right-whale dolphin, Pacific white-sided dolphin, killer whale, short-finned pilot whale, an unidentified *Stenella* sp., and Cuvier's beaked whale. [Although Jamieson and Heritage (1988) note a single harbor porpoise taken, the great depth at which this would have occurred and the tentative nature of the identification given by the original observer (field notes provided by G.D. Heritage) lead us to conclude that it was not a harbor porpoise.] Cetaceans were not feeding on fish or squid in the net, but rather appeared to blunder into the net without detecting its presence (Jamieson and Heritage, 1988). From observer field notes provided by D. Heritage (Department of Fisheries and Oceans, Nanaimo, BC), animals were caught in all areas of the net. Those close to the cork line were occasionally alive and were released. Twenty individuals were released alive; 145 were caught and killed (Table 4). The mortality rate varied greatly with year and vessel, with a range of 0.03 to 0.001 cetaceans per km net-night and with a mean of 0.012 per km net-night. Typically, dead cetaceans would tear the net and fall out during net retrieval. Dead cetaceans were not utilized. Details on animals caught and released alive are presented by Baird and Stacey (1991; 1993) and Stacey and Baird (1991).

Jamieson and Heritage (1988) noted that one of the eight net groups operated by one of the Japanese vessels during 1987 had 20 consecutive tans (1km of net) with 2 meshes of hollow-core 3-thread filament woven into the 80-mesh deep net at meshes 39 and 40. The rationale was that air trapped inside the thread might improve detection of the net by marine mammals by presenting a stronger acoustic target. This net group was fished on 17 nights, but no information was presented on catches in that section of the net.

Table 4

Cetacean mortality in the British Columbia experimental squid fishery (from Jamieson and Heritage, 1988). Animals caught and released are not included.

Species	1983	1985	1986	1987
Dall's porpoise	3	1	33	58
Short-finned pilot whale	1	-	5	3
Pacific white-sided dolphin	-	1	3	16
Harbor porpoise	2	-	-	1
Northern right-whale dolphin	-	-	4	9
Killer whale	-	-	2	-
Cuvier's beaked whale	-	-	1	-
Stenella sp.	-	-	-	1
Unidentified	-	-	2	-
Total	6	2	50	87

Pinniped bycatches and other information

Two northern fur seals and one Steller sea lion were recorded killed in this fishery.

Discussion

If this fishery is ever started again, it is clear that the potential is great for significant impact on marine mammal populations. Any additional fishing of this type should be carefully monitored. Before this should be allowed, more information is needed on the size and status of the affected populations.

(F) Yakutat and southeastern Alaska gillnet fisheries for salmon

Gillnet fishing for salmon is allowed only with set nets in the Yakutat district and only with driftnets in the southeastern Alaska district.

Primary ports

The primary ports are Sitka, Ketchikan, Petersburg, Haines, Juneau and Yakutat.

Target species

All five species of Pacific salmon are targetted, with primarily sockeye and chum in southeastern Alaska and sockeye and coho in Yakutat.

Area of operation

Operations are carried out in inshore waters of southeastern Alaska and between Cape Yakataga and Cape Fairweather.

Vessels and crew

In southeastern Alaska, vessels are typically 7–11m with a crew of 1–3 US fishermen. In Yakutat, small skiffs are run by 1–2 US fishermen, but some nets are also operated from shore without use of boats.

Gear specifications

For southeastern Alaska driftnets, the maximum net length varies from district to district, but is between 388 to 550m. Maximum depth is 60 meshes for nets with less than 20cm mesh and 40 meshes for nets with 20cm or larger mesh. For Yakutat set nets, the maximum length varies from 27m per net to 137m in aggregate for three nets. Maximum net depth is 45 meshes for nets with mesh size <20cm and 35 meshes for sizes >20cm.

Operations
Only driftnets are allowed in southeastern Alaska and only set nets are allowed in the Yakutat district. One net is fished by each vessel and the vessel must remain in attendance of the net. The drift gillnet season typically starts on the third Sunday in June and closes in late September or early October. Weekly fishing hours are set by emergency order, but typically last from Sunday through Wednesday and Sunday through Tuesday in northern and southern areas, respectively. Native Americans manage their own fisheries within 92 miles of the Annette Island Indian Reservation, where they use gillnets and purse seines. In the Yakutat area, seasons vary by district, but typically run in June through September, subject to emergency closures.

Economics and history
The value of landings varies annually and by species. Total earnings, in thousands of dollars, in 1987 and 1988 are given in Table 5.

Table 5
Total earnings ('000s$) in the Yakutat and southeastern Alaska fisheries for salmon, 1987 and 1988.

	Southeastern Alaska		Yakutat	
Species	1987	1988	1987	1988
Chinook	144	259	54	35
Sockeye	9,718	13,440	3,079	3,158
Coho	2,168	3,895	1,378	4,916
Pink	3,013	3,527	15	274
Chum	6,072	14,269	61	317
Total	$21,115	$35,390	$4,586	$8,701

Total landings
Yakutat landings were approximately 254,000 sockeye, 122,000 coho, 14,000 chum, 13,000 pink, and 1,750 chinook salmon for 1987 and 158,000 sockeye, 188,000 coho, 27,000 chum, 109,000 pink, and 870 chinook salmon for 1988.

Effort data
As in other Alaska salmon fisheries, effort is controlled by limited entry and by monitoring salmon escapement. There are 164 permanent permits in the Yakutat set net fishery and 468 permanent permits in the southeastern Alaska driftnet fishery. In Yakutat, the total number of permits fished in 1987 and 1988 were 154 and 159, respectively. For southeastern Alaska, the totals were 466 and 471, respectively.

Interactions with cetaceans
There have been no observer programs or other directed studies of marine mammal entanglement in gillnet fisheries in this part of Alaska. The NMFS Alaska Regional office in Juneau collects reports regarding marine mammal entanglement in gillnets and other fishing gear (NMFS, Alaska Region and Northwest Region, unpublished data). Since 1984, there have been 19 reports of humpback whale entanglement, of which 17 were in fishing gear (8 in gillnets, 4 in longlines or buoy lines, and 5 in unidentified gear). Eleven of these whales were freed by fishermen or volunteers, 1 freed itself, 1 died in a gillnet and 4 reports were unconfirmed with unknown outcome. The other two non-fishing entanglements were with abandoned logging gear and a boat anchor line. Six of the entanglements (including one death) occurred between 22 June and 22 July, 1987 in Upper Lynn Canal, south of Haines, Alaska. This anomalous situation probably resulted from an exceptionally dense aggregation of whale forage, probably sandlance, in an area of high gillnet effort. There were no reports of whale entanglement in Upper Lynn Canal in other years. In addition to humpback whales, one gray whale died in a stranding or entanglement incident at the mouth of the East Alsek River. The whale apparently followed schools of capelin over a sand bar at an extreme high tide and became entangled in set gillnets inside the sandbar. It was not clear whether the whale could have avoided stranding if it had not become entangled. There are anecdotal reports from individual fishermen of porpoise entanglements, probably both harbor and Dall's porpoises. Most may be released with little or no harm, but some may be killed. The opportunistic reports probably underestimate the total level of marine mammal entanglement.

In logbook reports submitted to NMFS for 1990 through 1992, fishermen reported 13 Dall's porpoise, 8 harbor porpoise, 1 Pacific white-sided dolphin and 8 unidentified cetaceans killed in the southeast Alaska driftnet fishery and no cetaceans in the Yakutat set net fishery (NMFS, unpublished data).

Pinniped bycatches and other information
Fishermen have reported one harbor seal, one sea otter and one northern elephant seal as being taken in gillnet fisheries in southeastern Alaska (NMFS, Alaska Region and Northwest Region, unpublished data). Previously, in response to harbor seal depredation of the salmon gillnet catch near the Stikine and Taku Rivers in southeastern Alaska during the 1940s and 1950s, resource managers hired seal hunters and levied bounties on seals (Imler and Sarber, 1947).

In 1990–92 NMFS logbooks, fishermen in southeastern Alaska reported 2 northern sea lions, 1 unidentified sea lion and 6 harbor seals killed in drift gillnets, and Yakutat fishermen reported, 12 harbor seals and 18 spotted seals killed in set gillnets (NMFS, unpublished data).

Discussion
There is a need for more information on cetacean entanglement in this fishery. There is no plan for an observer program to monitor marine mammal interactions in this fishery.

(G) Prince William Sound driftnet and setnet fisheries for salmon
The driftnet fishery includes areas from Prince William Sound to the Copper River Delta, Alaska. Marine mammal interactions with salmon driftnet fishermen on the Copper River Delta have existed for decades and have been relatively well documented. The setnet fishery occurs in western Prince William Sound.

Primary ports
The primary ports are Cordova, Whittier and Valdez, AK.

Target species
The target species are sockeye, chinook, chum, pink and coho salmon.

Area of operation
Operations take place in northwest Prince William Sound and the Copper/Bering River Delta.

Vessels and crew
Driftnet vessels are usually 7–11m long and made of fiberglass or aluminum. Both bowpicker and sternpicker designs are used. The crew is usually 1–2 US fishermen. Set nets are typically tended by small, open skiffs.

Gear specifications
In the driftnet fishery, multifilament nylon nets are used with stretched mesh sizes of 12–18cm. Vessels fish only one net panel which is a maximum of 275m long and is typically 90–240 meshes deep (8–27m). Late in the season when the sun is lower, beacons are required to mark the ends of the net during night sets. Driftnets are hauled with a net reel. Set nets are typically hauled and tended by hand.

Operations
Durations of fishing trips are dependent on Alaska Department of Fish and Game (ADF&G) openings (allowable fishing periods); openings are variable depending on the time of year and run strength, but may generally be from 12hrs to 7 days long. Typically there are less than 30 openings per season. Driftnets are fished at the surface in waters less than 366m (Prince William Sound) or less than 128m (Copper River Delta). Vessels are not allowed to anchor and must remain in attendance of their net. Nets may be set throughout the day, but fishing may be limited by tides in some areas. Soak times are typically 15 minutes to 5hrs. It may take 15–90 minutes to haul the net, depending on the catch. The catch is typically 0–1,000 fish per set. Set nets are hung from the surface, anchored at one end and set roughly perpendicular to shore.

Economics and history
Prices for landings vary annually and by species. In 1990, the average prices were $5.28/kg for sockeye salmon, $0.66/kg for pink salmon and 2.20/kg for coho salmon. The total ex-vessel value for the driftnet catch was $35.5 million in 1988. Fish are processed locally as fresh, frozen and canned salmon (and roe) and are shipped to domestic and foreign markets. Salmon originally released from hatcheries constitute 50–70% of the fish harvested in recent years.

Total landings
Combined landings for Prince William Sound and the Copper River Delta are given in Table 6.

Table 6

Combined landings (number of fish caught) for Prince William Sound and the Copper River Delta, 1988 and 1989.

Species	1988	1989
Chinook salmon	31,366	31,336
Sockeye salmon	724,619	1,171,335
Coho salmon	421,203	276,456
Pink salmon	1,562,221	705,431
Chum salmon	562,200	199,754
Total	3,304,609	2,384,312

Effort data
Effort in Alaskan commercial salmon fisheries is controlled by 'limited entry'. There are 550 permit holders for the Prince William Sound/Copper River driftnet fishery and 30 permit holders for the set net fishery. Of the driftnet permit holders, 519 reported landings in 1987 and 525 reported landings in 1988.

Interactions with cetaceans
Cetacean interactions in this fishery involve harbor porpoises, Dall's porpoises, killer whales and humpback whales. The larger cetaceans reportedly swim through the nets. There have been no documented deaths of large cetaceans. Porpoises get entangled in the net, but some 50% of harbor porpoises and 33% of Dall's porpoises are reportedly released alive (Matkin and Fay, 1980; Wynne, 1990; Wynne *et al.*, 1991; 1992). Harbor porpoises are generally not badly entangled and are easily rolled out of the net. Dall's porpoises are more severely entangled and often have to be cut from the gear. Porpoises are generally not brought aboard due to the limited size of the vessels. One entangled humpback whale calf was released when two vessels applied tension at each end of the net.

Twelve of 31 harbor porpoise carcasses examined from the Copper River Delta between 1988 and 1993 bore net marks indicating that they had been entangled (Wynne, 1990; Wynne *et al.*, 1991; 1992). The cause of death for the remaining specimens could not be determined. Matkin and Fay (1980) estimated that 58 harbor porpoises and 31 Dall's porpoises were killed in the salmon driftnet fishery in 1978. Based on dockside interviews in 1988, Wynne found no harbor porpoises taken in 67 trips, a rate that is not significantly different from that obtained by Matkin and Fay in 1978 (4 taken in 179 trips) ($p > 0.1$). Total marine mammal mortality was not estimated in the 1988 study due to clumped distributions and small sample sizes. A manditory observer program monitored marine mammal mortality in the Prince William Sound fisheries in 1990 (setnet and driftnet) and in 1991 (driftnet only). No marine mammal entanglements were observed during more than 300 hours of setnet monitoring. In 1990, 2 harbor porpoise entanglements (one dead, one released alive) were documented in 3,166 observed driftnet sets. The extrapolated mortality estimate was 8 harbor porpoise for the observed portion of the 1990 season (Wynne *et al.*, 1991). In 1991, 7 porpoise entanglements (4 dead, 3 released alive) were documented in 5,875 observed sets. Extrapolated across the driftnet fishery, an estimated 43 harbor porpoise died incidentally in this fishery in 1991 (Wynne *et al.*, 1992). In 1990–92 logbooks, fishermen also reported the catch of Dall's porpoise, white-sided dolphin and common dolphin in this fishery (NMFS, unpublished data).

Both harbor and Dall's porpoise are common in this area, but the impact of fishery interactions on their populations is unknown. In 1993, NMFS conducted aerial surveys to determine their abundance in this area, but estimates are not yet available.

Pinniped bycatches and other information
Matkin and Fay (1980) estimated total pinniped mortality as 516 harbor seals and 333 Steller sea lions (including both incidental and intentional take). Ten years later, Wynne (1990) found that the rate of intentional pinniped take was much reduced. Data from 1990 and 1991 observer programs indicate that pinniped interactions are frequent with driftnets on the Copper River Delta but are rarely

lethal. Lethal entanglements of 3 harbor seals and 1 Steller sea lion were recorded during 3,166 sets observed in 1991 for the Prince William Sound/Copper River Delta areas. Mean estimates of total pinniped mortality were 36 in 1990 and 27 in 1991 (Wynne *et al.*, 1991; 1992). In 1990–92 logbooks, fishermen also reported lethal entanglements of northern fur seals (2) and a sea otter.

Discussion
Entanglement and driftnet related cetacean mortality in this fishery appears limited to smaller species, primarily harbor porpoises. Although entanglement appears to be infrequent and is not necessarily fatal, assessment of its impact requires a better understanding of the populations' abundance, status and trends.

(H) Cook Inlet driftnet and set net fishery for salmon
Cook Inlet supports a large driftnet fishery and a set net fishery, both for salmon. Little is known about marine mammal entanglement in these fisheries.

Primary ports
The primary ports are Kenai, Kasilof, Homer and Ninilchik, Alaska.

Target species
The main target species is sockeye salmon (and to a lesser degree the other four species of Pacific salmon).

Area of operation
Driftnets are used in the central district of upper Cook Inlet, from the latitude of Anchor Point northward to the latitude of Boulder Point. Set nets are used along most of the shoreline of Cook Inlet.

Vessels and crew
Driftnet vessels range in length from 7–22m. Smaller vessels are typically made of aluminum and larger vessels of wood or steel. Crews range from 1 to 5 US citizens. Set net vessels are primarily small skiffs operated by 1–2 US fishermen.

Gear specifications
For driftnets, the maximum net size is 275m long by 45 meshes deep. The maximum mesh size is 15cm and typical size is 13cm. For set nets, the maximum length is 64m per net and with a maximum of 192m in aggregate. The maximum mesh size and net depth is the same as for driftnets in this area.

Operations
Only one driftnet is fished by each vessel and the vessel must remain in attendance of the net. The fishing season is from 25 June to September, but most fishing stops in mid-August. Typically there are only two 12-hour openings each week when fishing is allowed. The length and frequency of these openings can vary with the strength of the salmon run.

Economics and history
The value of landings varies annually and by species. Total earnings, in thousands of dollars, in 1987 and 1988 are given in Table 7.

Total landings
A total of 2,300,000 sockeye salmon was landed in 1990.

Table 7

Total earnings ('000s$) in the Cook Inlet driftnet and setnet fishery for salmon, 1987 and 1988.

	Drift gillnets		Set gillnets	
Species	1987	1988	1987	1988
Chinook	192	124	1,359	1,326
Sockeye	59,962	71,004	38,852	44,390
Coho	1,001	2,645	1,288	2,844
Pink	32	406	64	572
Chum	584	3,926	381	804
Total	$61,772	$78,103	$41,944	$49,936

Effort data
As in other Alaska salmon fisheries, effort is controlled by limited entry and by careful monitoring of salmon escapement. There are 560 permanent permits in the Cook Inlet driftnet fishery and 743 permanent permits in the set net fishery.

Interactions with cetaceans
There have been no studies of marine mammal entanglement in gillnet fisheries in Cook Inlet. White whales and harbor porpoises have been entangled in drift and set gillnets (NMFS, Alaska Region, unpublished data). In logbooks, fishermen reported 1 Dall's porpoise killed in gear in 1990 and none in 1991 (NMFS, unpublished data). The levels of mortality, release or overall take are not known.

Pinniped bycatches and other information
Earlier, pinniped conflicts led to bounties in the 1950s and an initial quantification of numbers of salmon damaged by pinnipeds (Imler and Sarber, 1947). Recently, incidental takes of harbor seals and Steller sea lions have been reported (NMFS, Alaska and Northwest Region, unpublished data). There were no pinnipeds reported killed in fishery logbooks for 1990 and 1991 (NMFS, unpublished data).

Discussion
Clearly there is a need for more information on cetacean entanglement in this fishery. The relatively small, geographically isolated stock of white whales is of particular concern. There is no plan for an observer program to monitor marine mammal interactions with this fishery.

(I) Kodiak, Alaska Peninsula and South Unimak driftnet and set net fisheries for salmon
Salmon gillnet fisheries exist around Kodiak Island (set nets) and along the Alaskan Peninsula (both set nets and driftnets).

Primary ports
The primary ports are Kodiak, King Cove, False Pass, Sand Point and Port Moller, Alaska.

Target species
The main target species is sockeye (and to a lesser degree chum and pink) salmon.

Area of operation
Gillnets are allowed in the region of Kodiak Island and along the northern shoreline of the Alaska Peninsula from the South Unimak area to Ugashik Bay. The South Unimak fishing zone is a sub-set of the Alaska Peninsula and includes coastal areas within 10 miles of Cape Lutke and along both sides of the Ikatan Peninsula, from Cape Pankof to Cape Lazaref.

Vessels and crew
Driftnet vessels are typically 9–14m in length and have crews of 3 US fishermen. Set net vessels are primarily small skiffs with 1–2 US fishermen.

Gear specifications
Drift gillnets are less than 366m in length and must have a stretched mesh size greater than 13cm. Set nets have a maximum length of 183m with an aggregate length of 275m (Kodiak area) and 92 to 366m (along different regions of the Alaska Peninsula).

Operations
Only set nets are allowed in the Kodiak region, only driftnets in the South Unimak area, and both set and driftnets along the Alaska Peninsula. The fishing season is open from early June to late October (Kodiak) or to September (Alaska Peninsula). The South Unimak fishery is limited to June and July. Fishing is subject to openings and closings by emergency order.

Economics and history
Value of landings varies annually and by species. No information on total landings is available. Total earnings, in thousands of dollars, in 1987 and 1988 are given in Table 8.

Table 8

Total earnings ('000s$) in the Kodiak, Alaska Peninsula and South Unimak driftnet and setnet fisheries for salmon, 1987 and 1988.

	Kodiak set gillnet	
Species	1987	1988
Chinook salmon	4	29
Sockeye salmon	5,638	12,428
Coho salmon	190	415
Pink salmon	914	6,678
Chum salmon	376	1,752
Total	$7,121	$21,303

	Alaska Peninsula (including South Unimak)			
	Drift gillnets		Set gillnets	
	1987	1988	1987	1988
Chinook	194	173	87	114
Sockeye	13,694	20,939	6,118	7,194
Coho	597	1,304	648	1,315
Pink	8	489	90	841
Chum	1,145	2,958	286	773
Total	$15,637	$25,864	$7,229	$10,238

Effort data
Effort in Alaskan commercial salmon fisheries is controlled by 'limited entry'. There are about 187 permanent permits in the Kodiak area and 158 permits for the Alaska Peninsula area. Anyone with an Alaska Peninsula permit can fish in South Unimak. The number of boats actually fishing in South Unimak may reach 140–150 in June and usually drops to 50 in July. Allowable fishing periods (openings) are variable depending on the time of year and run strength, but may generally be from 12–72hrs long.

Interactions with cetaceans
Previous records of entanglement exist for gray whales and harbor porpoises in the South Unimak or Alaska Peninsula (NMFS, Alaska Region, unpublished data). This fishery had a mandatory observer program in 1990. The extrapolated estimate of cetacean mortality in this driftnet fishery was 28 Dall's porpoises in 1990 (Wynne *et al.*, 1991). In 1990–92 logbooks, fishermen also indicated that harbor porpoises were taken in driftnet and setnet fisheries (NMFS, unpublished data).

Pinniped bycatches and other information
In observed sets in 1990, one Steller sea lion and two northern fur seals were briefly entangled, but each broke free unharmed (Wynne *et al.*, 1991). Fishermen's logbooks also indicate that harbor seals, spotted seals and sea otters were killed in setnet and driftnet fisheries in this area (NMFS, unpublished data).

Discussion
Little is know about marine mammal mortality in these fisheries. Except for the small area in the vicinity of South Unimak, there is no plan for an observer program.

(J) Alaskan trawl fishery for pollock and other groundfish
Although the Alaskan trawl fishery for groundfish does not use passive fishing gear and is therefore outside the intended purview of this report, this huge fishery generates massive quantities of lost and discarded net which then acts as passive fishing gear. Some direct marine mammal mortality occurs in addition to entanglement in discarded gear (Loughlin *et al.*, 1983).

Primary ports
The primary ports are Dutch Harbor, Kodiak and Akutan, Alaska.

Target species
The main target species are pollock (approximately 70% by weight), cod (approximately 10%) and various flatfish.

Area of operation
Operations take place in Bristol Bay and other regions in the Bering Sea, and in the Gulf of Alaska, including Shelikof Strait.

Vessels and crew
Trawling vessels are up to 92m long and are of steel construction. Larger vessels have on-board processing capabilities. Smaller vessels take their catch to factory ships or land it in Alaska. Currently most of the vessels are US owned and operated. The at-sea catcher-processor fleet produces frozen pollock filets. During the spawning season, roe is frozen and sent to Japan. The shore-based catcher vessels produce frozen filets and fish paste for *surimi*.

Gear specifications
Trawl nets have a mouth opening of approximately 92m by 69m.

Operations
Vessels use acoustic methods to find dense schools of pollock. Trawlings is conducted both in mid-water and on the bottom.

Economics and history
Since the 1930s, this fishery has evolved from (1) being primarily a Japanese far-seas fishery, to (2) being an international fishery with vessels from Japan, the former Soviet Union, Korea and Taiwan, to (3) being a US/ Japanese joint venture, to (4) an entirely US fishery. It is currently the largest single-species fishery in the world. More than 20,000 residents of Alaska and Washington are employed in catching and processing pollock, and the total annual landings are worth approximately $200 million.

Total landings
The current quota on landings of Alaskan pollock is 2,200,000 tonnes. The actual US landings were 230,000, 590,000 and 1,100,000 tonnes for the years 1987, 1988 and 1989, respectively. These landings were worth $45 million, $95 million and $187 million, respectively. The joint-venture landings during the same time decreased from about 900,000 to 270,000 tonnes. In addition to this catch in the western North Pacific, the catch of pollock in the eastern North Pacific is about 3,000,000 tonnes (Northridge, 1984).

Effort data
Effort has increased substantially since the early 1980s. Total landings (joint-venture and US combined) increased from roughly 45,000 tonnes in 1981 to approximately 1,400,000 tonnes in 1988 and 1989.

Interactions with cetaceans
In the past, marine mammal take in the pollock trawl fishery was monitored only on foreign and joint-venture vessels. Prior to 1985, this included virtually all vessels. Cetaceans that have been observed taken between 1986 and 1988 (NMFS, unpublished data) include Dall's porpoises (20), killer whales (2), Pacific white-sided dolphins (3), harbor porpoises (3) and other unidentified cetaceans (18). There has been no evidence of cetacean entanglement in discarded netting, but it should be considered as a possible additional source of mortality.

Pinniped bycatches and other information
The direct catch of Steller sea lions has been observed in the trawl nets. Steller sea lion populations have been declining and this species is currently listed as threatened under the US Endangered Species Act. The cause of the decline is not known, but possible causes include resource depletion by overfishing, incidental mortality in trawl and gillnets, shooting, disease, predation, or combinations of the above. Of the pinnipeds, only Steller sea lions have been caught in substantial numbers in pollock trawls (Lowry *et al.*, 1989). The number of Steller sea lions caught and killed in groundfish trawls averaged 724 from 1978–81, 1,436 in 1982, 324 in 1983, and 355 in 1984 (Loughlin and Nelson, 1986). Direct catch in trawls has also been observed (NMFS, Alaska Fisheries Science Center) for California sea lions (1), northern fur seals (48), northern elephant seals (3), harbor seals (36), spotted seals (3), ringed seals (17), bearded seals (4) and walrus (76). Entanglement in discarded trawl net fragments may be an important factor in the decline of the Pribilof Islands population of fur seals (Fowler, 1982) and may account for an extra 15–20% mortality of juvenile fur seals (Fowler, 1985). Net fragments have also been seen on Steller sea lions (Loughlin *et al.*, 1986). Simultaneous with the development of the fishery was a precipitous decline in Steller sea lion populations in the Gulf of Alaska and Aleutian Islands, from 140,000 in 1960 to 25,000 in 1989 (Loughlin *et al.*, 1990). The direct Steller sea lion mortality is insufficient to explain the marked population decline; however, the effects of the fishery on sea lion prey abundance has been implicated as a potential cause of the decline.

Discussion
Discarded trawl nets and lines litter the beaches on many sites in the Aleutian Islands, Alaska (Merrell, 1985). Seventy-five beaches were examined on 21 Aleutian Islands in 1988–90 in a study on the impact of plastic debris on wildlife (A. Manville, unpublished data; Manville, 1990). Fishing-related debris was found to be the most prevalent form of plastic on the beaches. Fishing debris on these 75 beaches included 4,283kg of rope, 120kg of driftnet buoys, and 6,053kg of fishing net (95% of the net debris was from trawl nets). Although this beach survey found 3 Steller sea lions entangled in plastic debris, in all cases it was strapping bands and not fishing gear. Given the isolated nature of most of these islands, the large quantity of fishing-related debris found on these beaches and indications of the continued loss and/or discard of fishing-related gear, the potential for marine mammal entanglement in passive fishing debris is great. The danger is probably much greater for pinnipeds than for cetaceans.

US vessels are required to have mandatory observers on a subset of their trips. The observed incidental take in 1989 included 5 Steller sea lions, 1 Dall's porpoise and 1 ringed seal. These estimates have yet not been extrapolated to the entire US fleet. In the same year, the observer coverage on the joint-venture fleet was approximately 95% and the bycatch included 3 Steller sea lions, 1 fur seal and 1 unidentified marine mammal.

(K) Bristol Bay set net and driftnet fisheries for salmon
A large, intensive fishery for salmon occurs in the northeastern part of Bristol Bay.

Primary ports
The primary ports are Dillingham, Egegik and Naknek, Alaska.

Target species
The main target species is sockeye salmon, but coho, pink, chum and chinook salmon are also taken.

Area of operation
Operations take place principally in Nushagak and Kvichak Bays and adjacent coastal waters along the Alaska Peninsula.

Vessels and crew
Set net boats are small skiffs crewed by 1–2 US fishermen. Driftnet boats are limited to a maximum of 10m in length and are crewed by 2–4 US fishermen.

Gear specifications
Multifilament nylon gillnets are used with maximum stretch mesh of 11 to 17cm (depending on season). Maximum net length is 183m for set nets and 275m for driftnets. Maximum depth is limited to 29 meshes. Marker floats are required on the free end of the net.

Operations
Set nets are laid perpendicular to shore and are anchored at the seaward end. Some nets are set slightly offshore (<183m) and anchored at both ends. Driftnets must remain attached to the boat on one end with a buoy on the other, free end. All nets float at the surface. Soak times and durations of fishing periods are dependent on fishing conditions and current regulations.

Economics and history
This area has the largest run of sockeye salmon in Alaska and the fishery is consequently large. Most of the fish are frozen, but some are canned or sold fresh. Chinook salmon are important earlier in the year. Fish are sold to both domestic and foreign markets. Value of landings varies annually and by species. Total earnings, in thousands of dollars, in 1987 and 1988 are given in Table 9.

Table 9

Total earnings ('000s$) in the Bristol Bay setnet and driftnet fisheries for salmon, 1987 and 1988.

	Drift gillnets		Set gillnets	
Species	1987	1988	1987	1988
Chinook	1,402	699	372	237
Sockeye	115,696	168,098	18,015	24,920
Coho	134	1,101	193	1,041
Pink	-	782	-	424
Chum	2,643	2,340	332	387
Total	$119,875	$172,991	$18,912	$27,009

Total landings
Combined landings for set and driftnet fisheries were 16,048,000 sockeye, 69,000 coho, 1,510,000 chum and 77,000 chinook salmon for 1987; 14,010,000 sockeye, 187,000 coho, 1,475,000 chum, 922,000 pink and 45,000 chinook salmon for 1988. Total landings in 1989 were 80,557 tonnes for all salmon species.

Effort data
Effort in Alaskan commercial salmon fisheries is controlled by 'limited entry'. There are 943 permanent permit holders for the Bristol Bay set net fishery and 1,746 permanent permit holders for the Bristol Bay driftnet fishery. Allowable fishing periods (openings) are variable depending on the time of year and run strength, but may generally range from 12hrs to 7 days long. Fisheries are managed based on escapement goals, so after the desired escapement is achieved the fishery may be open continuously.

Interactions with cetaceans
A group of about 1,000–1,500 white whales occur in this area, some of which are incidentally caught in gillnets (Brooks, 1954; 1955; Frost *et al.*, 1984). There is no systematic program for measuring the level of take, but studies conducted in 1982–83 suggested that about 10–20 whales per year were killed. Most mortality seems to occur in the chinook salmon fishery which uses larger mesh sizes. Evidence indicates that the white whale population's distribution and abundance was largely the same in 1984 as it was 30 years earlier (Frost *et al.*, 1984). Some take of harbor porpoises is also likely in this fishery.

Non-lethal harassment was used from 1956–72 to displace the white whales which feed on sockeye salmon adults and smolt (Frost *et al.*, 1984). White whales are thought to consume less than 1% of the commercial catch of sockeye salmon and less than 5% of the total smolt production; however, they may consume up to 9% of the commercial catch of other salmon species (Frost *et al.*, 1984).

Fishermen logbooks for 1990–92 indicate that other species are occasionally killed, including the common dolphin, northern right whale dolphin and gray whale.

Pinniped bycatches and other information
Logbook data for 1990–92 show the deaths of 18 harbor seals and 1 spotted seal (NMFS, unpublished data).

Discussion
The group of white whales in Bristol Bay is usually considered to be a separate stock that numbers in excess of 1,000 animals. Although available data suggest that numbers have been stable and that incidental take has not affected the stock, there are suggestions that the level of take has increased since the 1950s. This warrants further study.

(L) Northern Alaska set net fisheries
Harbor porpoises are sometimes taken in gillnets that are set for salmon (and other fish) in Norton Sound, Kotzebue Sound and other areas north of Bristol Bay. Most fisheries interactions are likely to involve pinnipeds, including harbor, spotted, ringed and bearded seals, although there are no published records that describe this interaction.

Primary ports
The primary ports are Nome, Unalakleet, Golovin and Kotzebue, Alaska.

Target species
The main target species are coho, chum and chinook salmon.

Area of operation
Operations are primarily in coastal waters of Norton Sound and Kotzebue Sound.

Vessels and crew
The small skiffs used are crewed by 1–2 US fishermen.

Gear specifications
Mostly multifilament nylon gillnets are used. In Norton Sound, nets have a maximum stretch mesh of 11 or 15cm (depending on season). The maximum length is 183m. In Kotzebue Sound, there are no limitations on mesh size and nets are a maximum of 275m long. There are no restrictions on net depth. Floats are required on the free end of the net.

Operations
Nets are set perpendicular to shore and are anchored at the seaward end. All nets are floating at the surface. Soak times and durations of the fishing season depend on fishing conditions and current regulations.

Economics and history
Subsistence-caught fish are for personal use but may be bartered. Commercially-caught fish are sold to both domestic and foreign markets and may be sold fresh, canned, smoked or frozen. Price and ex-vessel value vary

considerably depending on run strength and market conditions. Value of landings varies annually and by species. Total earnings, in thousands of dollars, in 1987 and 1988 are given in Table 10.

Table 10

Total earnings ('000s$) in the northern Alaska setnet fisheries in 1987 and 1988.

Species	1987	1988
Chinook salmon	6,787	6,880
Sockeye salmon	1,706	2,134
Coho salmon	2,818	7,158
Pink salmon	1	69
Chum salmon	3,382	13,046
Total	$14,694	$29,287

Total landings
In 1989, catches of all salmon species amounted to 337 tonnes in Norton Sound and 989 tonnes in Kotzebue Sound.

Effort data
Effort in Alaskan commercial salmon fisheries is controlled by 'limited entry'. There were 1,952 permanent permit holders in 1987 for the Kuskokwim, Lower Yukon, Norton Sound, and Kotzebue management areas. Fishing periods (openings) are variable depending on the time of year and run strength, but may generally be from 12hrs to 7 days long. Harvests are continually monitored and fishing hours in particular areas are controlled by emergency order to achieve escapement goals.

Interactions with cetaceans
Harbor porpoises are occasionally entangled and drowned. ADF&G has recorded 7 instances during 1981–87 in the area from Nome to Unalakleet and 3 near Kotzebue in 1989–90. One harbor porpoise was even caught in a net set at Barrow (Hall and Bee, 1954). There is no formal program of monitoring and reporting.

Pinniped bycatches and other information
No pinniped bycatch has been reported, but some catch of spotted seals is likely. Any pinnipeds that are taken are likely to be used by Native American fishermen for subsistence purposes.

Discussion
The apparent level of take seems quite large considering the lack of a formal program for monitoring and the opportunistic nature of reports that have been received. Harbor porpoises probably occur in this area only during summer and fall since they would be excluded by sea ice during November-June. It is not known to which population these porpoises might belong.

(M) Driftnet fishery for salmon in eastern Russia
Gaskin (1984) reported that there were no records of harbor porpoise take from Korean waters, from the northern coast of China, or from gillnet operations in far-eastern Russian waters. Little mention was made of fishery/marine mammal interactions in Russian waters by Northridge (1984). Kornev (1994) mentions the entanglement and death of one right whale in a gillnet. There has been no specific research on problems of marine mammal mortality in fisheries of the east coast of the former USSR. Information provided in this review is based on one author's (VNB's) opportunistic observations, on data provided by researchers at the Kamchatka Department of the Pacific Institute of Fisheries and Oceanography, on information provided by inspectors of the Kamchatribvod Protective Service and on reports from the chiefs of Glavribvod and Kamchatribvod of the former USSR Department of Fisheries.

Primary ports
The primary ports are Petropavlovsk-Kamchatsky, Severo-Kurilsk, Vladivostok, Nakhodka, Preobrazhenye, and Hokkaido (Japan)

Target species
The main target species are pink and chum salmon, but all five Pacific species are caught.

Area of operation
Operations take place in the Sea of Okhotsk and the Bering Sea.

Vessels and crew
Driftnet fishing for salmon off eastern Russia is typically by Russian and Japanese fishermen (Kornev, 1994). In 1990, 2 larger (approx. 500 tonnes) and 6 smaller (100–120 tonnes, 40m, crew of 16–18) Japanese vessels participated in this fishery. That same year, 6 larger (800 tonnes, crew of 26) and 3 smaller (<100 tonnes, crew of 10–12) Russian vessels participated. In 1992–94 the number of small Japanese vessels increased to 30–40 per year.

Gear specifications
Nets are constructed of thin-vein, monofilament nylon mesh made in Japan or Taiwan. Panels are 45–50m long by 8–9m deep. Single nets (or 'oders') are made of 50–300 panels. A vessel typically fished 1 or 2 oders in 1990 and 4–7 oders in 1992–94. Each net is marked with lights and radio beacons.

Operations
Drift gillnet fishing for salmon in the eastern economic zone of Russia is conducted under a special research program of the Pacific Institute of Fisheries and Oceanography (PIFO) and, since 1992, as a commercial fishery. Research fishing operations occur from 20–25 July to 10–25 August, although sometimes it is carried into September. Commercial fishing occurs from 20 May to 20–25 July. Fishing takes place in the Sea of Okhotsk and the Bering Sea. Some additional fishing may take place in the northern Sea of Okhotsk and near the northern coast of Sakhalin Island, but information on that region is scarce. Typically nets are set after sunset and are hauled after sunrise or early the next day. Soak times are 9–12hrs.

Economics and history
Russian fishermen in 1990 received 23 rubles, 76 copecks ($30US: official rate, $2–3US: black market rate) per 100kg of cleaned salmon. Fish are cleaned immediately after being caught and are kept refrigerated on the vessel. Fish are sold to foreign and domestic markets.

Total landings
The 1990 landings for Russian vessels in the Bering Sea (in the former USSR economic zone) were 300 tonnes of salmon (approx. 100t pink and 195t chum). Total salmon

landings were down considerably from previous years. Record highs of 2,100 tonnes were recorded in 1988. The 1990 salmon landings from the Sea of Okhotsk and the Bering Sea were approximately 1,500 tonnes. The species composition of the catch varies with natural salmon cycles.

The Japanese driftnet fishery for salmon in the former Soviet economic zone was steady at 4–6,000 tonnes over the years 1987–90 in the region near the Okhotsk and Pacific coasts of the south Kuril Islands. A Soviet-Japanese joint venture firm (Pilenga GODO) fished with Japanese vessels in the Karaginsky Gulf in 1989 and in the Sea of Okhotsk near western Kamchatka in 1990. Total landings were 522 tonnes (and are included in the above 1,500 tonnes).

Effort data
The scientific gillnet fishery for salmon developed in 1986 and reached a peak in 1988. A commercial gillnet fishery in the Russian economic zone increased dramatically in 1992–94 with an agreement between Russia and Japan.

Interactions with cetaceans
In the research fishery, PIFO representatives and vessel captains report Dall's porpoises being caught in the scientific salmon gillnetting (G.E. Karmanov, A. N. Zaochny, M. T. Orlov, and V. A. Shniperov, pers. comm.). Porpoises were caught most frequently near the Kuril Islands, south to 51°N. Fishing in 1990 between 51°-51°30′N and 149°20′-155°50′E, G.E. Karmanov reported (pers. comm.) 8 Dall's porpoises entangled out of 2,295 panels of retrieved net (109.6km), of which 3 were released alive. Captains of two other vessels fishing in approximately the same area reported 20–25 Dall's porpoises killed per fishing season. Porpoises are caught much less frequently in the Karaginsky Gulf (Bering Sea, 58–60°N). In this area in 1990, PIFO natural resource observers saw no porpoises entangled in 5,000 panels of retrieved net. In the 1992–94 commercial fishery, several hundreds of Dall's porpoise were caught each year. Some harbor porpoise and unidentified whales were also caught. Porpoises are typically thrown back into the sea.

One entangled right whale (which died) was discovered on the Pacific side of Cape Lopatka in October 1989. It was caught in a fragment of green 6 x 6cm mesh gillnet with foam plastic floats (Kornev, 1994).

Pinniped bycatches and other information
Northern fur seals, ribbon seals, bearded seals and spotted seals were taken in the 1992–94 commercial fishery (probably less than 10 of each species per year).

Discussion
Fishery inspectors of the Kamchatribvod controlled fishery reported that a rather developed, unpermitted fishery existed in the Sea of Okhotsk and near the Pacific coast of the Kuril Islands prior to 1992. Each year, Russian patrol boats chased off Japanese, Korean and Taiwanese vessels in this area. This unpermitted fishery has been largely replaced by a permitted commercial fishery in 1992. This commercial fishery includes a bycatch observer program which is now providing needed information on marine mammal mortality.

(N) Eastern Russia coastal trap-net fishery for salmon
The vast majority of Russian-caught salmon on the east coast come from nearshore trap nets. These are passive nets that intercept salmon as they travel along the shore to their spawning river and guide the fish into a holding pen. Little information has been published regarding cetacean entanglement in this type of net, but it is considered very rare.

Target species
All five Pacific salmon species are taken.

Area of operation
Operations occur in near shore waters of the Russian Far East.

Gear specification
Trap nets are set with a wing net perpendicular to shore and leading to a trap or pen approximately 200–400m from shore.

Operations
Approximately 6–12 fishermen tend each trap net. Fish are transported to shore-based processing plants in special boats.

Total landings
The vast majority of Pacific salmon caught in Russian waters are caught in trap nets. Average landings in eastern Russian waters from 1987–90 were 131,000 tonnes per year, of which approximately 79,000 tonnes were caught on the Kamchatka peninsula.

Effort data
Annually in June-August, about 50 trap nets are set on the western (Okhotsk) coast of Kamchatka and about 50–80 are set on the eastern coast.

Interactions with cetaceans
Other than one reported narwhal entanglement (I.I. Muroshov, pers. comm.), interactions with cetaceans appear minimal in this fishery.

Pinniped bycatches and other information
Often spotted seals gather in groups of approximately 100 near the traps. Steller sea lions have also been reported. The trap itself is apparently not dangerous to pinnipeds, but fishermen often shoot at them, killing or wounding some.

Discussion
More details regarding the level of pinniped mortality by shooting are clearly needed. However, the available information suggests that this method of fishing appears to be effective at catching salmon without incidental entanglement of marine mammals.

(O) Other fisheries
There are many reports for the eastern North Pacific regarding marine mammals mortality in passive and active fishing gear in fisheries other than those mentioned above. Some of these fisheries are small and others have been discontinued. For completeness, we include all references we were able to find, without providing extensive details. The following list should not be considered complete.

In California, Scammon (1874) first documented the take of harbor porpoises in a beach seine in San Francisco. Although not strictly-speaking entangling gear, many short-finned pilot whales were thought to entangle and die (or were shot) in a market squid purse seine fishery in the California Channel Islands (Miller *et al.*, 1983; Seagers and Henderson, 1985; Heyning *et al.*, 1994).

In Oregon and Washington, significant pinniped mortality has been reported in the Columbia River salmon gillnet fishery (Beach *et al.*, 1985), but cetacean mortality does not seem important there. Scheffer and Slipp (1948) felt that fish nets were responsible for a large number of harbor porpoise deaths each year in Washington state. Harbor porpoises were also killed in trawl gear off Washington State (Leatherwood and Reeves, 1986).

In British Columbia, there are records of cetacean bycatch in several temporary experimental or now-discontinued fisheries. Cowan (1939) reported a minke whale caught in a salmon trap near Sooke, on the southern tip of Vancouver Island. Pike and MacAskie (1969) reported the deaths of three short-finned pilot whales in a gillnet during experimental fishing in international waters off BC and the entanglement of two killer whales in 'fishing gear'. Porpoises are occasionally killed in research fisheries currently being undertaken by the Canadian Department of Fisheries and Oceans; in 1990 a Dall's porpoise was killed in a surface trawl research fishery on salmon smolts and a harbor porpoise was killed in a monofilament sunken set gillnet used in a research fishery for dogfish shark (Baird, unpublished data). In addition to the salmon gillnet fishery described above, five current commercial fisheries are known to take cetaceans in BC. These include salmon seine, salmon troll, bottomfish trawl, shrimp trap, and crab trap fisheries (Le Boeuf, 1974; Baird *et al.*, In press), in the latter two, take involves large whales becoming entangled in lines associated with the traps. In 1990 a gray whale entangled and died in a pen used to hold herring in a herring roe fishery and in 1991 a gray whale was entangled in a herring set gillnet from this fishery (Baird *et al.*, In press).

Frequent marine mammal/fishery encounters have been reported for the salmon purse seine fishery in South Unimak, Alaska (Melteff and Rosenburg, 1984), but more recent investigations by the State indicate that this may no longer be the case (Anon., 1989). Elsewhere in Alaska, four humpback whales were reported to have entangled in buoy lines associated with longline and shrimp pot gear (Sease, pers. data). A killer whale entangled and drowned in a sablefish longline in 1988. Some Steller sea lions also were killed in association with longline fisheries in Alaska, but many probably were killed intentionallly to protect catch and gear. [Currently there is a ban on shooting at or within 100 yards of Steller sea lions throughout their range.] Gray whale mortality due to fisheries ranges from 8.7 to 25.8% of all stranded gray whales from the Alaska Peninsula to Baja California Norte (Heyning and Dahlheim, In press).

Several other passive-type fisheries are found in the waters of eastern Russia. Near western Kamchatka, approximately 10 Japanese vessels fished in 1990 used long-lines for cod, walleye pollack, and flatfish and use traps for crab. Approximately 5–6 Japanese vessels fish for halibut and large perch using bottom-set gillnets in international waters in the middle of the Sea of Okhotsk. In the latter fishery, 20–25cm mesh nets are set at extreme depths of 500–800m. One vessel typically sets 27km of net which is allowed to soak for 2–4 days. No information is available on cetacean mortality in any of these fisheries.

Crustacean trap fisheries occur in most coastal waters including California, Oregon, Washington, British Columbia, Alaska, the western Bering Sea (Russia), and the Sea of Okhotsk. Based on experience elsewhere, trap lines are likely to occasionally entangle and kill some whales. Four of the entangled gray whales mentioned by Heyning and Lewis (1990) were caught in crab or lobster traplines. In British Columbia, there is one record of a humpback whale becoming entangled in lines associated with prawn trap gear (Langelier *et al.*, 1990). In Russia, one gray whale has been seen with a part of a crab trap on its fluke (L.S. Bogoslovskaya, pers. comm.) and a spotted seal has been reported entangled in crab fishing gear.

DISCUSSION

Clearly there is insufficient information on the number of marine mammals that are taken incidentally in passive fishing nets and traps. For many fisheries, there is no information at all. In the case of California gillnet fisheries, for which we have the best data, it is still difficult to evaluate the significance of the observed mortality on the cetacean populations. In all areas, a larger effort is needed both to determine the number of animals killed in fisheries and to evaluate the significance of this mortality to the populations.

Recent US legislation that requires an observer program for certain fisheries is likely to fill many of the gaps in our knowledge about the level of marine mammal mortality in these fisheries. The resulting information will not be complete, however. The US program concentrates on fisheries with a high likelihood of taking marine mammals. Although vessel owners in other fisheries are required to report on levels of fishing effort and marine mammal interactions, there is no validation to ensure accurate reporting. For many fisheries without observer programs, there was no quantitative information on the levels of marine mammal catch. In this situation, a lack of information is perpetuating a continued lack of information. Some, perhaps low level of observation in all fisheries might be appropriate to better estimate the total level of cetacean mortality in US fisheries.

In Canada, the level of knowledge on fishery/marine mammal mortality is poor. The exception is the experimental squid fishery with its 100% observer program. Seldom has bycatch been adequately studied in experimental fisheries and seldom (as it was in this case) is bycatch a factor in deciding against continuing a potentially profitable fishery. In contrast, however, there is little direct information on cetacean mortality in the much larger drift gillnet fishery for salmon in BC. Most of the available information is from questionnaires, which are typically less reliable than direct observation. Some level of direct observation seems necessary in order to validate the level of incidental mortality that was estimated in the questionnaire survey.

In Russia, little information is available on the levels of incidental marine mammal mortality in fisheries. This report was based almost entirely on information for the Sea of Okhotsk and the Bering Sea. More information is needed regarding fisheries near Sakhalin Island and in the Sea of Japan. The largest and economically most important fishery, the trap-net fishery for salmon, appears to have little incidental marine mammal mortality. Driftnet fishing for salmon is, however, increasing rapidly. There is a need to continue studies of marine mammal/fishery interactions in eastern Russia and to expand the program of fishery observers.

It should be recognized that indirect methods of estimating marine mammal mortality in fisheries (including data from stranded animals, from dockside surveys and from questionnaires) are all likely to underestimate total marine mammal mortality. The biases are likely to be different for each method. Stranding data are likely to underestimate takes from offshore fisheries more than inshore fisheries (Heyning *et al.*, 1994). Problems with questionnaires and dockside surveys are addressed by Lien *et al.* (1994). Indirect methods of estimating bycatch of marine mammals should not be considered as a substitute for direct observation.

Knowing the level of marine mammal mortality in fishing operations is an obvious first step in evaluating the significance of this mortality on the populations of marine mammals. Ideally, one would like to directly measure whether fishery mortality is adversely affecting populations. Data on population trends are rare for most marine mammal species. Populations appear to be increasing for California gray whales, killer whales in British Columbia, California sea lions, northern elephant seals and harbor seals in California, Oregon, Washington and British Columbia. The population of white whales in Bristol Bay appears stable. This type of information gives us some confidence that fisheries are not disadvantageous to these populations. In contrast, there are examples such as harbor seals, northern fur seals and Steller sea lions in Alaska where the populations are declining, but where the reasons for this are not understood and any possible relationship to gillnet entanglement is unclear. Unfortunately, trends in abundance are difficult and expensive to obtain, require long time series and may be difficult to interpret. Although it is anticipated that information on trends in harbor porpoise abundance in California will be available after 4 additional years of study (Forney *et al.*, 1991), this is one of the few cetacean populations for which this is likely. Trends are not always a practical approach to determining the significance of incidental marine mammal mortality in fisheries.

A more basic first step should be to estimate the size of the populations that are being affected by fishery mortality. A comparison between the estimated level of fishery mortality and the population size can quickly indicate whether fishery mortality is likely to be a problem for those populations. Most biologists would agree that incidental mortality rates of less than 1% per year are not likely to have an appreciable impact on a marine mammal population unless that population is suffering from additional factors that result in reduced productivity and/or survival. Similarly, most biologists would agree that incidental mortality rates greater than 4% per year for cetaceans or 10% per year for pinnipeds are not sustainable and could lead to catastrophic population declines. Between these values (1–4% for cetaceans, 1–10% for pinnipeds), there may be considerable difference of opinion as to the likely effect of incidental mortality. Using such a scheme, it is possible to classify fishery mortality on a population as being probably negligible, clearly too high, or potentially too high. Researchers and managers could then take action to reduce mortality where it is obviously too high and to gather adequate data in cases where we are unsure of the potential impact of a fishery on a marine mammal population.

RECOMMENDATIONS

(1) Baseline data on levels of marine mammal mortality for all fisheries based on direct observations and other appropriate methodology should be obtained. Fisheries that are found to have a significant level of marine mammal mortality should continue to be monitored. Countries which allow foreign vessels to fish in their waters may be able to require such an observation program as a condition for obtaining a fishing permit.

(2) Estimates of population size for species that are likely to be adversely affected by fishery mortality should be obtained. For most species, this will include determining stock boundaries, abundance and seasonal distribution. When possible, trends in abundance should be determined.

(3) Alternative fishing strategies that will minimize encounters with marine mammals (e.g. seasonal closures for gillnet fisheries) should be developed.

(4) Consideration should be given to the level of incidental marine mammal mortality when fishery management agencies decide the allocation of fish to various fishing methods. As an example, the use of trap nets for salmon could be allowed in place of using gillnets.

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Appendix 1

SCIENTIFIC AND COMMON NAMES

Marine Mammals	
Bearded seal	*Erignathus barbatus*
Bottlenose dolphin	*Tursiops truncatus*
California sea lion	*Zalophus californianus*
Common dolphin (short-beaked)	*Delphinus delphis*
Common dolphin (long-beaked)	*Delphinus capensis*
Cuvier's beaked whale	*Ziphius cavirostris*
Dall's porpoise	*Phocoenoides dalli*
Elephant seal	*Mirounga angustirostris*
Gray whale	*Eschrichtius robustus*
Harbor porpoise	*Phocoena phocoena*
Harbor seal	*Phoca vitulina*
Hubbs' beaked whale	*Mesoplodon carlhubbsi*
Humpback whale	*Megaptera novaeangliae*
Killer whale	*Orcinus orca*
Mesoplodont beaked whale	*Mesoplodon* spp.
Minke whale	*Balaenoptera acutorostrata*
Narwhal	*Monodon monoceros*
Northern fur seal	*Callorhinus ursinus*
Northern right whale dolphin	*Lissodelphis borealis*
Northern right whale	*Eubalaena glacialis*
Pacific white-sided dolphin	*Lagenorhynchus obliquidens*
Pygmy sperm whale	*Kogia breviceps*
Ringed seal	*Phoca hispida*
Risso's dolphin	*Grampus griseus*
Sea otter	*Enhydra lutris*
Short-finned pilot whale	*Globicephala macrorhynchus*
Sperm whale	*Physeter macrocephalus*
Spotted seal	*Phoca largha*
Stejneger's beaked whale	*Mesoplodon stejnegeri*
Steller or northern sea lion	*Eumetopias jubatus*
Walrus	*Odobenus rosmarus*
White whale	*Delphinapterus leucas*

Fishes	
Angel shark	*Squatina californica*
California halibut	*Paralichthys californicus*
Capelin	*Mallotus villosus*
Mako shark	*Isurus oxyrinchus*
Market squid	*Loligo opulescens*
Neon flying squid	*Ommastrephes bartramii*
Opah	*Lampris regius*
Pacific cod	*Gadus macrocephalus*
Pacific salmon	*Onchorhynchus* spp.
Chinook or king salmon	*O. tshawytscha*
Chum or dog salmon	*O. keta*
Coho or silver salmon	*O. kisutch*
Pink or humpback salmon	*O. gorbuscha*
Sockeye or red salmon	*O. nerka*
Swordfish	*Xiphias gladias*
Thresher shark	*Alopias vulpinus*
Walleye pollock	*Theragra chalcogramma*
White croaker	*Genyonemus lineatus*
White seabass	*Cynoscion nobilis*

Harbor Porpoise Interactions With a Chinook Salmon Set-Net Fishery in Washington State

Patrick J. Gearin[1], Sharon R. Melin[1], Robert L. DeLong[1], Hiroshi Kajimura[1] and Michael A. Johnson[2]

ABSTRACT

A cooperative study based on an agreement between the National Marine Fisheries Service and the Makah Indian Tribe was conducted during 1988–90 to assess the nature and magnitude of harbor porpoise (*Phocoena phocoena*) interactions in the Makah chinook salmon set-net fishery. The Makah set-net fishery operates annually along the northern coast of Washington State (USA) in the North Pacific Ocean and in the western Strait of Juan de Fuca from 1 May to 15 September. The fishery targets on chinook salmon (*Oncorhynchus tshawytscha*) using submerged gillnets up to 100 fathoms (200m) long. An observer program was conducted during the 1988–90 seasons and fishing effort was estimated. A total of 138 harbor porpoises was observed or reported taken incidentally during the three years of which 100 were collected and necropsied. Harbor porpoises were primarily taken during a one month period from mid-July to mid-August at the Spike Rock fishing grounds in the Pacific Ocean. The number of harbor porpoises observed or reported taken in the fishery declined dramatically during 1989 and 1990 due to low fishing effort. Of the harbor porpoises collected, 55 were males, 45 were females, 100 were aged and the reproductive condition of 99 was determined. The maximum estimated age (based on growth layer groups within the dentine) was five for females and eight for males. A large proportion (54%) of the aged porpoises were one and two years old. Most (63.6%) of the 99 animals examined were reproductively immature. Males were reproductively mature at age four with a body length of approximately 132cm. Females were reproductively mature at age three with a body length of approximately 155cm. The principal prey of both harbor porpoise and chinook salmon were Pacific herring (*Clupea harengus pallasi*), market squid (*Loligo opalescens*) and smelt (Family Osmeridae).

KEYWORDS: INCIDENTAL CAPTURE; NORTH PACIFIC; HARBOUR PORPOISE; BIOLOGICAL PARAMETERS; FEEDING; SQUID FISH; REPRODUCTION; SEXUAL DIMORPHISM

INTRODUCTION

This paper summarises a cooperative study assessing the nature and magnitude of harbor porpoise (*Phocoena phocoena*) fishery interactions in the Makah chinook salmon (*Oncorhynchus tshawytscha*) set-net fishery in Washington State (USA). The study was conducted from 1988–90 by the National Marine Mammal Laboratory (NMML) and the Makah Tribal Fisheries Management Division based on a cooperative agreement between the Makah Tribe and the National Marine Fisheries Service (NMFS) in 1988. This paper reports and updates the results of the 1988–89 studies reported in Kajimura (1990). A population assessment of harbor porpoises along the Washington State coast from aerial, shipboard and shore-based platforms is presented in Kajimura (1990) as well as more detailed information about the biology of the harbor porpoises collected during the fishery (Calambokidis, 1990; Gearin and Johnson, 1990; Gearin *et al.*, 1990; Melin *et al.*, 1990; Rugh and Melin, 1990; Turnock *et al.*, 1990).

In this paper we describe the Makah set-net fishery and the results of the observer programs conducted from 1988–90, report the incidental catches of harbor porpoises and other cetaceans taken in the fishery and present life history information on harbor porpoises collected during the fishery. We also discuss the measures that have been taken to reduce the incidental take of harbor porpoises and the potential impact of this fishery on the regional harbor porpoise population.

METHODS

Description of fishery

The Makah set-net fishery operates along the northern coast of Washington State in the Pacific Ocean and along the southwest coast of the Strait of Juan de Fuca (Fig. 1).

Tribal fishing grounds in Washington State were re-established under the Boldt decision of 1974 (*United States* v. *Washington*, 384 F. Supp. 312). The Makah tribe, like other northwest coastal Indian tribes, have a designated 'Usual' and 'Accustomed' (U and A) fishing area. The Makah tribal U and A area is shown in Fig. 1. The set-net fishery operates in a small portion of the U and A area corresponding to the Washington State Department of Fisheries commercial salmon statistical catch Areas 3, 4, 4A, 4B and 5 (Fig. 1). The fishery is open from 1 May to 15 September with peak landings of chinook salmon occurring in July and August.

The set-net fishing fleet consists of 6–10 boats, 16–24ft (5–8m) in length. Each fisherman is allowed three gillnets, 100 fathoms (183m) long. Nets are generally sunk to 6–10 fathoms (11–18m) and anchored at both ends with the lead line resting along the bottom. The nets are composed of mono- or polyfilament nylon ranging from 7.75–8.5 inch (19–22cm) stretch mesh and are up to 100 meshes deep. The set-nets are checked every 24 hours on average and remain in place for periods of up to several weeks. The nets are only pulled completely out of the water to be repaired, cleaned or moved to a new location.

Observer program

Observers rode on Makah set-net fishing boats and recorded data on the location and depth of nets, time of net retrieval, soak time, chinook salmon taken and the incidental catch of harbor porpoises and other marine mammals. Incidental catch data included date, time, location, net number, depth where taken, location of porpoise in the net and core body temperature of porpoise upon retrieval. Porpoises taken in the set-nets were assigned field numbers and transported to shore and necropsied.

[1] *National Marine Mammal Laboratory, AFSC/NMFS, 7600 Sand Point Way NE, Seattle, WA 98115–0070, USA*
[2] *6411 Fremont Ave. N. Seattle, WA 98103, USA*

Fishing effort estimates

Fishing effort is defined as net days fished where one net day (ND) equals a 100 fathom net set for 24 hours (Polacheck, 1989). Total fishing effort was calculated by multiplying the total number of 100-fathom nets by the total number of days set (a 50-fathom net was treated as 0.5 of a net).

Seasonal fishing effort estimates for 1988–90 were derived from three sources: the Makah fisheries sign-up forms; interviews with Makah set-netters; and direct observations made by observers during the fishery. Using these sources, the seasonal effort was estimated by month and area.

Determining incidental catches of harbor porpoises

Observed-plus-reported incidental catch

Fishermen were asked to report their catches of cetaceans to observers during the fishing season from May through August. Informal interviews were conducted with most of the Makah set-netters at the end of the fishery each year to obtain further information on fishing effort and data on incidental catches of harbor porpoises and other cetaceans. These interviews were helpful in reconstructing the seasonal fishing effort and in obtaining a record of incidental catches by area and time, where observations were minimal or not conducted. Observer data, previously reported porpoise catch data and interview data were combined to give the observed-plus-reported catch.

Rate of catch

The incidental catch rate (using observed-plus-reported catch data) of harbor porpoises was calculated for the Spike Rock fishing grounds during June through August 1988–90. The catch rate was defined as the catch of porpoises per unit of effort (CPUE). The rates for any stratum, such as month, are therefore the number of porpoises caught per net day fished. Rates for May at Spike Rock were not calculated as the absence of observer coverage would have meant that the values would not have been comparable to the other months.

Incidental catch estimates

Incidental catch estimates for harbor porpoises were calculated for the 1989 season by month and for the total season. The estimates were derived only from the numbers of incidentally caught porpoises that were observed by NMFS observers. Estimates for 1988 were not calculated because observer coverage was: (1) limited to one vessel; (2) only 3.1% of the total fishing effort and included observations of only six nets at Spike Rock; (3) limited to 14 days out of a 138-day season; and (4) confined to the period of the highest observed-plus-reported catches. An extrapolated estimate for 1988 using these data would thus be biased and invalid. No extrapolated estimates of incidental catch are reported for 1990 because observer coverage in the areas where porpoises were caught was near 80% and estimates would have only confirmed the accuracy of the observed-plus-reported catch data.

The 1989 harbor porpoise catch estimate was calculated for the Spike Rock area during June-August. This was the only area and period when porpoises were observed taken. The rates of incidental take of harbor porpoises during 1989 were calculated using two methods; a straight ratio estimate (T_i) and a bootstrap estimate (Diamond and Hanan, 1986).

The formula for the straight ratio estimate is

$$T_i = (t_i/n_i)\, S_i$$

where: i = area, T = total take, t = number observed taken, n = number of net days observed and S = estimated total number of net days.

The bootstrap estimate uses the computer generated resampling method described in Efron (1982). In

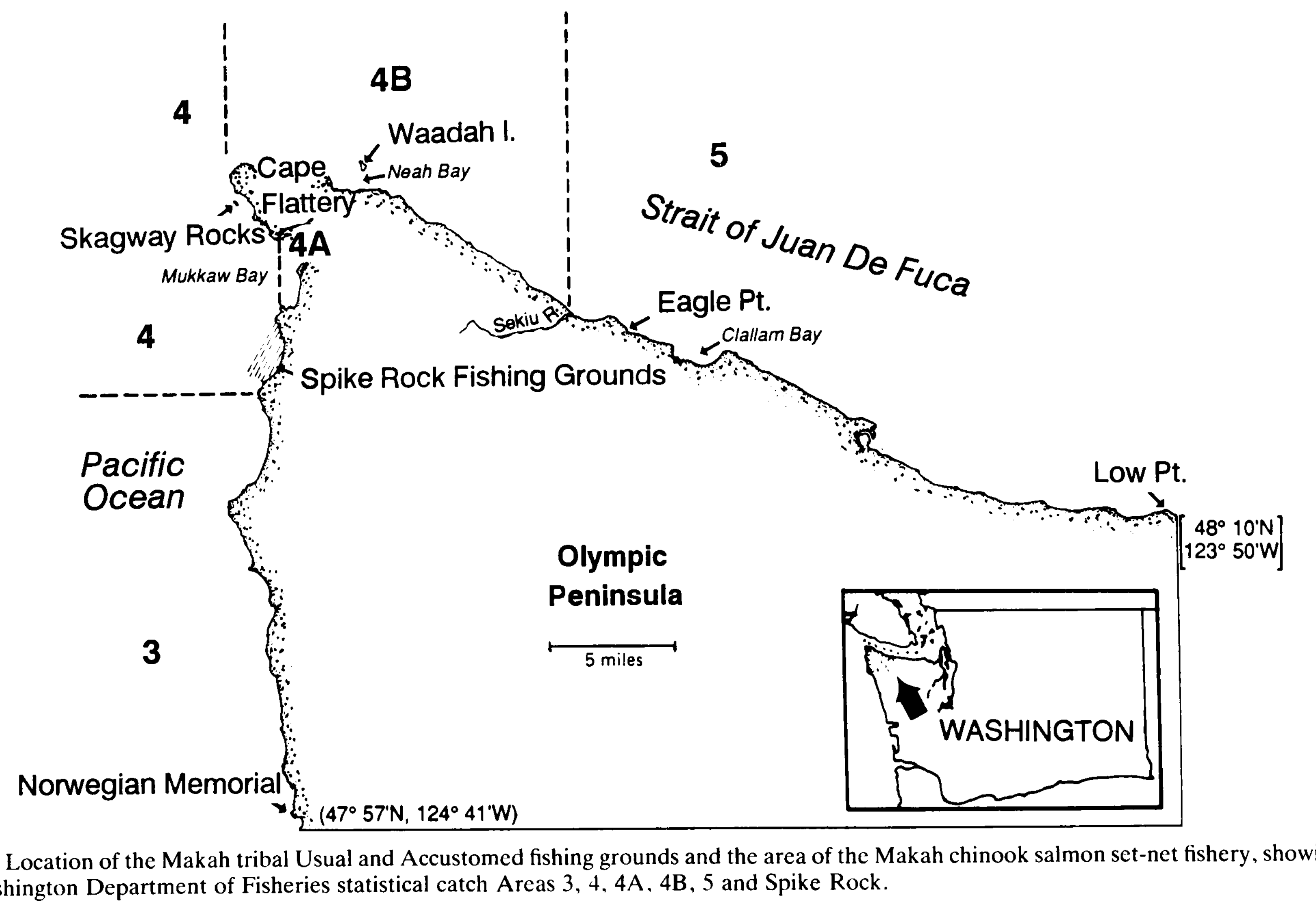

Fig. 1. Location of the Makah tribal Usual and Accustomed fishing grounds and the area of the Makah chinook salmon set-net fishery, showing the Washington Department of Fisheries statistical catch Areas 3, 4, 4A, 4B, 5 and Spike Rock.

calculating the bootstrap estimates, the following assumptions were made: (1) porpoise takes occurred only where observed (at Spike Rock); (2) porpoise takes occurred only in June-August (based on observed takes); and (3) porpoise takes were not necessarily evenly distributed in time (i.e. multiple takes could occur on the same day in the same net).

Life history parameters (collection and necropsy of specimens)

A total of 100 harbor porpoises incidentally caught in the set-net fishery from 1988 to 1990 were collected. Detailed necropsies were performed on all specimens. A brief summary of necropsy procedures is presented here and a more detailed description is provided in Melin *et al.* (1990).

Each animal was weighed, photographed and measured (47 straight line external measurements following Norris, 1961). For porpoises caught in 1988–89, rectal temperatures were taken when the animals were pulled on board the fishing vessels.

Tooth preparation and ageing techniques

Teeth were extracted from the middle of the lower jaw; they were stored in 70% ethyl alcohol for ageing (Gaskin and Blair, 1977; Perrin and Myrick, 1980; Hohn *et al.*, 1989). A growth layer group (GLG) is defined as a repeating or semi-repeating pattern of adjacent groups of incremental growth layers within the dentine or cementum (e.g. IWC, 1980). For the harbor porpoise, one GLG represents one year of age (Gaskin and Blair, 1977). Each tooth was cleaned, weighed and measured. The teeth were decalcified and stained following methods used for *Stenella attenuata* and *Stenella longirostris* (Myrick *et al.*, 1983) with several modifications (Melin *et al.*, 1990). Teeth were mounted on a freezing microtome and sectioned at 15–20 microns. Each tooth was read three times by three independent readers and twice by one reader. The average (modal) age for each tooth was determined for each reader. The ages were compared among readers. When readings did not agree, the tooth was read again by two readers who determined a final age estimate. The ages reported represent the maximum number of completed GLGs. The readings were done with a compound microscope at 40x and 100x magnifications with transmitted light. The cementum was also used as an index of age, but it did not help in determining the actual age estimate.

Reproductive organs

MALES

Both testes were removed, weighed and measured. The epididymis was removed from the left testis and the testis was reweighed. Fluid from each epididymis was examined for sperm. For each sample, the diameter for several seminiferous tubules ($n=10$) was measured in microns and the mean tubule diameter and standard deviation was calculated. Using the histological pattern of seminiferous tubules, four reproductive conditions representing different levels of testis activity were determined, two describing immature and two describing mature males. Reproductive conditions 1 and 2 represent reproductively immature males: (1) testes with very small tubules, no evidence of spermatogenesis and epididymal tubules that appear collapsed; (2) testes with small tubules with early signs of mitosis of the germinal epithelium but no evidence of spermatogenesis. Reproductive conditions 3 and 4 represent reproductively mature males: (3) testes with mitosis of the germinal epithelium, varying degrees of spermatogenesis but empty epididymal tubules and tubule diameters significantly larger than for 1 and 2; (4) testes with large tubules with mitosis of germinal epithelium, spermatogenesis, and spermatozoa within the lumen of the seminiferous tubules and epididymal tubules.

To account for possible differences in tubule diameters or germinal epithlium characteristics due to freezing before sampling for histological examination, specimens that had been frozen prior to histological sectioning and fresh specimens were examined and the results of tubule diameters and characteristics were compared. No differences were apparent and therefore the results were pooled.

FEMALES

Each female was checked for lactation by palpation or incision into the mammary gland before the reproductive tract was removed. The uterus and uterine horns were examined for signs of reproductive activity (i.e. thickened uterine walls, distended horns, embryos) and placed with ovaries attached in 10% buffered formalin. Following their preservation, both ovaries were weighed, measured and serially sectioned. The method of examination followed that of Miller *et al.* (1978).

Females were classified as mature if their ovaries had corpora lutea or corpora albicantia. Females without corpora were classified as immature.

Mature females were categorised as (1) post-partum and lactating (P/L), (2) post-partum and not lactating (P/NL) or (3) pregnant with fetus and colostrum in mammary glands (PR/C).

Stomach contents

Stomachs were examined from 100 harbor porpoises caught in the salmon set-nets during June through August, 1988–90. Ninety-seven porpoises examined were from the Point of the Arches area on the Spike Rock fishing grounds and three were from Skagway Rocks (Fig. 1). Stomachs were excised from porpoises during necropsy and examined. They were weighed with contents intact and then each compartment was examined. The pyloric and main stomach compartments were severed from the forestomach and opened along their length. The forestomach was weighed and each compartment was examined for contents and then rinsed over 3–4 nested metal sieves ranging from 4.75mm to 0.50mm in mesh size. The empty forestomach was then reweighed to obtain the prey content mass. If whole prey were recovered from the stomach, they were counted, weighed and measured. Standard length measurements were taken on whole fish and dorsal mantle lengths (DML) on whole squid. When vertebral columns were intact or partially intact, vertebral columns and vertebral segments were counted to obtain minimum number of prey present. Identification of whole fish prey was based on fish keys (Hart, 1973). Otoliths, fish skeletal remains and squid or squid beaks were identified using the reference collection at the NMML. Three indices of prey importance were used: *percent occurrence* calculated as a percentage of each prey type found in the total number of stomachs that had identifiable prey; *number of prey* determined by counting the fish otoliths, squid beaks, partial fish vertebral columns and whole prey found in the stomachs; and *size of prey*.

The stomachs of 50 chinook salmon caught in the Spike Rock area and in the same nets as harbor porpoises were collected during July 1988. The stomachs were excised, placed in plastic bags and frozen. They were later thawed and weighed. Contents were then removed and weighed. Identification and measurement techniques of prey were the same as those used for harbor porpoise stomachs. Chinook salmon and harbor porpoise prey were compared by size of prey and percent occurrence.

RESULTS AND DISCUSSION

Observer coverage

Total observer coverage in 1988 was 80.7 ND (about 3.1% of the seasonal fishing effort) of which 76.6 ND were in the Spike Rock area and the remainder were in the Strait of Juan de Fuca (Table 1a). It was limited to one fishing vessel which generally fished six nets set at Spike Rock, and amounted to only 14 days out of the 138-day fishery, 11 of which were from 15–31 July.

Observer coverage for the 1989 fishery was 361.2 ND or 26.9% of the seasonal effort (Table 1b). It was evenly distributed by area except for a lack of coverage in Mukkaw Bay (fishing Area 4A). The most concentrated coverage was in July and August. Four of the eight fishing boats accepted observers for at least one trip during 1989. Observers covered 79 of 199 total chinook salmon landings (39.6%) and no chinook salmon landings were made on 17 of 96 observer trips.

Observer coverage for the 1990 season was 264.1 ND or 47.1% of the seasonal fishing effort (Table 1c). Four of the five fishing boats which operated during the 1990 season had observer coverage. Observers covered 56 of 143 chinook landings (39.1%).

Fishing effort estimates

The majority of Makah fishing effort during 1988–90 was in Area 4 near Spike Rock and Skagway Rocks and in Area 4B in the western portion of the Strait of Juan de Fuca from Clallam Bay to Cape Flattery (Fig. 1, Table 1). The fleet size ranged from 3 to 10. Effort by month and area was quite variable among years. Effort was highest in 1988 with an estimated 2,600 ND fished, compared to 1,342 in 1989 and 560 in 1990 (Table 1). This was due primarily to more effort in the Spike Rock area and the Strait of Juan de Fuca in 1988. Total fishing effort for the Spike Rock area was 1,312 ND in 1988, 241 ND in 1989 and 31.9 ND in 1990, the lower effort in 1989 and 1990 reflecting the scarcity of chinook salmon in the area. In contrast there was more effort in the Skagway Rocks area in 1989 than in 1988. During 1988 and 1990, several fishermen fished as far east as Clallam Bay in the Strait of Juan de Fuca whereas in 1989 the eastern limit was near Eagle Point.

Observed-plus-reported incidental catch

In 1988, 102 harbor porpoises were reported or observed taken (22 were observed by NMFS observers), of which 70 were collected. During 1989, 23 harbor porpoises were reported or observed taken (14 were observed by NMFS observers) of which 17 were collected. During 1990, all 13 harbor porpoises reported or observed incidentally taken were collected.

All but four harbor porpoises taken during the three years were taken in the Spike Rock area; three of those were taken at Skagway Rocks in 1990 and one in the Strait of Juan de Fuca near Waadah Island in July 1989. Thus, a total of 138 harbor porpoises were observed or reported to be taken between 1988 and 1990, of which 100 were collected.

Rate of catch

Table 2 gives estimated incidental catch rates of harbor porpoises at Spike Rock from 1988 to 1990. Although the observed-plus-reported catch varied among years, the combined catch rates were equal for 1988 and 1989. The rate for 1990 was the highest despite having the lowest actual catch. The lower number of total takes in 1989 and 1990 reflects the reduced fishing effort at Spike Rock during those years. During those seasons, few chinook salmon were caught there although the harbor porpoise CPUE was equal to or higher than the 1988 values (Table 2). The catch of harbor porpoises is thus primarily a function of fishing effort.

Table 1

Total and observed ( ) effort* during the Makah salmon set-net fishery (effort recorded in net days fished).

Month	Spike Rock		Skagway		Strait of Juan de Fuca		Mukkaw Bay		Total	
(a) 1988										
May	250	(0)	60	(0)	150	(0)	0	(0)	460	(0)
June	300	(0)	12	(0)	180	(0)	0	(0)	492	(0)
July	383	(71.6)	0	(0)	480	(0)	0	(0)	863	(71.6)
August	339	(5)	0	(0)	406	(4.1)	0	(0)	745	(09.1)
Sept.	40	(0)	0	(0)	0	(0)	0	(0)	40	(0)
Total	1,312	(76.6)	72	(0)	1,216	(4.1)	0	(0)	2,600	(80.7)
(b) 1989										
May	21	(0)	0	(0)	93.75	(0.10)	0	(0)	114.75	(0.10)
June	53	(09.98)	0	(0)	127.50	(6.06)	0	(0)	180.50	(16.04)
July	162	(65.5)	53	(42.2)	321.25	(82.85)	36.25	(0)	572.50	(190.55)
August	5	(04.04)	95	(44.15)	316.25	(106.29)	54.25	(0)	470.50	(154.48)
Sept.	0	(0)	0	(0)	0	(0)	3.75	(0)	3.75	(0)
Total	241	(79.52)	148	(86.35)	858.75	(195.30)	94.25	(0)	1,342.00	(361.17)
(c) 1990										
May	0	(0)	0	(0)	45.6	(0)	0	(0)	45.6	(0)
June	1.0	(0)	13.2	(10.8)	134.6	(52.3)	0	(0)	148.8	(63.1)
July	29.5	(27.7)	11.5	(07.86)	188.4	(101.0)	11.5	(07.89)	240.9	(144.5)
August	1.4	(01.4)	11.5	(06.16)	100.3	(42.8)	11.5	(06.14)	124.7	(56.5)
Total	31.9	(29.1)	36.2	(24.8)	468.9	(196.1)	23	(14.0)	560.0	(264.1)

* 1 net day = one 100 fathom net set for a 24-hour period.

In each season, the June CPUE values were considerably lower than for the other months, suggesting low harbor porpoise abundance in the Spike Rock area during June. Although we have no observer data for this area during May, we suspect that few if any animals are taken then; fishermen did not report any porpoises taken then from 1988–90.

Incidental catch estimates

No harbor porpoises were observed to have been taken during May and thus no estimates were made for that month. The straight ratio estimate of harbor porpoises caught during 1989 was 36.2 animals (Table 3), based on observed rates of take at Spike Rock. No estimate was made for the Strait of Juan de Fuca because observers saw none taken there. The bootstrap estimate for 1989 was 36.3 (SD 12.3) with a 95% confidence interval of 14–60. The estimates from both methods are in close agreement with the observed-plus-reported catch of 23 porpoises in 1989, which is within the range of the 95% confidence interval of 14–60 animals.

Incidental catch of other cetaceans

Two other species of cetaceans were involved in the Makah fishery from 1988–90; a minke whale (*Balaenoptera acutorostrata*) was reported taken at Spike Rock during July 1988 and a gray whale (*Eschrictius robustus*) was observed taken at Skagway Rocks during 1990. Both animals died in the nets.

Porpoise entanglement factors

The Spike Rock area is a shallow, sloping bay with a flat, sandy bottom. The fishable portion of the bay ranges from 6 to 16 fathoms (11–30m) in depth and extends 0.5 to 1 n.mile offshore. Incidental porpoise catches occurred at all depths fished although more were taken in the deeper areas (further offshore) in the Spike Rock area. The mean depth in the locations where porpoises were caught (n=52) was 10.3 fathoms (18.8m). Most porpoises were caught near the bottom or in the lower half of the net; of the 40 for which the location of the animal in the net was accurately determined, 23 (57.5%) were near the lead line, 16 (40%) were near the middle of the net and only one was closer to the surface near the cork line. This suggests that porpoises generally forage along the bottom or in deeper portions of the water column in the Spike Rock area.

All of the porpoises taken appeared to have entered the net head on (perpendicular to net) or at a slight angle. Most porpoises collected had 360° net marks around their heads where they may have been straining against the net and most animals appeared to have twisted after hitting the net, entangling themselves in several layers of web.

In 1988 and 1989, core body temperatures of 17 harbor porpoises were taken. These ranged from 11°-35°C (mean 18.6°C). Of an additional 16 porpoises from which temperatures were not taken but for which a general comment was made, 13 were still warm. The four porpoises taken on 28 July 1988 between 0730 and 2015 hrs were most likely taken after 1200 hrs since core temperatures were 25°, 23°, 35° and 34°C. These body temperatures suggest that at least some porpoises were entangled during daylight hours because many were still warm when the nets were checked in mid-morning or afternoon.

We observed 17 instances when more than one porpoise was entangled in the same net. Animals that were entangled at the same time were usually either females with calves or individuals of the same sex and age category. The greatest number of porpoises caught in a single set of one net was seven in 1988. However, in this case 48 hours had passed since the last check due to adverse weather.

No direct correlation was found between the CPUE of harbor porpoise and chinook salmon from those nets which caught harbor porpoise at the Spike Rock area in 1988 (r=0.277). However, the 1988 Spike Rock CPUE values for nets which caught harbor porpoises were significantly higher than for those which did not catch porpoises but were set on the same day (Mann-Whitney test; $p<0.001$). These results indicate that, although there was no direct correlation between the salmon and porpoise catch, the nets that caught porpoises contained significantly more salmon than those which did not. A probable explanation for these seemingly contradictory findings is that harbor porpoises and chinook salmon are attracted to the same areas where they feed on the same prey (see section on stomach contents).

Table 2

Incidental catch rates of harbor porpoises at Spike Rock during June through August, 1988-90.

Year/ month	No. of porpoise observed plus reported	Effort, net days	Rate of catch
1988			
June	2	300	0.006
July	65	383	0.169
August	35	339	0.103
Total	102	1,020	0.100
1989			
June	1	53	0.018
July	20	162	0.123
August	1	5	0.200
Total	22 *	220	0.100
1990			
June	0	1	0
July	9	29.5	0.305
August	1	1.4	0.714
Total	10	31.9	0.313

* 22 porpoises were observed and reported taken at Spike Rock and 1 was reported taken in the Strait of Juan de Fuca during 1989.

Table 3

Observed and estimated incidental catch of harbor porpoise at Spike Rock, May-August 1989. SR = straight ratio method.

Month	Number observed	Estimated catch: SR	Estimated catch: Bootstrap (SE)
May	0	0.00	0.00
June	1	5.31	5.3 (4.8)
July	12	29.68	29.7 (11.1)
August	1	1.24	1.3 (1.1)
Total	14	36.23	36.3 (12.3)
95% CI	-	-	14-60

Life history parameters

Sex ratio of specimens collected

Of the 100 harbor porpoises collected during the three seasons, 55 were males and 45 were females. The life history data for these are presented in Tables 4 and 5.

Table 4

Life history data for male harbor porpoises (n=55) taken in the Makah set-net fishery, June 1988 - August 1990. Mean seminiferous tubule diameter is the mean of 10 tubules. Reproductive status is calf (C), immature (I) or mature (M). Reproductive condition is immature with very small tubules (1), immature with evidence of mitosis but no spermatogenesis (2), mature with early spermatogenesis and no sperm in epididymal tubules (3), or mature with active spermatogenesis (4).

Specimen	Date	Total length (cm)	Weight (kg)	Age	Reprod. status	Reprod. condition	Specimen	Date	Total length (cm)	Weight (kg)	Age	Reprod. status	Reprod. condition
PJG081	16/07/88	82.0	9.5	<1	C	C	PJG089	17/07/88	133.9	37.0	2	I	1
PGJ083	16/07/88	86.5	9.5	<1	C	C	PJG096	28/07/88	134.8	47.0	6	M	4
HK09	03/08/88	92.8	13.0	<1	C	C	PJG117	20/06/90	135.5	33.5	2	I	1
HK010	02/08/88	98.0	16.0	<1	C	C	MAJ12	25/07/89	136.0	47.1	2	I	2
RLD959	13/08/88	107.4	27.0	1	I	1	MAJ022	24/06/90	136.1	38.0	2	I	1
PJG092	17/07/88	115.1	33.0	2	I	1	PJG071	14/07/88	136.4	41.5	5	M	4
HK006	03/08/88	115.6	29.5	1	I	1	MAJ18	25/07/89	136.7	42.0	4	M	3
PJG114	08/07/89	115.8	26.2	1	I	1	PJG078	15/07/88	137.7	46.0	3	M	3
PJG104	31/07/88	117.7	37.0	1	I	1	PJG088	16/07/88	139.4	43.0	3	I	2
PJG085	16/07/88	120.4	31.0	1	I	1	PJG108	07/06/89	140.0	48.0	5	I	1
PJG099	28/07/88	120.5	31.0	1	I	1	PJG091	17/07/88	140.5	52.0	5	M	4
PJG111	05/07/89	120.7	29.9	1	I	1	MEG006	02/08/90	140.7	44.5	5	M	4
PJG107	22/08/88	121.7	31.0	1	I	1	RLD960	13/08/88	141.5	44.0	5	M	4
PJG115	17/07/89	123.4	28.5	1	I	1	HK014	09/08/88	142.0	44.5	4	M	4
RLD958	13/08/88	124.0	39.0	1	I	1	PJG094	25/07/88	142.1	61.0	5	M	4
PJG119	22/07/90	124.2	33.7	1	I	1	HK015	10/08/88	144.0	45.0	5	M	4
PJG093	19/07/88	124.3	31.0	2	I	1	HK003	03/08/88	144.6	52.0	5	M	4
MAJ6	10/07/89	125.2	35.3	1	I	1	HK007	03/08/88	144.9	48.0	8	M	4
PJG070	14/07/88	125.6	34.0	1	I	1	RLD955	13/08/88	146.0	48.0	5	M	4
PJG087	16/07/88	126.4	32.0	1	I	1	PJG102	29/07/88	147.0	52.0	6	M	4
PJG100	28/07/88	126.7	31.0	1	I	1	PJG086	16/07/88	147.1	52.0	7	M	4
PJG109	05/07/89	128.0	36.7	2	I	1	HK016	10/08/88	147.5	50.0	7	M	4
HK020	09/08/88	128.5	35.0	1	I	1	PJG110	05/07/89	148.3	52.7	6	M	3
MAJ021	24/06/90	129.1	32.0	2	I	1	PJG106	19/08/88	148.5	44.0	4	M	3
PJG076	15/07/88	131.8	35.0	3	M	3	HK013	06/08/88	149.0	54.0	7	M	4
HK017	09/08/88	132.1	39.0	2	I	1	HK021	09/08/88	149.8	53.0	5	M	4
PJG105	31/07/88	133.2	48.0	8	M	4	HK004	03/08/88	155.4	55.0	8	M	4
HK002	03/08/88	133.5	39.5	3	I	1							

Table 5

Life history data for female harbor porpoises (n=45) taken in the Makah set-net fishery, June 1988-August 1990. For follicle diameter and corpora diameter, --- indicates not present. Reproductive status is immature (I) or mature (M). Reproductive condition is post-partum (P), pregnant (PR), lactating (L), not lactating (NL) and colostrum (C).

Specimen	Date	Total length (cm)	Weight (kg)	Age	Reprod. status	Reprod. condition	Specimen	Date	Total length (cm)	Weight (kg)	Age	Reprod. status	Reprod. condition
MAJ8	10/07/89	115.2	26.7	1	I	-----	MEG005	28/07/90	148.0	48.4	2	I	-----
PJG066	29/06/88	116.0	29.0	1	I	-----	MEG004	28/07/90	148.5	50.1	3	-	-----
PJG112	08/07/89	117.9	25.8	1	I	-----	PJG065	23/06/88	149.0	50.0	3	I	-----
HK018	09/08/88	119.5	36.0	2	I	-----	PJG074	15/07/88	149.2	50.0	2	I	-----
HK001	03/08/88	120.8	24.0	1	I	-----	PJG075	15/07/88	149.7	43.0	3	I	-----
RLD956	13/08/88	122.6	34.0	1	I	-----	HK012	06/08/88	152.0	49.0	3	I	-----
PJG118	07/03/90	124.0	30.0	1	I	-----	PJG077	15/07/88	152.3	59.0	3	I	-----
PJG090	17/07/88	125.9	38.0	1	I	-----	PJG103	30/07/88	152.4	49.5	3	I	-----
HK019	09/08/88	126.5	36.5	1	I	-----	PJG101	29/07/88	152.9	53.0	3	I	-----
MEG003	10/07/90	127.4	-----	1	I	-----	PJG079	15/07/88	154.8	70.0	4	M	PR/C
HK011	06/08/88	127.5	40.0	1	I	-----	PJG121	23/07/90	156.5	50.5	3	M	P/L
PJG069	08/07/88	128.0	37.0	1	I	-----	PJG097	28/07/88	157.8	62.0	3	M	P/L
PJG113	08/07/89	130.3	35.0	1	I	-----	PJG116	17/07/89	158.4	52.2	3	M	P/NL
RLD957	13/08/88	130.4	32.0	1	I	-----	HK005	03/08/88	159.5	60.0	4	M	P/NL
MAJ16	25/07/89	132.6	34.9	2	I	-----	PJG120	22/07/90	160.8	70.2	4	M	P/L
PJG072	14/07/88	135.7	40.5	2	I	-----	PJG080	16/07/88	161.0	-----	4	M	P/L
MAJ20	02/08/89	136.0	36.6	1	I	-----	MAJ17	20/07/89	161.4	56.6	4	M	P/NL
PG082	16/07/88	137.2	42.0	1	I	-----	PJG098	28/07/88	163.0	54.0	3	M	P/NL
PJG073	14/07/88	139.6	46.0	2	I	-----	MEG001	10/07/90	168.2	60.0	4	M	P/L
MAJ7	10/07/89	140.0	34.4	2	I	-----	HK008	03/08/88	170.4	63.0	5	M	P/L
MEG002	10/07/90	140.9	35.0	1	I	-----	PJG084	16/07/88	177.5	86.5	5	M	P/L
PJG067	06/07/88	142.0	49.0	4	I	-----	PJG095	25/07/88	177.7	77.0	5	M	P/L
PJG068	07/07/88	143.0	45.0	3	I	-----							

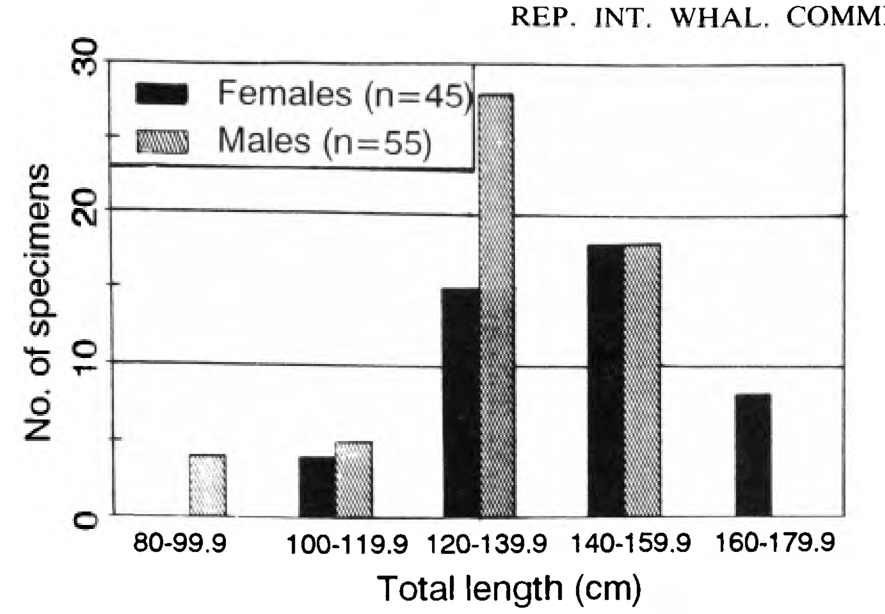

Fig. 2. Length distribution for female and male harbor porpoises collected during 1988–90.

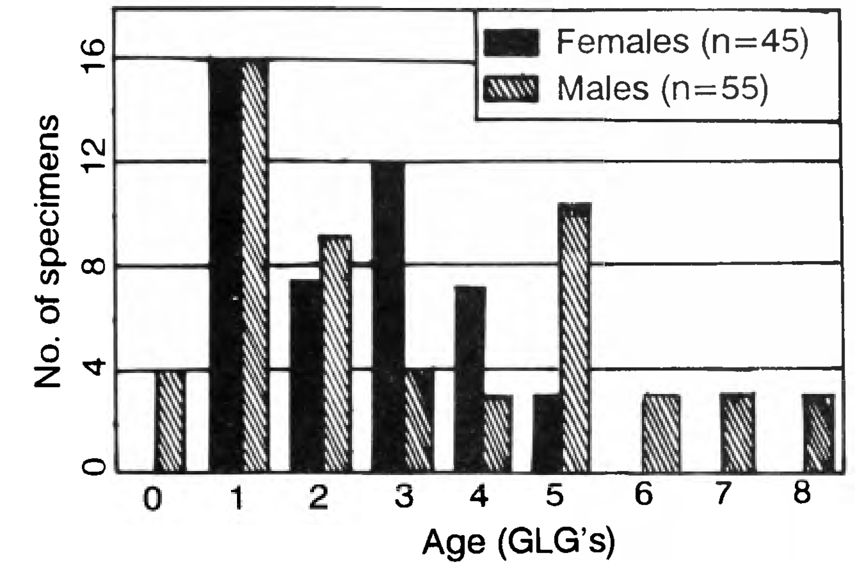

Fig. 3. Age distribution of female and male harbor porpoises collected during 1988–90.

Size and age of porpoises

The analyses of the mean length and weight distributions of sexually mature animals (Table 6, Fig. 2) showed that females were significantly longer and heavier than males (Mann-Whitney, $p<0.001$). Mature males had mean values of 143.0cm and 48.3kg while mature females had mean values of 163.6cm and 63.5kg (Table 6). Size dimorphism has been reported for other harbor porpoise populations (Möhl-Hansen, 1954; van Utrecht, 1978; Stuart, 1980; Gaskin *et al.*, 1984).

A large proportion of both sexes (48%) caught during 1988–90 were one and two year old animals (Fig. 3). There were more three year old females than males and no females over five years old. The absence of females over five years old may reflect a biassed sample given the small geographic area. Males ranged from newborn to eight years old, with 16% of the males being over five years old.

Table 6

Mean total lengths, body weights and ranges for 99 harbor porpoise collected from the Makah set-net fishery, July 1988-August 1990.

Reproductive class	n	Mean total length (cm)	Range (cm)	Mean body weight (kg)	Range (kg)
Immature females	31	134.9	115.2-152.9	39.9	24.0-59.0
Immature males	28	125.9	107.4-140.0	34.6	26.2-48.0
Mature females	13	163.6	154.8-177.7	63.5	50.5-86.5
Mature males	23	143.0	131.8-155.4	48.3	35.0-61.0
Calves	4	89.8	82.0-98.0	12.0	9.5-16.0

Gaskin and Blair (1977) and Read (1990a) reported the maximum age of porpoises in the Bay of Fundy at 10–13 years but suggested that most do not live beyond 7–8 years. Stuart (1980) reported a maximum age of 10 years in porpoises from the northeastern Pacific Ocean.

Reproductive condition

MALES

Four male calves were taken in the fishery in July and August. The mean total body length of calves (Table 6) was 89.8cm (SD=7.0cm). The mean seminiferous tubule diameters for three calves was 55.5μm (SD=15.79μm) and the mean paired testes weight was 12.6g (SD=6.3g).

Twenty-eight of 51 (54.9%) males (excluding calves) were immature and occurred in the fishery area throughout the collection period (Table 4). Immature males were 140cm or less in total body length (mean=125.9cm, SD=7.5cm) and were 5 years old or younger (Table 4). The mean seminiferous tubule diameter for immature males (reproductive classes 1 and 2) was 51.0μm (SD=14.9μm). This is similar to the results for mean tubule diameter for immature males in the Bay of Fundy (mean=48.0μm) (Gaskin *et al.*, 1984). The mean for paired testes weights was 142.7g (SD=237.9g).

Twenty-three males were mature (45.1%) and were present in the fishery area from 5 July through 19 August. Mature males (reproductive classes 3 and 4) were 3 years of age with a mean total body length of 143.0cm (SD=5.8cm) (Table 4). The mean seminiferous tubule diameter was 185.9μm (SD=31.4μm) and the mean of paired testes weights was 1742.1g (SD=1103.9g). The mean of the seminiferous tubule diameters for mature males in this study is greater than that reported for mature males in the Bay of Fundy population (mean=124.2μm) (Gaskin *et al.*, 1984). The differences in the range and mean tubule diameters are probably a reflection of individual variability but may also be due to the time of collection of each of the samples from the two populations relative to the reproductive cycle of animals in each population.

The seminiferous tubule diameter was significantly different for immature and mature males and increased with age (ANOVA $F=112.7$, $p<0.001$); Fig. 4). Based on

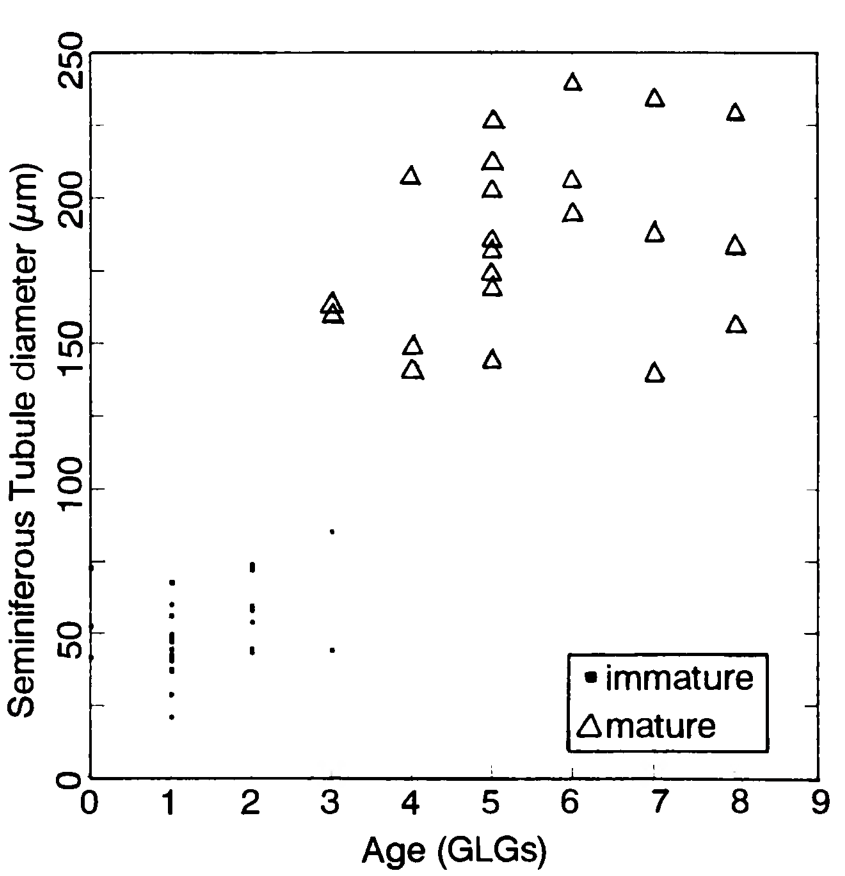

Fig. 4. Seminiferous tubule diameter versus age for male harbor porpoises collected during 1988–90.

histological evidence from the seminiferous tubules, the average age at attainment of sexual maturity was 3.5 years for this sample (DeMaster, 1978).

These values are similar to those estimated for the Bay of Fundy (Fisher and Harrison, 1970; Gaskin *et al.*, 1984; Read, 1990b) but the age is lower than that (5yrs) reported for porpoises from the North Sea (van Utrecht, 1978) and higher than that for animals in Danish waters (3yrs) reported by Clausen and Andersen (1988).

FEMALES

Immature females occurred in the fishery area from June through late August (Table 5). Thirty-one of 44 females (70.5%) (ovaries from one female were not collected) collected were reproductively immature (Table 5). Immature females were 4 years old or younger (Table 7) with a mean total body length of 134.9cm (SD=11.5cm).

Thirteen females were reproductively mature (29.5%) (Table 5). Mature females were 3 years old or older (Table 7) with a mean total body length of 163.6cm (SD=7.3cm). Eight of the mature females had recently given birth and were lactating and four females had recently given birth but were not lactating (Table 5). One female was pregnant with a full term fetus and producing colostrum.

The age at attainment of sexual maturity was 3.9 years for females in this sample (DeMaster, 1978).

Gaskin *et al.* (1984) and Fisher and Harrison (1970) found similar results for porpoises in the Bay of Fundy. Whereas van Utrecht (1978) reported 6 years (about 150cm) for North Sea females and Clausen and Andersen (1988) reported 3 years (140cm) for porpoises in Danish waters.

Although the sample size is small, 9 of the 13 sexually mature females had calves in the year of collection (based on presence of corpora lutea and lactation) yielding an estimated calving rate of 0.85 (calving rate = pregnancy rate).

Table 7

Occurrence of corpora (combined number of corpora lutea or corpora albicantia) in female harbor porpoise by age collected June 1988 - August 1990.

		Number of corpora					
Age	*n*	0	1	2	3	4	5
1	16	16	-	-	-	-	-
2	7	7	-	-	-	-	-
3	10	7	1	-	1	-	1
4	8	1	3	2	2	-	-
5	3	-	-	1	-	-	2

Stomach contents analysis

Of the 100 harbor porpoise stomachs collected in 1988–90, 94 contained identifiable prey, including four from calves that contained milk. The latter are excluded from the subsequent analyses. Although all compartments of each stomach were examined, only traces of bone or fish eye lenses were found in the main or pyloric compartments. Most food remains were found in the forestomachs (hereafter referred to as stomachs). Twenty-seven stomachs contained only trace amounts (less than 5.0g) of prey remains such as fish vertebrae, scales, eye lenses, otoliths or squid beaks. Three stomachs were completely empty.

Table 8

List of prey identified in harbor porpoise stomachs (n=96) from the 1988-90 Makah salmon set-net fishery.

Family or class	Common name	Scientific name
Clupeidae	Pacific herring	*Clupea harengus pallasi*
Osmeridae	Longfin smelt	*Spirinchus thaleichthys*
	Rainbow smelt	*Osmerus mordax*
	Capelin	*Mallotus villosus*
Gadidae	Pacific tomcod	*Microgadus proximus*
	Pacific hake	*Merluccius productus*
Salmonidae	Coho salmon	*Oncorhynchus kisutch*
Embiotocidae	Pile surfperch	*Damalichthys vacca*
Scorpaenidae	Yellowtail rockfish	*Sebastes flavidus*
Loliginidae	Market squid	*Loligo opalescens*
Crustacea	Shrimp	*Crangon alba*
	Isopoda	*Tecticeps pugettensis*

Prey identified

There is little published information on the food habits and foraging behaviour of harbor porpoises in the coastal waters of Washington State. Wilke and Kenyon (1952) reported a harbor porpoise collected near Port Townsend that had the remains of five Pacific herring (*Clupea harengus pallasi*) in its stomach. Scheffer (1953) examined the stomach of a stranded harbor porpoise (Twin Harbor Beach, WA) which contained 37 capelin (*Mallotus villosus*) and had suffocated due to a shad (*Alosa sapidissima*) lodged in its throat. Another harbor porpoise choked by a shad had been found dead on the same beach five years earlier (Scheffer and Slipp, 1948). Beach *et al.* (1985) reported the stomach contents of 10 harbor porpoise found dead on beaches near the Columbia River. Prey, including nine species of bony fishes and market squid (*Loligo opalescens*), was found in seven of the stomachs. One stomach also contained the remains of salmon. In our study (Table 8), six families and at least 9 species of bony fishes were identified from the stomachs as well as one species each of cephalopod (market squid), shrimp (*Crangon alba*) and isopods (*Tecticeps pugettensis*).

Percent occurrence (Table 9)

The dominant prey species for all years combined in order of percent occurrence were Pacific herring, smelt (Family Osmeridae), market squid, gadids and shrimp; Coho salmon (*Oncorhynchus kisutch*), rockfish (Family Scorpaenidae), surfperch (Family Embiotocidae) and isopods occurred in one stomach each. Some differences between years were apparent although the sample size was smaller in 1989–90 (Fig. 5). During 1988, Pacific herring was the dominant prey identified (78.7% of the stomachs) followed by market squid (37.7%) and smelt (32.8%) – whereas in 1989, smelt predominated (76.4%) followed by squid and gadids (64.7% each) and Pacific herring (52.9%). In 1990, Pacific herring was again the number one ranked prey (75.0%) followed by smelt (41.6%) and gadids (33.3%).

Number of prey (Table 10)

The 1988 stomachs contained 845 otoliths and 195 squid beaks. Smelt otoliths accounted for 57% of the total otoliths, followed by Pacific herring otoliths (32%) and gadids (10%). Of the 195 squid beaks recovered, 100 were upper beaks indicating that at least 100 individuals were represented.

Table 9

Percent occurrence of prey found in harbor porpoise stomachs collected from the Makah salmon set-net fishery, 1988 (n=61); 1989 (n=17) and 1990 (n=12).

	1988		1989		1990		Total	
Prey	No.	%	No.	%	No.	%	No.	%
Pacific herring	48	78.7	9	52.9	9	75.0	66	73.3
Osmeridae	20	32.8	13	76.4	5	41.6	38	42.2
Market squid	23	37.7	11	64.7	2	16.6	36	40.0
Gadidae	13	19.7	11	64.7	4	33.3	28	31.3
Shrimp	3	4.9	3	17.6	1	8.3	7	7.7
Coho salmon	1	1.6	0	0	0	0	1	1.1
Pile surfperch	1	1.6	0	0	0	0	1	1.1
Yellowtail rockfish	1	1.6	0	0	0	0	1	1.1
Isopoda	0	0	1	5.9	0	0	1	1.1

Table 10

Otoliths and squid beaks recovered from harbor porpoise stomachs collected during the 1988 Makah salmon set-net fishery 1988-90.

	1988		1989		1990	
Prey	No. of beaks or otoliths	%	No. of beaks or otoliths	%	No. of beaks or otoliths	%
Osmeridae	482	57.04	643	59.98	45	28.90
Pacific herring	269	31.83	40	3.73	86	55.10
Gadidae	88	10.41	389	36.29	25	16.00
Embiotocidae	3	0.36	0	0	0	0
Scorpaenidae	2	0.24	0	0	0	0
Salmonidae	1	0.12	0	0	0	0
Market squid	195 [1]		63 [2]		5 [3]	
Total	845	100.00	1,072	100.00	156	100.00

[1] 100 upper and 95 lower squid beaks were recovered. [2] 32 upper and 31 lower beaks were recovered. [3] 3 upper and 2 lower beaks were recovered.

During 1989, 1,072 otoliths were recovered of which Osmeridae accounted for 59.9% and Gadidae 36.2%. During 1990, 156 otoliths were recovered of which 55% were Pacific herring, 28.9% osmerids and 16% gadids.

For all years combined, fresh (with flesh still intact) or whole prey were recovered from 66 out of 96 stomachs (68.7%). Whole fish remains were recovered in 56 stomachs and whole squid in 22 stomachs. Eighteen stomachs contained both fish and squid. Pacific herring was the dominant prey numerically (203 were represented by the anatomical parts recovered) followed by smelt (135) and squid (54).

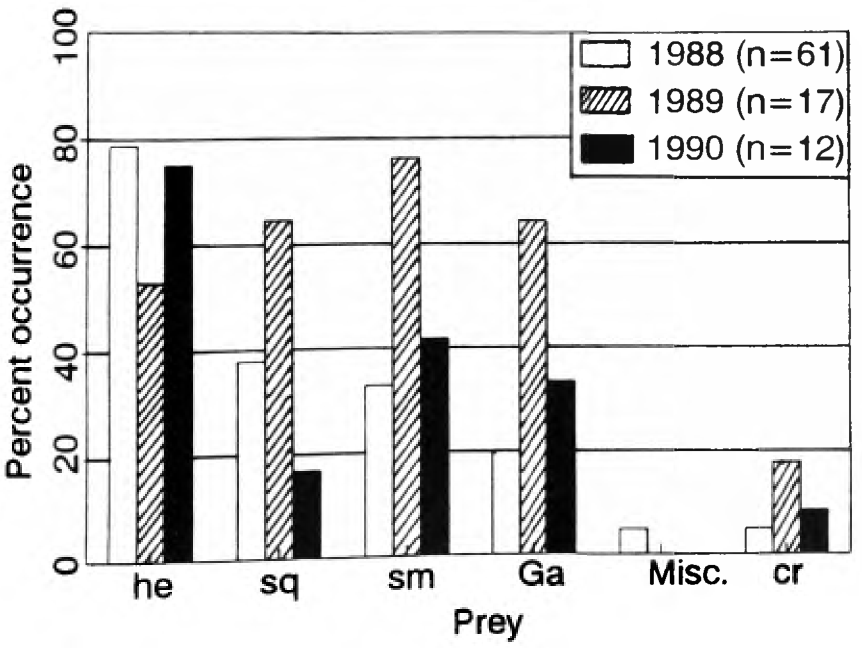

Fig. 5. Percent occurrence of major prey identified from harbor porpoise stomachs during 1988–90.

Size of prey

Harbor porpoises are known to feed on smaller, soft-bodied prey and rarely consume prey larger than 35cm in length (Rae, 1965; Jones, 1981; Recchia and Read, 1988).

The mean length of Pacific herring (n=15) found in porpoise stomachs in our study was 15.8cm (range 12–18cm). This length corresponds to juvenile herring in the 2–3 year old year classes with weights of approximately 70g apiece (Hart, 1973). The mean length of smelt (n=21) was 8.8cm (range 6–10.5cm) and based on otolith size, most appeared to be juveniles. The mean DML of market squid (n=28) was 8.53cm (range 6–10cm) and the mean mass was 8.97g (range 4–12g). Market squid of this size are juveniles of ages 6–15 months, with most probably 12 months old (Hixon, 1983). The size of a single coho salmon found in one stomach was an estimated 30–40cm long and probably a juvenile of about 1kg based on the sizes of the vertebrae and otolith. Most harbor porpoises appeared to be feeding on juvenile gadids as estimated by the relative size of the otoliths when compared to otoliths from known length fish from the NMML reference collection. Some gadid otoliths were minute (1mm or less in length) which would probably be from very young or even larval fish.

Sex and age differences

No major differences were found in stomach contents between males and females in terms of percent occurrence or numbers of prey consumed. Recchia and Read (1988) reported that pregnant or lactating harbor porpoises feed on the same prey but had a higher mass of contents in their stomachs than males or subadult animals. Our sample

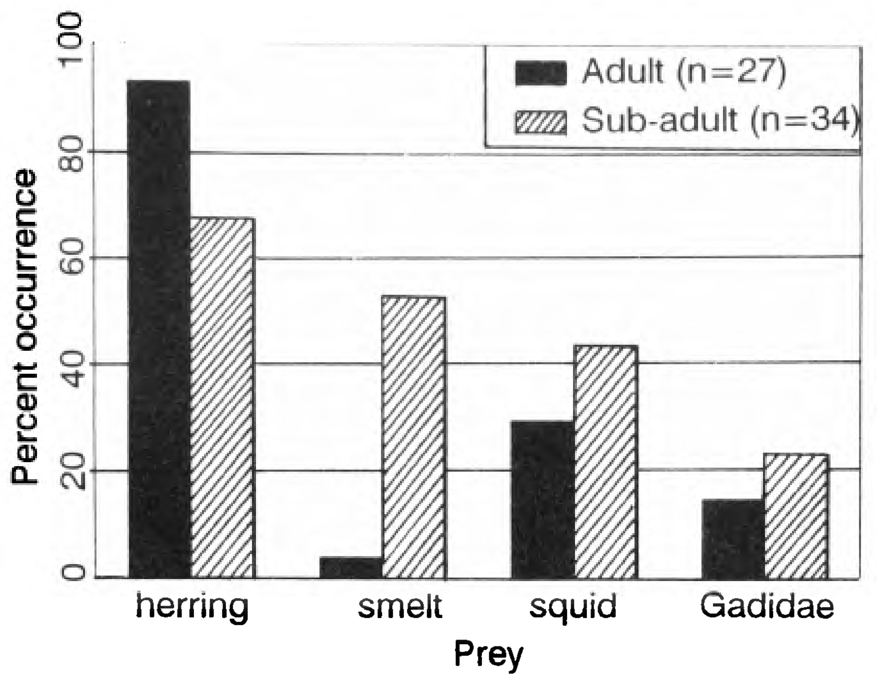

Fig. 6. Percent occurrence of major prey identified from adult and subadult harbor porpoise stomachs during 1988.

contained few lactating or pregnant females. However, one lactating female we examined had the largest mass of stomach contents (1,000g) and was the only individual which fed on salmon.

There were major differences in prey consumed by adults and subadults (reproductively mature vs. immature). Adult porpoises fed primarily on Pacific herring, with very few feeding on smelt (Fig. 6). Subadult porpoises fed on Pacific herring and over 60% fed on smelt. The numbers of fish otoliths and squid beaks recovered in porpoise stomachs were compared between adult and subadult porpoises during the 1988 season. Adult porpoises had significantly more Pacific herring otoliths in their stomachs than subadults (two sample t-test $p=0.052$) and significantly fewer smelt otoliths (two sample t-test $p=0.002$). There were no significant differences in the numbers of gadids consumed by adults and subadults based on otolith counts (t-test $p=0.44$). Subadult porpoise stomachs also contained significantly more squid beaks than adults (twosample t-test $p=0.023$).

Salmon stomachs

Information on the diet of adult chinook salmon from the northwest coast of Washington is scarce. However, northern anchovy (*Engraulis mordax*), Pacific herring, crab (*Cancer* sp.) and market squid have been recorded (Brodeur *et al.*, 1987). In British Columbia, Hart (1973) reported that they feed on Pacific herring, Pacific sand lance (*Ammodytes hexapterus*), pilchard (*Sardinops sagax*) and rockfish (Family Scorpaeniade).

Six of the 50 stomachs examined in this study were empty and the remainder contained identifiable prey. Pacific herring was the dominant prey of chinook salmon (found in 93.1% of the stomachs) followed by smelt (18.1%) and market squid (12.5%). No other prey were recovered. Numerically, herring were represented by 89 whole or partial fish followed by 23 smelt and 19 market squid.

Prey comparison

The prey taken by harbor porpoises and chinook salmon were compared using percent occurrence and the relative size of the prey consumed (Fig. 7). The three major prey items for both predators were Pacific herring, market squid and smelt. Pacific herring was the dominant prey for both species during the 1988 season, although it was found in a

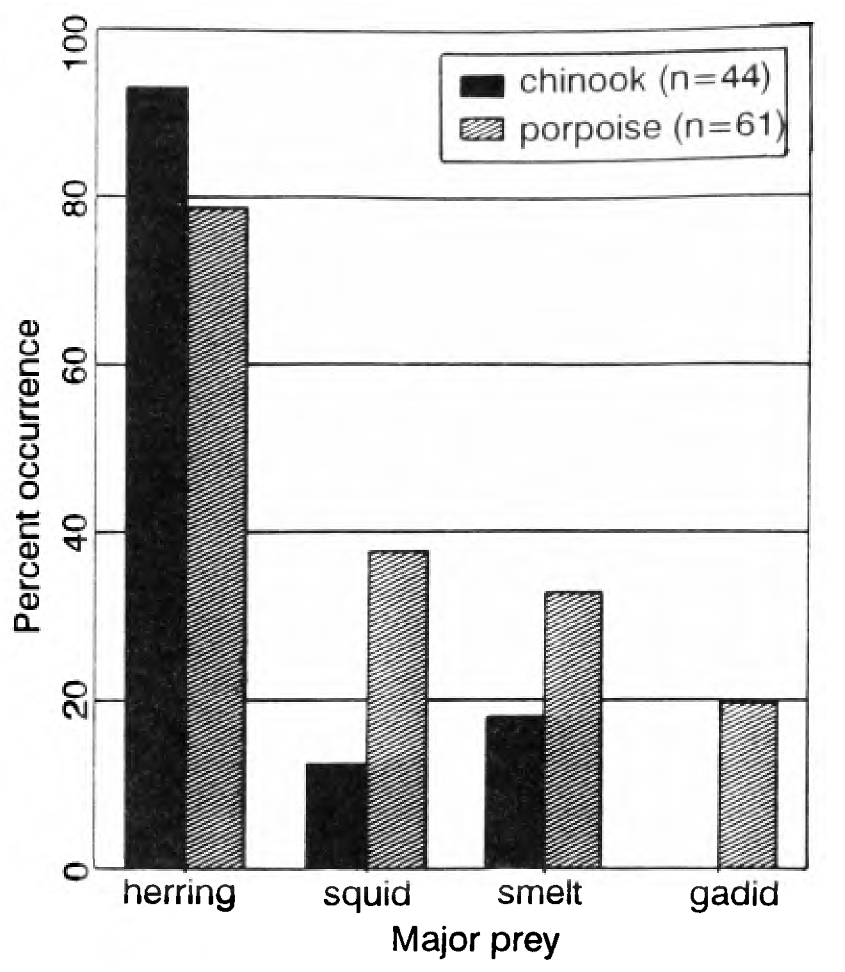

Fig. 7. Percent occurrence of major prey identified from harbor porpoise and chinook salmon stomachs during 1988.

greater percentage of chinook stomachs. Market squid and smelt were the second and third most prevalent prey in porpoise stomachs whereas the reverse was true for chinook salmon. Chinook salmon fed on significantly larger herring than did porpoises (Mann Whitney test $P < 0.00001$). The mean lengths of herring consumed were 20.8cm ($n=19$, range 19–23cm) for salmon and 15.86cm ($n=15$, range 12–18cm) for porpoises. Pacific herring of lengths between 19 and 23cm are adult fish 4–8 years old that weigh 85–183g (Hart, 1973). No chinook salmon stomachs were collected from the Spike Rock area in 1989; however, the several hundred chinook salmon stomachs examined from the Skagway Rocks area in 1989 contained primarily Pacific sand lance with few containing Pacific herring.

Measures to reduce porpoise catches

Individual fishermen took steps to reduce the level of incidental take of harbor porpoises during 1989 and 1990, primarily by reducing fishing effort in the Spike Rock area during July and August, the period of the highest rates of porpoise catches (Table 2). Effort was reduced by setting fewer nets and by decreasing the number of days the nets were in the water. Several nets were set for several days at a time at Spike Rock as indicator nets to see if chinook salmon were present. If only a few chinook salmon were caught, the nets were pulled out. After 1–2 weeks, the indicator nets were again set. By contrast in 1988 and previous years, nets were often left in place for several months at a time. During the 1988 fishing season, as many as 12 nets were in place at one time in the Spike Rock area, while only four nets were set in 1989 and two in 1990.

During 1990 fishermen also attempted to reduce the bycatch by setting nets in areas that had been low catch areas in previous years, i.e. in the southern inshore areas of the Spike Rock grounds. The effectiveness of this is questionable since the rates of porpoise catch were higher in 1990 than in 1988 or 1989.

Part of the reason for reduced fishing effort at Spike Rock during 1989–90 was related to low numbers of chinook salmon in the area. Fishing effort probably would have been greater in this area had chinook salmon been abundant.

CONCLUSIONS

The observations of the Makah salmon set-net fishery from 1988–90 demonstrate that the interactions between harbor porpoise and the fishery are limited to a small area and time span. Harbor porpoises were taken almost exclusively (97%, $n=138$) at the Spike Rock fishing grounds, which is a small fraction of the overall Makah set-net fishing grounds (Fig. 1). Similarly most (80%, $n=138$) of the porpoises taken from 1988–90 were caught between 14 July and 13 August. No harbor porpoises were reported or observed taken during May and only six were taken during June, despite the presence of nets set at Spike Rock during May and June of 1988 and 1989.

The low fishing effort at Spike Rock during 1989 and 1990 was partially a result of low numbers of chinook salmon in the area.

Both harbor porpoises and chinook salmon were actively foraging in the Spike Rock area and feeding on similar prey, although harbor porpoises appear to have a more diverse prey base. For both predators, Pacific herring was the principle prey species, although the salmon fed on significantly larger individuals. The results suggest that the reason for chinook salmon and harbor porpoises frequenting the Spike Rock area was correlated with prey availability, leaving both species susceptible to entanglement in gillnets.

The potential impact of the Makah set-net fishery on the regional harbor porpoise population is difficult to assess because little is known about the size, movements and discreteness of the population. If the animals in northern Washington coastal waters (estimated at about 900 individuals; Calambokidis et al., 1992) are viewed as a discrete group with little or no immigration, then the reported incidental catches for 1988–90 (102, 23, and 13) represent between 1.4% to 11.3% of the population. If the harbor porpoises in northern waters are part of a freely mixing population incorporating the entire Washington coast and the Swiftsure Bank area of Canada, the incidental catches would represent between 0.01% and 1.1% of the population estimate of about 13,000 (Calambokidis *et al.*, 1992).

A further factor to be considered in assessing the impact of incidental catches is that 63% of the mortality involved immature animals. In the short term this might suggest that the mortality will have less impact than if most or all of the mortality involved mature animals (e.g. see Chapman, 1987), but it has the potential of affecting future recruitment rates and thus remains a cause for concern. This is particulary true given the reproductive capacity of harbour porpoises. Most females give birth annually and only bear 4–5 calves in their lifetime (Gaskin *et al.*, 1984; Read, 1990a). Their apparently short life span limits reproductive flexibility, particularly with respect to any density-dependent response to high levels of mortality (Kasuya, 1976; 1985), further accentuating the need to resolve interactions.

It is clear that future research should concentrate on the refinement of population estimates and the delineation of boundaries of local populations (should they exist) or a demonstration of the continuity of harbor porpoise stocks along the Washington coast.

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A Note on Odontocete Mortality from Fishing Gear Entanglements off Southern California

John E. Heyning and Thomas D. Lewis

Section of Birds and Mammals, Natural History Museum of Los Angeles County, 900 Exposition Blvd., Los Angeles, CA 90007, USA

and

Charles D. Woodhouse

Section of Vertebrate Zoology, Santa Barbara Museum of Natural History, 2559 Puesta del Sol Road, Santa Barbara, CA 93105, USA

ABSTRACT

Strandings and sightings data of toothed whales entangled in fishing gear are documented for the Southern California Bight from 1975–90. Entanglements involve three fisheries: a nearshore set gillnet fishery; an offshore drift gillnet fishery; and a purse seine fishery for squid. Common dolphins were the most frequently entangled species south of Point Conception and harbor porpoises north of this point. For common dolphins, the majority of records were from the long-beaked species. Pilot whales were the most frequently documented takes prior to the 1982–83 El Niño event. Records of entanglement for other species include white-sided dolphins, Risso's dolphins and bottlenose dolphins with single records each for a killer whale, Cuvier's beaked whale and Hubb's beaked whale.

KEYWORDS: INCIDENTAL CAPTURE; NORTH PACIFIC; HARBOR PORPOISE; COMMON DOLPHINS; WHITE-SIDED DOLPHINS; RISSO'S DOLPHINS; BOTTLENOSE DOLPHINS; KILLER WHALE; CUVIER'S BEAKED WHALE; HUBB'S BEAKED WHALE; PILOT WHALE-LONG FINNED

INTRODUCTION

Twenty one species of odontocetes have been recorded off the coast of southern California (Leatherwood *et al.*, 1988). Although entanglements of baleen whales in fishing gear in this region have been summarised (Heyning and Lewis, 1990), there are few accounts documenting incidental kills of odontocetes (Norris and Prescott, 1961; Seagers and Henderson, 1985; Heyning, 1988; Bodkin and Jameson, 1991; Sinclair, 1992). In this report we summarise such data in order to determine which populations of odontocetes might be affected. Interactions in this region primarily involve three fisheries: the nearshore set gillnet fishery for sea bass and halibut; the offshore drift gillnet fishery for swordfish and shark; and the purse seine fishery for squid.

MATERIALS AND METHODS

Data on mortalities of toothed whales resulting from entanglement in fishing gear were gathered for southern California waters from the northern border of San Luis Obispo County to the Mexican border for the years 1975–90, inclusive. The data were obtained primarily from examinations of dead, stranded animals; only a few specimens were retrieved directly from nets. Specimens were normally included only if they bore direct marks such as net lacerations, knife cuts, or severed appendages (Hare and Mead, 1987) although some specimens were included if strong circumstantial evidence was present, such as apparently healthy animals whose stomachs were full of recently consumed food. Often several such animals in this condition were found dead within a small area over a short period of time. Common dolphin specimens were categorised into the long-beaked species (*Delphinus capensis*) (synonymous with *Delphinus bairdii*) and the short-beaked species (*Delphinus delphis*) based on the pigmentation and cranial criteria (Banks and Brownell, 1969; Evans, 1975, Evans, 1982; Heyning and Perrin, 1994).

RESULTS

We documented 69 fishery-related takes of odontocetes during the study period (Table 1). Of these, 44.9% (n=31) were of common dolphins (*Delphinus* spp.) with no detectable sex bias (15 males, 14 females). Sixteen specimens examined for reproductive condition included equal numbers of sexually mature and immature animals. Of the specimens identified to species, 19 were *D. capensis* and two were *D. delphis*.

Pilot whales (*Globicephala macrorhynchus*) were the next most frequently involved species (n=14) representing 20.3% of the total sample. With one exception, all takes of pilot whales occurred in 1980 or prior to this (Fig. 1).

Harbor porpoise (*Phocoena phocoena*) were the most frequently documented species killed in fishery operations north of Point Conception with 10 records. Most of the entangled harbor porpoises (8 of 9) were sexually immature.

Of the remaining records, bottlenose (*Tursiops truncatus*) and Risso's dolphins (*Grampus griseus*) were each represented by four records, white-sided dolphins (*Lagenorhynchus obliquidens*) by three records, and killer (*Orcinus orca*) and two species of beaked whales (*Mesoplodon carlhubbsi* and *Ziphius cavirostris*) each by single records. Records of fishery-related kills were lower in the summer months (Fig. 2).

Table 1

Records of odontocetes found dead due to interactions with fisheries in southern Californian waters. Entries followed by an 'E' indicate an estimated length. The long-beaked species of common dolphins are noted as *Delphinus capensis* and the short-beaked species as *D. delphis*. Institutional acronyms are LACM = Natural History Museum of Los Angeles County and SBMNH = Santa Barbara Museum of Natural History.

Source	Species	Sex	Length (cm)	Date	Locality	Comments
SBMNH 77-56	*Delphinus* sp.	F	144	1977/12/05	Ventura Co., Ventura Marina	Floating, crabpot line
LACM 72496	*Delphinuis delphis*	M	180E	1983/02/28	Orange Co., Huntingdon Beach	Stranding, flukes severed
LJH 106	*Delphinus* sp.	M	159	1983/08/22	San Diego Co., Carlsbad	Stranding, net marks
LJH 127	*Delphinus capensis*	M	215	1984/01/19	San Diego Co.	Stranding, flukes severed
DK 84-01	*Delphinus* sp.	M	201	1984/01/19	Orange Co., Dana Point	Floating, net marks
DK 84-04	*Delphinus capensis*	M	206	1984/03/09	Orange Co., Huntingdon Beach	Stranding, net marks
DK 85-02	*Delphinus capensis*	M	208	1985/03/03	Orange Co., San Clemente	Stranding, stomach full
DK 85-08	*Delphinus* sp.	M	180E	1985/04/18	Orange Co., San Clemente	Stranding, flukes severed
DK 85-12	*Delphinus* sp.	M	195	1985/05/18	Orange Co., Newport Beach	Stranding, stomach full
DK 85-13	*Delphinus capensis*	M	215	1985/05/31	Orange Co., Huntingdon Beach	Stranding, net marks
SBMNH 3407	*Delphinus* sp.	M	190	1985/11/27	Santa Barbara Co., Embarcadero	Stranding, flukes severed
HJB 26	*Delphinus capensis*	F	207	1986/02/11	San Diego Co., Cardiff	Stranding, net marks
HJB 29	*Delphinus capensis*	F	212E	1986/04/14	San Diego Co., Cardiff	Stranding, flukes severed
DK 86-06	*Delphinus* sp.	M	198	1986/04/21	Orange Co., Huntingdon Beach	Stranding, net marks
HJB 37	*Delphinus* sp.	M	193	1986/10/16	San Diego Co., San Diego Bay	Floating, line around tail
LACM 84258	*Delphinus capensis*	F	?	1986/12/13	San Luis Obispo Co., Morro Bay	Floating, flukes severed
SBMNH 3664	*Delphinus capensis*	F	218	1986/12/16	Santa Barbara Co., Coal Oil Pt.	Stranding, knife cuts
SBMNH 86-29	*Delphinus* sp.	?	182	1986/12/31	Santa Barbara Co., Gaviota	Stranding, knife cuts
LACM 84021	*Delphinus capensis*	F	211	1987/02/02	Los Angeles Co., Palos Verdes	Stranding, net marks
LACM 84092	*Delphinus capensis*	F	206	1987/02/15	Orange Co., Laguna Beach	Sranding, net marks
LACM 84040	*Delphinus capensis*	F	189	1987/03/04	Orange Co., San Clemente	Stranding, knife cuts
LACM 72595	*Delphinus capensis*	F	190	1987/03/08	Orange Co., Laguna Beach	Stranding, net marks
LACM 84130	*Delphinus capensis*	F	185E	1987/11/12	Los Angeles Co., Off L.A. Harbor	Stranding, flukes severed
LACM 84129	*Delphinus delphis*	F	175E	1988/05/10	Orange Co., Newport Beach	Stranding, flukes severed
LACM 84121	*Delphinus capensis*	F	195	1988/05/20	Los Angeles Co., Cabrillo Beach	Stranding, net marks
LACM 84100	*Delphinus capensis*	F	200E	1988/05/26	Orange Co., Newport Beach	Stranding, flukes severed
LACM 84184	*Delphinus capensis*	M	220E	1988/12/08	Los Angeles Co., San Pedro	Stranding, flukes severed
SBMNH 3959	*Delphinus* sp.	?	152	1989/03/05	Santa Cruz Island	Stranding, flukes severed
SBMNH 3893	*Delphinus capensis*	F	216	1989/03/22	Santa Barbara Co., Pt. Conception	Stranding, rope marks, bullets
LACM 84256	*Delphinus capensis*	M	198	1990/01/07	Los Angeles Co., Paradise Cove	In gillnet
SBMNH 3979	*Delphinus capensis*	M	228	1990/02/12	Santa Barabara Co., Goleta	Stranding, net marks
LACM 54182	*Globicephala macrorhynchus*	F	470E	1975/10/15	Los Angeles Co., Palos Verdes	Stranding, flukes severed
LACM 54749	*Globicephala macrorhynchus*	M	610	1977/11/07	Los Angeles Co., Palos Verdes	In purse seine net
LACM 54185	*Globicephala macrorhynchus*	F	433	1977/11/19	Los Angeles Co., Paradise Cove	Stranding, stomach full of squid
LACM 54184	*Globicephala macrorhynchus*	F	419	1977/11/19	Los Angeles Co., Paradise Cove	Stranding, stomach full of squid
SBMNH 77-53	*Globicephala macrorhynchus*	?	419	1977/11/22	Ventura Co., 5km S of Pt. Mugu	Stranding, circumstantial evidence
SBMNH 1637	*Globicephala macrorhynchus*	?	430E	1977/11/23	Ventura Co., La Jolla Beach	Stranding, stomach full of squid
WFS 1042	*Globicephala macrorhynchus*	?	500E	1980/01/22	Santa Catalina Island	Stranding
Seagers 1985	*Globicephala macrorhynchus*	?	?	1980/12/17	Santa Catalina Island	Floating, circumstantial evidence
Seagers 1985	*Globicephala macrorhynchus*	?	?	1980/12/17	Santa Catalina Island	Floating, circumstantial evidence
Seagers 1985	*Globicephala macrorhynchus*	?	?	1980/12/17	Santa Catalina Island	Floating, circumstantial evidence
Seagers 1985	*Globicephala macrorhynchus*	?	?	1980/12/17	Santa Catalina Island	Floating, circumstantial evidence
Seagers 1985	*Globicephala macrorhynchus*	?	?	1980/12/17	Santa Catalina Island	Floating, circumstantial evidence
Seagers 1985	*Globicephala macrorhynchus*	F	463	1980/12/19	Santa Catalina Island	Floating, stomach full of squid
LACM 84088	*Globicephala macrorhynchus*	?	250E	1988/03/24	San Clemente Island	Stranding, flukes severed
LACM 84174	*Grampus griseus*	M	229	1988/10/15	Orange Co., Crystal Cove	Stranding, stomach full of squid
LACM 84205	*Grampus griseus*	F	264	1988/10/17	Orange, Crystal Cove	Stranding, stomach full of squid
LACM 84201	*Grampus griseus*	F	314	1988/12/16	Los Angeles Co., L.A. Harbor	Stranding, stomach full of squid
LACM 84175	*Grampus griseus*	?	300E	1989/01/03	Los Angeles Co., Palos Verdes	Stranding, flukes severed
LACM 84053	*Lagenorhynchus obliquidens*	M	195	1981/05/16	Orange Co., Boisa Chica	Stranding, trammel net marks
LACM 84114	*Lagenorhynchus oliquidens*	M	232	1988/04/27	Orange Co., Huntingdon Beach	Stranding, circumstantial
LACM 84133	*Lagenorhynchus obliquidens*	?	201	1988/04/30	Orange Co., Huntingdon Bch.	Stranding, stomach full
LACM 72550	*Orcinus orca*	F	260	1985/04/21	Orange Co., Bolsa Chica	Stranding, net marks
WFP 520	*Tursiops truncatus*	M	300E	1976/06/28	San Diego Co., Cardiff	Stranding, flukes severed
LJH 6	*Tursiops truncatus*	F	236	1981/11/14	San Diego Co., La Jolla	Stranding, net marks
DK 85-19	*Tursiops truncatus*	M	218E	1985/10/05	Orange Co., Boisa Chica	Stranding, flukes severed
LACM 84285	*Tursiops truncatus*	F	272	1990/08/13	San Diego Co., La Jolla	Stranding, knife cuts
LACM 72588	*Phocoena phocoena*	M	100	1976/07/29	San Luis Obispo Co., Oceano	Stranding, net marks
SBMNH 1380	*Phocoena phocoena*	?	151	1977/03/01	San Luis Obispo Co., Ocean Beach	Stranding, probable gunshot
LACM 84016	*Phocoena phoecoena*	M	133	1983/08/13	San Luis Obispo Co., Pt. Estero	In monofilament gillnet
LACM 72541	*Phocoena phocoena*	M	133	1983/09/24	San Luis Obispo Co., Pt. Estero	In nylon trammel net
LACM 72563	*Phocoena phocoena*	F	138	1983/09/27	San Luis Obispo Co., Morro Bay	In monofilament gillnet
LACM 72540	*Phocoena phocoena*	F	135	1984/01/25	San Luis Obispo Co., Morro Bay	In monofilament gillnet
LACM 72536	*Phocoena phocoena*	M	124	1984/03/03	San Luis Obispo Co., Morro Bay	In monofilament gillnet
LACM 72539	*Phocoena phocoena*	M	121	1984/04/27	San Luis Obispo Co., Cayucos	In monofilament gillnet
LACM 72538	*Phocoena phocoena*	M	124	1985/04/27	San Luis Obispo Co., Off Cayucos	In monofilament gillnet
RLB 1006	*Phocoena phocoena*	F	184	1987/01/26	San Luis Obispo Co., Estero Bay	In monofilament gillnet
LACM 84018	*Mesopolodon carlhubbsi*	F	256	1986/06/04	Orange Co., San Clemente	Stranding, net marks
USNM 550122	*Ziphius cavirostris*	M	526	1980/11/20	San Diego Co., La Jolla	Stranding, knife cuts

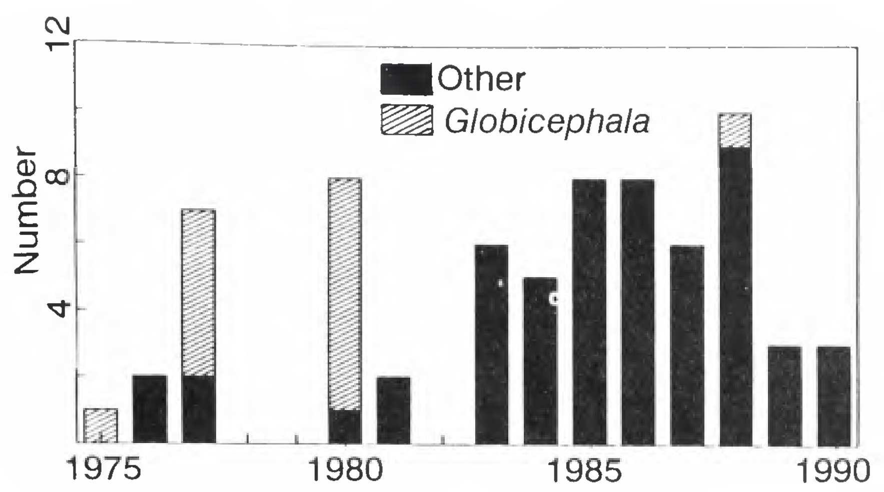

Fig. 1. Records of odontocete mortalities from fisheries interactions by year from 1975 through 1990.

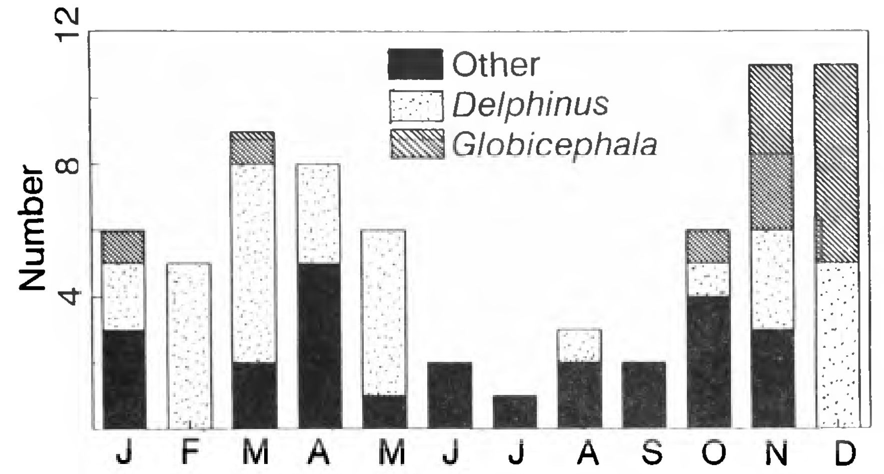

Fig. 2. Records of odontocete mortalities from interactions with fisheries by month.

DISCUSSION

Reports of fishery takes increased through the study period (Fig. 1), particularly if the takes of pilot whales are excluded. This apparent rise may result from an increase in fishing activities, an increase in the documentation of fishery-related mortalities or a combination of both.

Our stranding data greatly underestimate entanglements in fisheries, especially offshore drift gillnets, because cetacean carcasses typically do not drift significant distances shoreward (Heyning and Lewis, 1990; Bishop, 1985; Bodkin and Jameson, 1991). Data from stranded animals also are difficult to interpret because they represent an unknown percentage of the entanglements that actually occur (Seagers *et al.*, 1986) and carcass retrieval effort is difficult to quantify.

Absolute abundance estimates have only recently been available for most odontocete species in Californian waters (Barlow *et al.*, 1993). Common dolphins are the most abundant cetacean species in southern California waters (Evans, 1975; Leatherwood and Walker, 1979), although few surveys to date have distinguished between the two species. The long-beaked species is the most frequently entangled common dolphin based on strandings, but the population level of this species is unknown.

White-sided dolphins are also abundant in southern California waters (Leatherwood and Walker, 1979; Leatherwood *et al.*, 1984) but absolute abundance estimates for southern Californian waters are not available. In the eastern North Pacific, there are two putative stocks of white-sided dolphins; a larger, southern form and a smaller, northern form (Walker *et al.*, 1986). These two forms overlap in the Southern California Bight. Although this species represents only three specimens in our data, it is rarely found in waters shallower than about 40m (Leatherwood *et al.*, 1984). It is thus more susceptible to entanglements in offshore drift gillnets where catches have been documented by fisheries observers (Diamond *et al.*, 1987).

Prior to the 1982–83 El Niño event, pilot whales were abundant during the winter in the waters surrounding the Channel Islands. Although there are potential problems with the previous abundance estimates (A. Hohn, pers. comm.), it is likely that the number of pilot whales in southern California waters ranged from several hundred to a few thousand animals during the winter months prior to 1983. The reasons for the decreased sightings of pilot whales in this region since 1983 are unknown. There have been no studies to determine the structure of pilot whale stocks in the eastern North Pacific. We believe that most of the pilot whales in our data were killed in purse seine operations for squid. One specimen was recovered directly from such a vessel. During November 1977 and December 1980, several pilot whales were found dead within a small area (Table 1). All animals examined (Seagers and Henderson, 1985; Sinclair, 1992) had stomachs full of market squid (*Loligo opalescens*) and commercial squid boats were reported to have been working those areas at that time. The high number of dead animals reported prior to 1981, when documentation of fishery-related kills was low, suggests that the absolute number of pilot whales killed may have been significant.

Harbor porpoises in California currently may be at 30–97% of carrying capacity due to fisheries-related mortalities (Barlow and Hanan, 1994). Our finding that more sexually immature animals are represented in our sample is corroborated by the much larger sample of incidentally killed California harbor porpoise studied by Hohn and Brownell (1990).

Although no quantifiable data are available, the numbers of Risso's dolphin sightings have increased noticeably over the past 15 years (pers. obs.). There is no information on the presence of distinct stocks of Risso's dolphins in the North Pacific. We believe that Risso's dolphins are killed primarily in purse seine operations for squid; as with pilot whales, these stranded animals have stomachs filled with fresh market squid (*L. opalescens*). We have often heard reports of squid boats working the region on nights prior to the discovery of dead animals.

Bottlenose dolphins off southern California have been classified into offshore and inshore types (Walker, 1981). Abundance estimates are only available for the inshore type, with a population in southern Californian waters ranging from 173 to 240 animals (Hansen, 1990). With such a low population level, if this represents a discrete stock, it would be susceptible to impact even from low numbers of annual takes.

For the beaked whales (Ziphiidae), virtually nothing is known of population levels or the status of stocks. The same is true of the status of killer whales in southern Californian waters but, based on infrequent sightings, we assume that the numbers probably do not exceed the very low hundreds.

Limited data from observers placed on offshore drift gillnet boats indicates that both species of common dolphins are the most frequently taken species south of Pt. Conception (Diamond *et al.*, 1987). North of Pt. Conception *P. phocoena* is the most frequently entangled cetacean species in nearshore set gillnets fishing for either white seabass, halibut, or white croaker (Barlow, 1987).

However, both the observer and our stranding data sets are based on small sample sizes and more data are needed to assess the impact of these takes on local populations.

CONCLUSIONS

It is difficult to assess the potential impacts of entanglements for two reasons: (1) the limited quantifiable data on the population size and structure of most cetacean species; and (2) the limited data on the numbers of animals of the various species that are killed in fishing gear annually. We believe that management agencies should invoke the concept of Diamond (1988), who stated that conservation efforts should be directed not only towards endangered species, but also to populations for which the status is unknown but may be depleted. It is clear that more data are needed.

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A Note on the Death of a Right Whale (*Eubalaena glacialis*) off Cape Lopatka (Kamchatka)

S.I. Kornev

KAMCHATRYBVOD, Partizanskaya 9, Petropavlovsk-Kamchatskiy, 683000, USSR

ABSTRACT

This note reports the death of a 12.15m male right whale due to its entanglement in a gillnet off the southern tip of the Kamchatka peninsula. The animal was found stranded on the beach near Cape Lopatka

KEYWORDS: NORTH PACIFIC; RIGHT WHALE; INCIDENTAL CAPTURE; FISHERIES

In 1985, a sea otter observation station was set up by KAMCHATRYBVOD on Cape Lopatka (on the southern tip of Kamchatka). In addition to the major task of monitoring sea otters, observations of marine mammals occurring in the area were made. This included recording stranded animals. Between 1985 and 1989 the carcasses of 8 Dall's porpoise (*Phocoenoides dalli*), 1 fin whale (*Balaenoptera physalus*), 1 killer whale (*Orcinus orca*) and 1 right whale (*Eubalaena glacialis*) were discovered. In most cases the state of decomposition of the animal made it difficult to determine the cause of death.

However, for the right whale specimen the cause of death was identified. The whale, a 12.15m male, was found on the Pacific coast of Cape Lopatka at 1630hrs local time on 16 October 1989 (Fig. 1), apparently soon after it had died. It was examined and some measurements were taken at low tide (Table 1). The body was covered in cyamids and was bleeding from the mouth and the caudal peduncle. A 20m long salmon net was tightly wrapped around the caudal peduncle. The deep wounds visible (Fig. 2) show that the whale must have dragged the net for a long period.

The green net had a 6 x 6cm stretched mesh size, with foam plastic floats and no weights. Its design and the light yellow band fixing the floats suggested that it was manufactured abroad (probably in Japan or Taiwan). In 1988, the USSR fishery guard had detained three fishing

Table 1

Measurements of the right whale found dead on Cape Lopatka on 16 October 1989.

Body length	Length of lower jaw	Median length of flipper	Width of flipper	Fore-edge length of fluke	Width of fluke
12.15m	3.28m	2.17m	1.39m	2.45m	1.43m

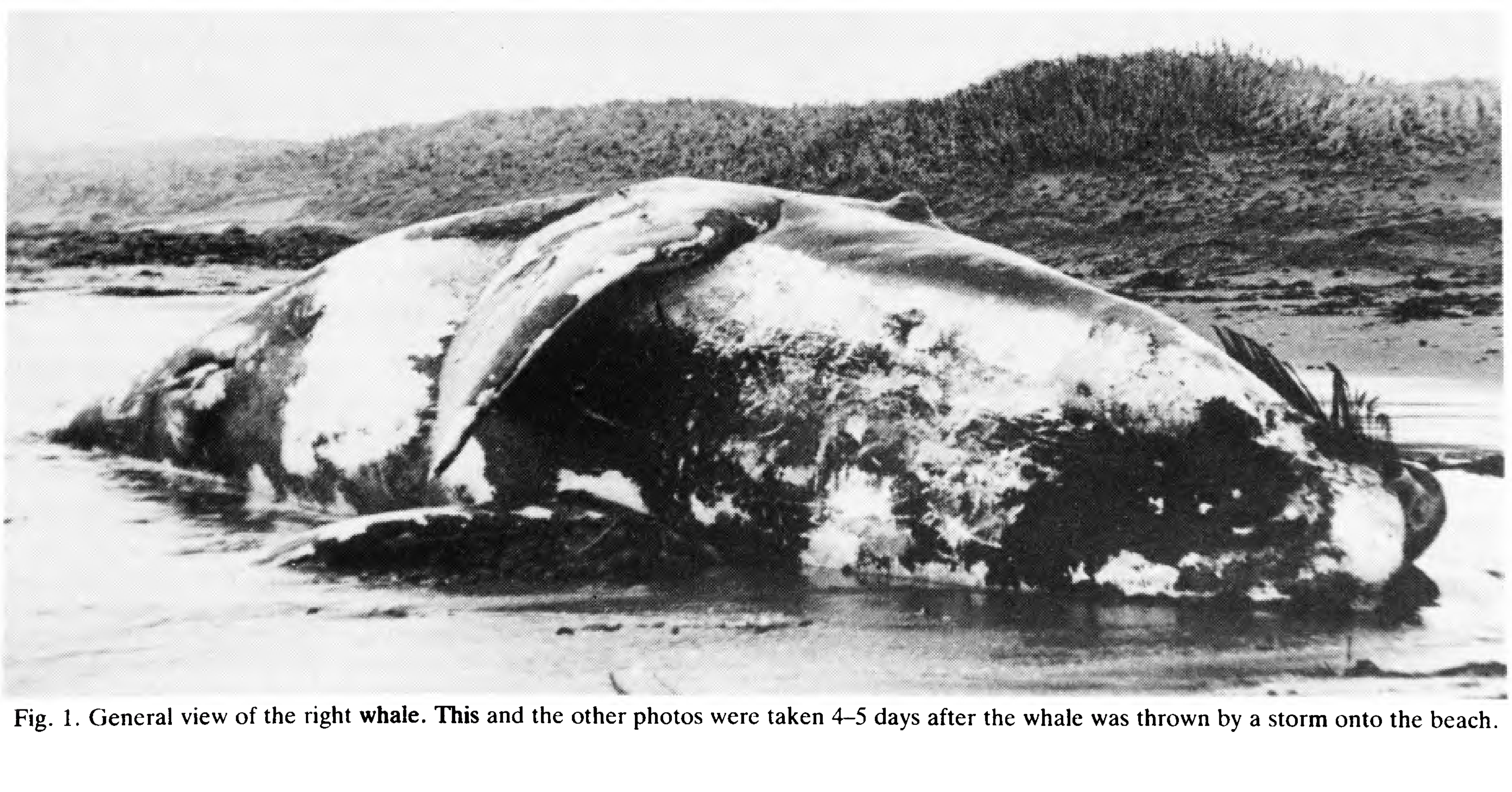

Fig. 1. General view of the right whale. This and the other photos were taken 4–5 days after the whale was thrown by a storm onto the beach.

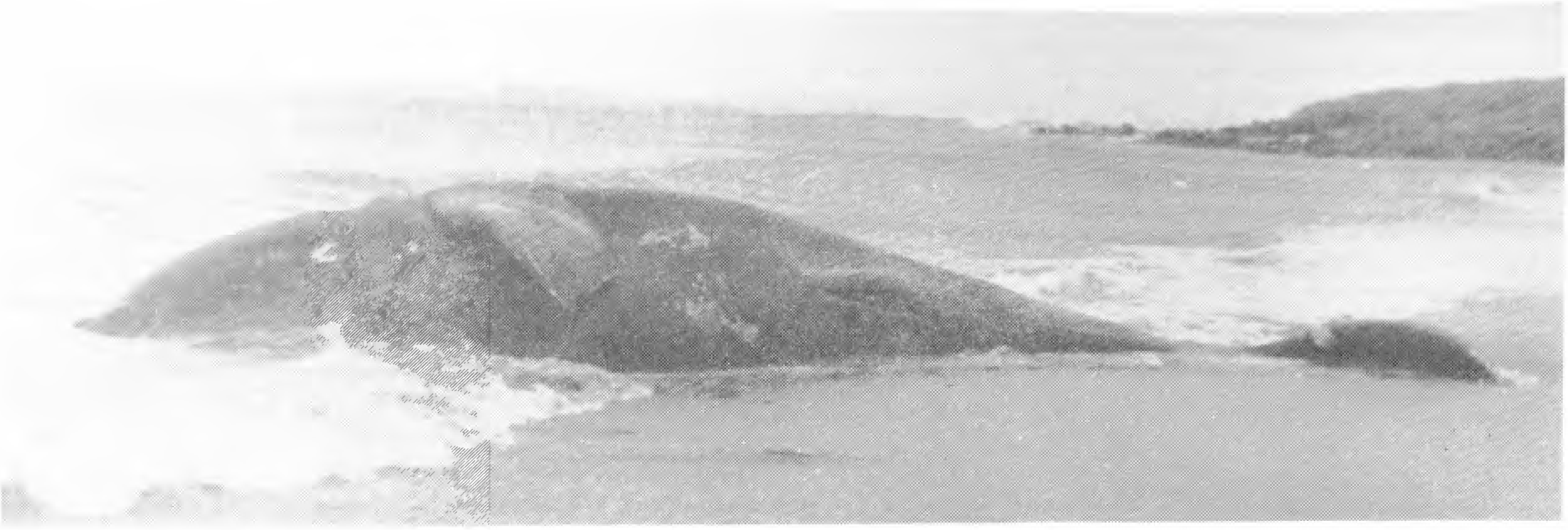

Fig. 2. Right whale in the shallows.

Fig. 3. Fishing net wrapped around the tail.

vessels belonging to Taiwan in the coastal waters of the Kuril Islands. The vessels were engaged in illegal fishing using nets similar to that found on the whale. Barlow *et al.* (1994) reviewed incidental mortality of cetaceans in fishing gear in coastal Pacific waters and noted that vessels from a number of countries, including Taiwan, Japan and the Democratic People's Republic of Korea fish in these waters.

This is the first record of this species in Kamchatkan waters for many years; the species is thought heavily depleted, numbering at best in the low hundreds (Berzin and Doroshenko, 1982). Any human-induced mortality is thus of concern.

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Harbor Porpoise Mortality in the Monterey Bay Halibut Gillnet Fishery, 1989

Thomas A. Jefferson[1], Barbara E. Curry[1] and Nancy A. Black
Moss Landing Marine Laboratories, PO Box 450, Moss Landing, CA 95039, USA

ABSTRACT

Harbor porpoises (*Phocoena phocoena*) have been killed in gillnets set for halibut in central California since at least 1969. In the Monterey Bay area (Pigeon Pt. to Pt. Sur), past estimates of mortality have ranged from 25–55/yr. In the spring of 1989, many dead harbor porpoises began washing ashore with evidence of gillnet entanglement. Observer records from the California Department of Fish and Game and stranding data indicated that a minimum of 53 harbor porpoises were killed in Monterey Bay gillnets in 1989, and it is likely that the total number killed in this area was several hundred. Two-thirds of the specimens were immature. If Monterey Bay harbor porpoises form a resident population, such high takes in the future threaten to decimate the population. We recommend closing the fishery or setting quotas and monitoring the kill with approximation of 100% observer coverage.

KEYWORDS: INCIDENTAL CAPTURE; MANAGEMENT; FISHERIES; HARBOUR PORPOISE; NORTH PACIFIC

INTRODUCTION

Harbor porpoises (*Phocoena phocoena*) are killed in entangling nets[2] throughout their range in the temperate waters of the Northern Hemisphere (IWC, 1994). In central California, such mortality occurs as a result of fishing for halibut with bottom-set gillnets and trammel nets (descriptions in Scofield, 1951; Ueber, 1988), and has occurred since at least 1969 (Barlow, 1987). Until 1980, there was no systematic monitoring of the fishery, but in that year some monitoring was begun by Moss Landing Marine Laboratories (MLML) and California Department of Fish and Game (CDFG) personnel (Miller *et al.*, 1983; Keating, 1986). Since 1983/84, CDFG has been systematically monitoring incidental mortality in this fishery and producing annual estimates of mortality of harbor porpoises and other by-catch species (Diamond and Hanan, 1986; Hanan *et al.*, 1986; 1987; Hanan and Diamond, 1989). These estimates for the 1983/84 to 1986/87 seasons have ranged from approximately 200–300 porpoises per year for the central coast, from Bodega Head to Pt. Conception.

Beginning in mid-February 1989, a much higher than normal number of harbor porpoises started washing up on Monterey Bay beaches, most with evidence of gillnet entanglement. CDFG observer data, which began in mid-March, confirmed that higher than usual levels of porpoise mortality were occurring in the Bay. There was a great deal of pressure put on CDFG to reduce the high kills. Before a ban on gillnet sets in waters shallower than 40 fathoms (73m), covering most of Monterey Bay, was put into effect on 15 April, a total of at least 34 porpoise deaths related to gillnets had been documented in the area.

This paper examines 1989 harbor porpoise gillnet-caused mortality in the Monterey Bay area and presents general information that may help in managing this situation in the future. In addition, it provides recommendations for management.

[1] Present address: *Marine Mammal Research Program, c/o Department of Wildlife and Fisheries Sciences, 210 Nagle Hall, Texas A&M University, College Station, TX 77843, USA.*
[2] Entangling nets include setnets, driftnets, and trammel nets. In this paper, the term 'gillnet' is used loosely to refer to any type of entangling gear.

MATERIALS AND METHODS

The Monterey Bay study area extends from Pigeon Pt. to Pt. Sur, and was divided into four regions of comparable size for analysis (Fig. 1). Materials were of two types: stranding records and gillnet observer data. Stranded cetaceans in the Monterey Bay area were reported to Moss Landing Marine Laboratories (MLML), and Long Marine Laboratory, University of California, Santa Cruz (LML), both participants in the California Marine Mammal Stranding Network (Seagars and Jozwiak, 1991). Personnel from MLML and LML responded to stranding reports and examined the carcasses. When possible, the carcass was collected for more detailed scientific study. Each porpoise was examined for evidence of gillnet entanglement, such as cuts and depressions along the head, flippers, dorsal fin, or flukes (Hare and Mead, 1987). Standard data, including photos, morphometrics, and tissue samples for analysis of reproduction, feeding habits and pollutant levels, were collected on site or at the lab during necropsies.

Gillnet observation data were kindly provided by C.W. Haugen, CDFG. Information on set location, water depth and by-catch was collected by CDFG observers, either from a shore-based observation platform (uncommon in Monterey Bay), from a research vessel that pulled alongside a gillnetter during net retrieval, or from on-board the fishing vessel. When possible, CDFG observers attempted to secure incidentally-taken porpoises, which were then examined by MLML or LML biologists. Samples and data were then forwarded to the Southwest Fisheries Science Center (SWFSC), National Marine Fisheries Service (NMFS), for life history analysis.

RESULTS

Harbor porpoise take in 1989

Table 1 shows the total minimum number of harbor porpoises known to be taken in the Monterey Bay gillnets in 1989. The total of 53 porpoises was computed by adding the number of takes observed by CDFG to the number of strandings with gillnet markings that could be excluded from the observed gillnet takes.

A reliable estimate of take is not possible without knowing the number of gillnet sets (fishing effort) in the

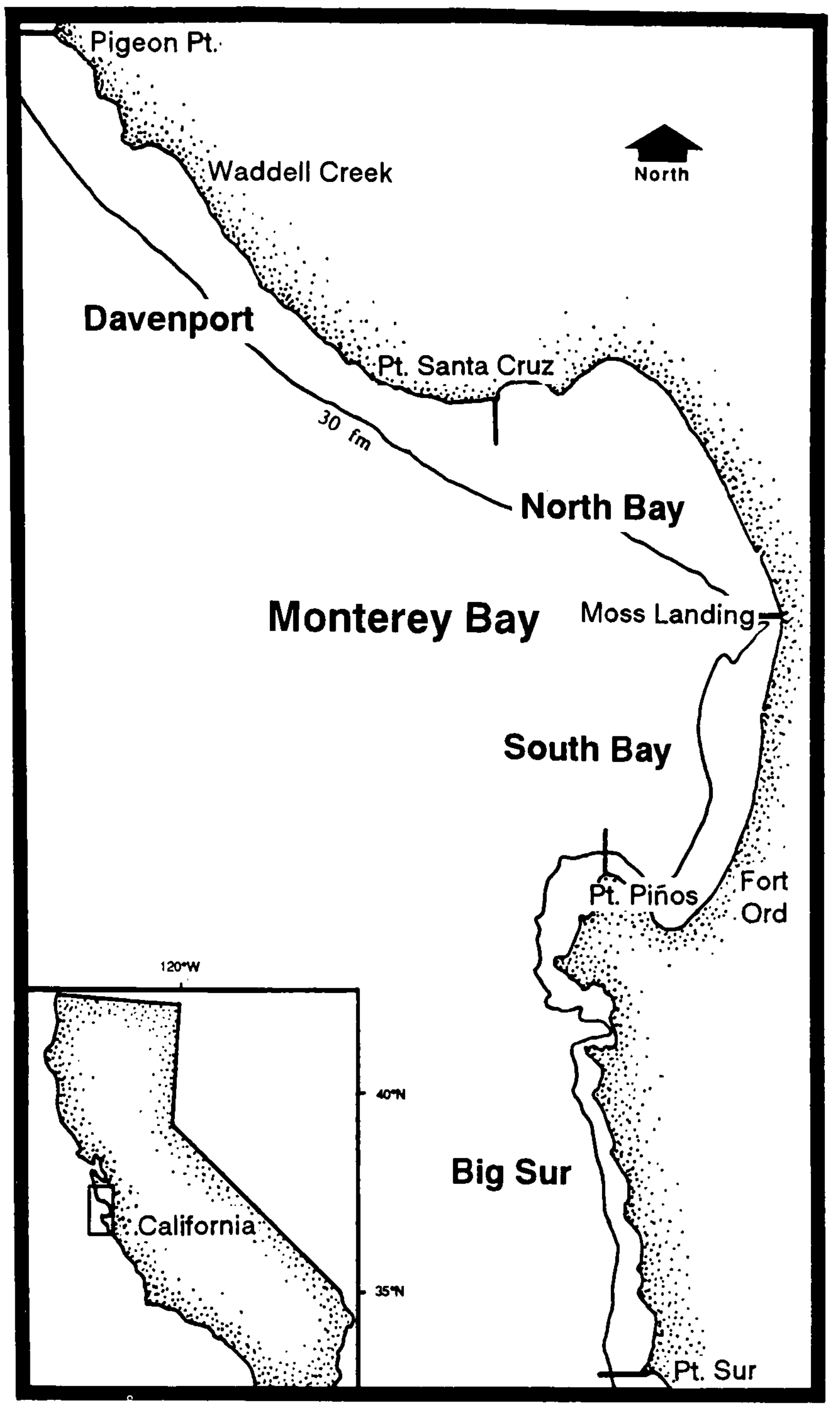

Fig. 1. Map of the study area, showing the four subareas and place names mentioned in the text. Inset shows location of Monterey Bay in central California.

Table 1

Summary of numbers of strandings and observed takes of harbor porpoises in 1989 in Monterey Bay, and an estimate of the minimum number taken in the halibut fishery.

Dates	Gillnet markins on strandings			Observed takes		Minimum taken
	Yes	No	?	Specimen	No	
15 Feb - 15 Apr.	14	1	5	4	16 [1]	34
16 Apr. - 1 Sept.	1	1	3	3	1 [2]	5
2 Sept. - 31 Dec.	0	0	0	5	9	14
				Total		53

[1] Six of these were slashed and sunk and 10 others were taken after the last stranding was recovered, so these 16 animals cannot be duplicates of the 14 stranded with gillnet markings.

[2] This animal cannot be a duplicate of the stranding during this period with gillnet markings, because the stranding, which was freshly dead (< 2 weeks), was found 3½ weeks after the last observed take.

Monterey Bay area in 1989. Fishing effort is estimated by CDFG, by combining data from fishing logs completed by the fishermen, with landing receipts or 'pink tickets', and CDFG observer data (see Diamond and Hanan, 1986). Not all of this information is available, so fishing effort is not known for 1989.

Data are available, however, for four previous years. Assuming that fishing effort in 1989 was within this range, the total number of harbor porpoises killed in the Monterey Bay area alone is possibly several hundred, many times higher than the estimates of 25–55 for previous years (Table 2).

Table 2

Estimated number of sets and estimated harbor porpoise take in Monterey Bay for 1989 and previous years compared.

Year	Est. no. sets (% observed)	Estimated mortality	Take rate	Source
1983/84	517 (4%)	45-47	0.091	Diamond and Hanan, 1986
1984/85	1,606 (7.8%)	25-26	0.016	Hanan *et al.*, 1986
1985/86	1,255 (3.9%)	55	0.041	Hanan *et al.*, 1987
1986/87	896 (3.9%)	26	0.029	Hanan and Diamond, 1989
1989	-	180-560[1]	0.349	CDFG, unpubl. data

[1] Based on range of estimated number of sets for 1983/84 to 1986/87.

Take rate in 1989

In 1989, CDFG observers saw 38 harbor porpoises taken in 109 observed sets, for a take rate of 0.35 ± SD 0.738 porpoises/set. This is much higher than the take rate of 0.02–0.10 observed in past years in the same area (Table 2).

Take rate between the four regions, and take rate between four depth categories (15–18, 19–22, 23–26 and 27–30 fathoms), were examined and no significant differences were found ($Chi^2=4.346$, df=3, $p>0.05$; $Chi^2=1.706$, df=3, $p>0.05$; respectively). There were no observed sets in water depths greater than 30 fathoms (55m).

A closure of waters shallower than 40 fathoms (73m), between Waddell Creek and Fort Ord, was in effect from 15 April to 1 September. During the closure, most of the fishing was still in less than 40 fathoms, south of Fort Ord. There was a significantly lower take rate during the closure (Fig. 2; $Chi^2=9.296$, df=1, $p<0.01$).

Biological observations

Of the 28 gillnet-caught porpoises examined by MLML or LML biologists, 16 (57.1%) were females (Table 3). This difference from parity was not statistically significant ($Chi^2=0.571$, df=1, $p>0.05$).

There was a preponderance of immature animals among the incidentally-taken porpoises. Based on Hohn and Brownell's (1990) information on lengths at sexual maturity for central California harbor porpoises ('best' averages: 140cm for males and 152cm for females[3]), 4 of 12

[3] Hohn and Brownell computed 152cm as the most representative length at sexual maturity for females in their sample (excluding one outlier). Male sexual maturity could not be determined with certainty until testes were examined histologically, but testis weight increased rapidly at 140cm, and this currently represents the 'best' length at sexual maturity.

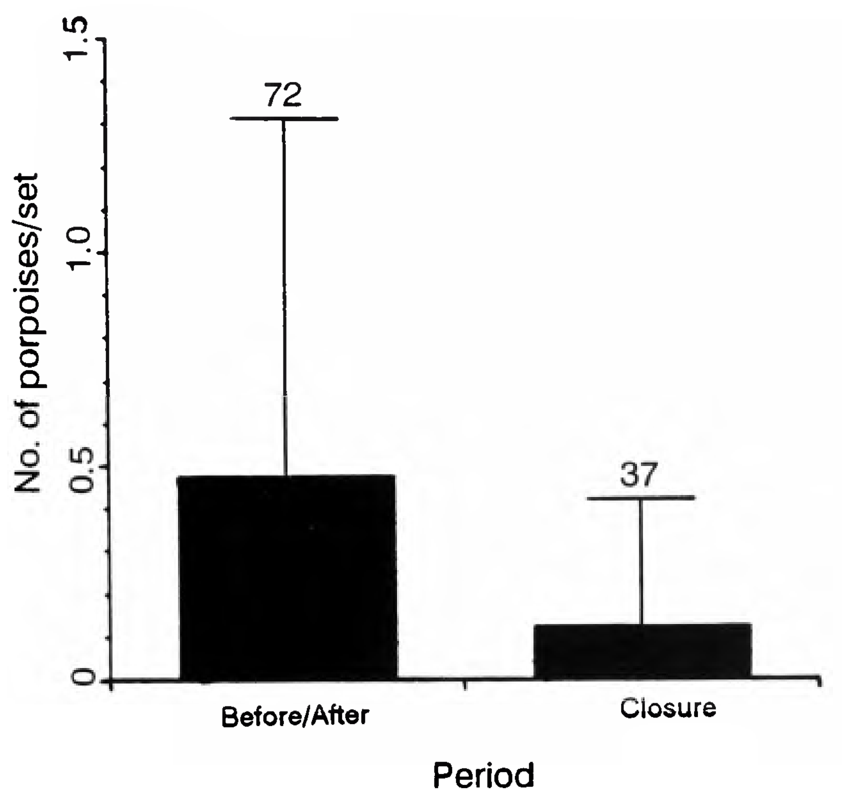

Fig. 2. Mean number of porpoises taken per set by period. The closure was in effect from 15 April to 1 September 1989, and prohibited sets in waters shallower than 40 fathoms north of Fort Ord. Bars are standard deviations and numbers are sample sizes (no. of sets).

(33.3%) males and 5 of 16 (31.1%) females were sexually mature. There were no newborn calves, but at least three of the females were pregnant.

DISCUSSION

Status of population and effect of take

The population structure of Monterey Bay harbor porpoises is not known (see review of status of central California harbor porpoises by Barlow, 1987; Barlow and Forney, 1993; Barlow and Hanan, 1994). The only evidence directly relating to population structure is from the work of Calambokidis and Barlow (1991), who compared PCB/DDE pollutant ratios from animals along the west coast of the United States. The variances and ranges of 13 Monterey Bay animals differed from those of animals from adjacent waters (two from Morro Bay to the south, and eight from around San Francisco Bay to the north). So, despite uncertainty resulting from very small sample sizes, the evidence indicates that Monterey Bay may contain a resident population of harbor porpoises, or at least that there is little movement of porpoises to the surrounding coastal areas.

Since 1984, NMFS and CDFG have conducted aerial and ship surveys for the purpose of estimating harbor porpoise abundance in California (Barlow, 1988; Barlow *et al.*, 1988; Forney *et al.*, 1991). Ship survey estimates are currently considered more accurate (see Kraus *et al.*, 1983), however aerial surveys have generally produced estimates similar to those from ship surveys. 'Best estimates' from these surveys are approximately 14,300 harbor porpoises for central and northern California and 1,460 (CV=0.61) for the Monterey Bay area (Barlow, 1988). If the Monterey Bay abundance estimate is correct, then our 1989 minimum take (53 porpoises) represents 3.6% of the population. This is probably unsustainable, and the estimated take of several hundred porpoises would be certainly unsustainable (see Woodley and Read, 1991). However, a more recent abundance estimate, based on aerial surveys, is somewhat higher, 1,948 (CV=0.28) (Barlow and Forney, 1993).

The 1989 fishing year was unusual because of the temporal and spatial distribution of fishing effort. This may be the reason for the high take in that year. However, such unusual years could quickly damage a small resident

Table 3

Harbor porpoise specimens obtained and examined that were either observed taken in gillnets or stranded with gillnet markings, Monterey Bay, 1989. [1] Stranding or capture. [2] NB = North Bay; SB = South Bay and D = Davenport.

Date	Specimen #	S or C[1]	Length (cm)	Sex	Location[2]	Date	Specimen #	S or C[1]	Length (cm)	Sex	Location[2]
15 Feb.	TAJ 181	S	134	F	NB (Pajaro Dunes)	04 Apr.	NAB 011	C	158	F	NB (Santa Cruz)
18 Feb.	EJD 007	S	155	F	NB (ML Beach	05 Apr.	NAB 012	S	132	F	SB (Marina)
22 Feb.	BEC 89-1	S	129	F	NB (Seascape)	13 Apr.	TAJ 1283	C	131	M	SB (Marina)
28 Feb.	EJD 008	S	135	M	SB (Marina)	13 Apr.	TAJ 184	C	178	F	SB (Marina)
05 Mar.	EJD 009	S	147	F	NB (Seacliff)	10 May	GAW 89-8	S	128	M	NB (Rio del Mar)
16 Mar.	NAB 005	S	139	F	SB (Marina)	10 Aug.	TRK 109	C	129	M	SB (Seaside)
16 Mar.	TRK 108	S	138	F	SB (Marina)	12 Aug.	EJD 020	C	125	M	SB (Seaside)
16 Mar.	EJD 010	S	150	M	SB (Marina)	18 Aug.	EJD 021	C	130	M	SB (South Fort Ord)
25 Mar.	EJD 011	S	151	F	SB (Salinas River)	22 Sept.	EJD 022	C	127	M	NB (Soquel Point)
29 Mar.	NAB 007	S	145	F	NB (Sunset Beach)	07 Oct.	EJD 024	C	138	F	SB (North Fort Ord)
29 Mar.	NAB 008	S	136	F	NB (Sunset Beach)	07 Oct.	EJD 025	C	120	M	SB (North Fort Ord)
29 Mar.	NAB 009	S	156	F	NB (Sunset Beach)	15 Oct.	NAB 013	C	150	F	D (Davenport)
03 Apr.	EJD 012	S	147	M	SB (Marina)	15 Oct.	NAB 014	C	122	F	D (Davenport)
04 Apr.	NAB 010	C	170	F	NB (Santa Cruz)						

population, such as that presumed to exist in Monterey Bay. Due to funding limitations, CDFG's observer effort has been extremely low in the past (see Table 2). In 1989, eight harbor porpoises with gillnet marks were recovered from Monterey Bay beaches before CDFG was able to begin net retrieval observations.

Barlow (1987) and Barlow and Hanan (1994) suggested that past levels of harbor porpoise setnet mortality have resulted in reduction of central California stock(s), possibly to levels below Optimum Sustainable Population (OSP). They further suggested use of the '2 percent rule' for maximum allowable take in this case. The high level of take in 1989 (>3.6% of the best population estimate) warrants serious concern for the future of harbor porpoises in Monterey Bay (and possibly the rest of the central California coast). Despite a great deal of uncertainty, the best available information suggests that the 1989 levels of take are too high for assured survival of the population.

RECOMMENDATIONS

Considering the current problems involved in management of harbor porpoise populations, we recommended one of the following two options:

(1) eliminating mortality by closing the Monterey Bay halibut setnet fishery until such time that effective methods of reducing or eliminating porpoise take in gillnets are discovered and implemented [the passage of proposition 132 (SB 2,563 1990, Chapter 884) effectively did so – see Wild, 1990 – but there is a move to overturn this legislation]; or

(2) if accurate estimates of abundance are available, monitoring the fishery with a goal of 100% observer coverage to eliminate uncertainty in estimating take (minimum acceptable coverage should be 35%, see Barlow, 1989), and observing the '2% rule' for maximum allowable take in any one year (with a quicker response to close the fishery than occurred in 1989, if required).

The main hindrance to sound management of central California harbor porpoise population(s) is the uncertainty involved in determining population status and in estimating incidental take and stock size. If the fishery is to continue, these shortcomings should be addressed immediately.

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Estimates of Incidental Marine Mammal Bycatch in California Gillnet Fisheries for July through December, 1990

Cleridy Lennert and Susan Kruse

Southwest Fisheries Science Center, National Marine Fisheries Service, NOAA, PO Box 271, La Jolla, CA 92038, USA

Marilyn Beeson

California Department of Fish and Game, 330 Golden Shore, Suite 50, Long Beach, CA 90802, USA

Jay Barlow

Southwest Fisheries Science Center, National Marine Fisheries Service, NOAA, PO Box 271, La Jolla, CA 92038, USA

ABSTRACT

Data are reported on marine mammal mortality collected from California's gillnet fisheries for California halibut and Pacific angel shark (set net) and swordfish and pelagic sharks (driftnet) during the first six months of a three-year mortality assessment program. NOAA Fisheries (NMFS) observer-technicians collected information on species composition, mortality and life history data from entangled cetaceans, pinnipeds and sea otters. Four harbor porpoises, three southern sea otters, 13 elephant seals, 30 harbor seals, 67 California sea lions, one unidentified otariid, and two unidentified pinnipeds were observed killed in the set net fisheries. Estimated total incidental mortality for these species during the six month period was: harbor porpoises (central California), 44 (SE=25); southern sea otters (central California), 33 (SE=18); elephant seals (central California), 144 (SE=58); harbor seals, 392 (SE=83); and California sea lions, 847 (SE=134). Nine common dolphins, three Pacific white-sided dolphins, one short-finned pilot whale, one Dall's porpoise, one mesoplodont beaked whale, four elephant seals, one harbor seal, two California sea lions and two unidentified otariids were observed killed in the driftnet fishery. Estimated total incidental mortality for these species during the six month period was: common dolphins, 203 (SE=82); Pacific white-sided dolphins, 68 (SE=38); short-finned pilot whales, 23 (SE=22); mesoplodont beaked whales, 23 (SE=22); Dall's porpoise, 23 (SE=22); elephant seals, 90 (SE=43); harbor seals, 23 (SE=22); and California sea lions, 90 (SE=62). Biological data including total length, sex, reproductive condition and age were collected from a subset of animals. Sex and length data were collected for some animals; age and reproductive condition have not been determined for most.

KEYWORDS: NORTH PACIFIC; INCIDENTAL CAPTURE; HARBOUR PORPOISE; COMMON DOLPHIN; PACIFIC WHITE-SIDED DOLPHIN; PILOT WHALE - SHORT-FINNED; DALL'S PORPOISE; BEAKED WHALES

INTRODUCTION

During the late 1970s and early 1980s there was a rapid expansion in the use of entanglement nets (driftnet, set net, multi-panel and trammel nets) in coastal California waters (Herrick and Hanan, 1988). The incidental kill of non-target species (including marine mammals) by these nets has become a focus of concern for state and national environmental and legislative bodies.

In the United States, marine mammals are managed under the Marine Mammal Protection Act (MMPA). Prior to amendments of the MMPA in 1988, incidental take of marine mammals in commercial fisheries was allowed if populations could be proven to be within a range of Optimal Sustainable Population levels (OSP). OSP has been defined operationally as the range of population sizes between carrying capacity and the maximum net productivity level. However, for most fisheries-affected marine mammal species, adequate information on abundance and population parameters that would allow estimation of status relative to OSP is unavailable. In 1988, amendments to the MMPA enacted a temporary exemption program for five years. In the interim, collection of statistically reliable data on the status of marine mammal stocks and total incidental mortalities has been congressionally mandated (United States Federal Register, 1989). These data are expected to be made available to the Congress prior to the scheduled re-authorisation hearings in 1994.

In order to facilitate monitoring incidental mortality and its impact on marine mammal populations, the exemption program classifies commercial fisheries into three categories according to expected levels of incidental mortality: Category I (frequent take of marine mammals incidental to fishing activities), Category II (occasional take of marine mammals) and Category III (rare or infrequent take of marine mammals) (United States Federal Register, 1989). All vessel operators are required to submit annual reports of incidental takes of marine mammals. Since 1990, Category I operators have been required to take NMFS observer-technicians onboard and allow them to collect information on the species and number of marine mammals taken. When possible, observers collect detailed biological information on entangled animals that are brought onboard. These data will be used to verify the adequacy of the vessel self-reporting program established under the MMPA amendments, as well as to provide a foundation for marine mammal management policy.

In this report, data are presented on marine mammal mortality collected from Category I gillnet fisheries in California including (1) a set net fishery for California halibut, (2) a set net fishery for Pacific angel shark, and (3) a driftnet fishery for sharks and swordfish (see Barlow *et al.*, 1994 for detailed synopses of each fishery). Set net fisheries in southern California (the Mexican border north to Point Conception) comprise year-round fisheries for California halibut (*Paralichthys californicus*) (effort peaks in spring and fall), and angel shark (*Squatina californica*) (Collins *et al.*, 1985; 1986). Category I set net fisheries off central California (Pt. Conception to Bodega Bay) include those for halibut (taken from May to October, with a summer peak), shark (November through February), and flounder (*Pleuronectiformes*) (March and April) (Wild, 1986; 1987; Herrick and Hanan, 1988). However, most California halibut and Pacific angel shark fishing effort in central California is concentrated between Point Conception and Monterey Bay. Coastal set net fisheries are not allowed in northern California (north of Bodega Bay).

California's driftnet fishery extends from the California-Mexico border in the south, to the Oregon border in the north, and beyond 200 miles offshore (Herrick and Hanan, 1988). Initially, common thresher (*Alopias vulpinus*) and short-fin mako (*Isurus rinchus*) sharks were the target species. In the last decade, swordfish (*Xiphias gladius*) has replaced sharks as the primary target species (Herrick and Hanan, 1988). Fishing is regulated by restricted seasons designated by distance from shore (California Department of Fish and Game, 1990). Within 75 n.miles of the coast, the driftnet fishery is active from 15 July to 31 January. Between 75 and 200 n.miles offshore, the fishery is open from 15 April through 31 January.

Prior to 1990, data on the composition of the incidental kill of marine mammals by California gillnet fisheries were collected by the California Department of Fish and Game (CDFG). These data, obtained from both set net and driftnet fisheries, have been summarised by Herrick and Hanan (1988) and Barlow *et al.* (1994). In this report, we present results of the first six months of a three-year study of incidental marine mammal mortality in California's Category I gillnet fisheries.

METHODS

Data collection

Data summarised herein were collected by NOAA Fisheries observer-technicians primarily from onboard commercial gillnet vessels. Observers collected data on net characteristics, target species, fishing operations, marine mammals interacting with fishing operations and bycatch composition. Tally data collected by observers included number and species of marine mammals incidentally entangled during fishing operations, each animal's location in the net, its condition at the time of net pull (i.e., dead, alive or injured) and if possible, its sex. Following procedures described by Perrin *et al.* (1976), observers collected life history data from a subset of individuals incidentally killed during fishing operations. As time permitted, observers also recorded length measurements and dispositions of various species of fish caught in the net. These data were edited in several stages prior to analysis.

In accordance with 1988 MMPA amendments, the targeted level of sampling coverage was 20% of the fishing activity, measured in terms of trips. A trip was defined as any period of active fishing terminated by a port call. Sampling methods differed between driftnet and set net fisheries. Safety considerations prohibited the placement of observers on some set net and driftnet vessels.

Set net

For the set net fishery, six port stations were established. Stations were staffed with a port coordinator, responsible for monitoring vessel activity, and one or more observers, depending on the anticipated level of fishing activity (determined from earlier CDFG programs). Port stations were established at San Diego, Los Angeles (San Pedro), Ventura, Santa Barbara, Morro Bay and Monterey. At the end of each day, a subset of 20% of those vessels which had nets actively fishing was selected. Vessel selection (i.e., trip selection) was done randomly whenever possible. However, sporadic fishing activity and limited cooperation of fishers with local regulating agencies often influenced observer placement (see Discussion). Selected vessels were obligated to permit observers to board and to collect data during net retrieval. Whenever possible, fishers were notified of their obligation to carry an observer after their nets had been set so as to minimise the influence of the observer program on fishing behaviour. Observers generally boarded vessels at the dock. However, in the Morro Bay area, a chartered vessel was occasionally used to observe fishing activity of vessels that were otherwise unobservable due to safety concerns. Information regarding the platform of observation and the time of fisher contact relative to net set (prior– or post–notification of observation) was recorded for each observed trip.

Driftnet

The driftnet fishery observer program was headquartered in San Diego where a staff of several observers and a port coordinator monitored fleet movements from San Diego to Eureka. Prior to the opening of the swordfish season, each active (and observable) driftnet vessel was assigned a first trip to carry an observer. This first trip was selected randomly from the first five trips the vessel was expected to make during the fishing season. On this and every subsequent fifth trip, the vessel would be obligated to carry an observer. Periodic contact between fishers and NMFS personnel established each vessel's fishing status.

Analyses/mortality

Simple descriptive statistics (e.g., mean, variance, and correlation coefficient) and scatter plots were used to screen the data for potential relationships between marine mammal mortality and various physical characteristics of the fisheries for the purpose of post-stratifying the data. Variables considered to potentially affect marine mammal mortality included water depth, soak time (number of hours the net is submerged), length of net and mesh size (driftnets only). Due to a paucity of observed marine mammal mortality for the driftnet fishery, post-stratification of the driftnet data was not deemed appropriate. However, simple correlation coefficients were still estimated.

Correlations between marine mammal mortality (summarised by trip) and variables representing measures of fishing effort (e.g., number of sets or soak time) were examined to try to determine a measure of effort most appropriate for calculating mortality rates for different species of marine mammals. Details of the methods used to post-stratify the data (set net) and to estimate total incidental mortality follow.

Set net

Gillnet fishers often participate in more than one fishery at a time. To separate halibut and angel shark data from circumstantial data collected for other set net fisheries, data were grouped by target species and mesh size. Analysis of set net data was restricted to sets with mesh size (stretched-mesh measurement) ≥8ins (20cm) and target species involving California halibut or Pacific angel shark. No attempt was made to analyse data for halibut and angel shark sets separately because the many similarities between the two fisheries (e.g., mesh size and fishing locations) often made the assignment of target species arbitrary.

POST-STRATIFICATION

Pinniped entanglement data from central California were used to try to determine if prior-notification of set net fishers of their obligation to carry an observer (notification before nets were set) affected the rate of pinniped take. Data from central California were used because they represented the highest percentage of non-zero mortality sets, as well as the highest frequency of prior-notification of fishers. It was assumed that biases in pinniped mortality due to prior-notification would not be species specific; that is, results were assumed to be relevant for sets involving cetaceans as well. A test of the effect of prior-notification on observed pinniped mortality was formulated as a multiple regression problem. It was assumed that variability in the natural logarithm of pinniped mortality (K) could be described by a linear combination of various explanatory variables. To better identify variation in the mortality data resulting from prior-notification, several other factors potentially affecting pinniped mortality were included in the model. These factors included soak time, length of net, water depth, and a 'port effect' – included to account for any regional differences between Monterey and Morro Bay. Occasionally, net characteristics (e.g., suspender length or net material) changed along the length of a net. In such cases, the net's characteristics were described by section, but mortality was tallied for the net as a whole. A 'gear effect' was included in the model to account for differences in mortality between nets with only one set of characteristics (one section) and nets with multiple sections. The natural logarithm transformation was used to stabilise the variance and to make the data more nearly normal. The addition of 1 (i.e., K+1) ensured that the logarithm function (denoted 'ln') was defined for sets with zero mortality. The resulting model (with intercept term β_0) was

$$\mu_j = \beta_0+\beta_1X_{1j}+\beta_2X_{2j}+\beta_3X_{3j}+\beta_4X_{4j}+\beta_5X_{5j}+\beta_6X_{6j} \quad (j=1, ..., 129),$$

where

μ_j = mean log (pinniped mortality plus 1) for the j^{th} set ($\mu_j = E(\ln(k_j+1))$, $\ln(k_j+1) \sim$ (indep.) $N(\mu_j, \sigma^2)$),

X_{1j} = soak time (hours) for the j^{th} set,

X_{2j} = length of net (fathoms) for the j^{th} set,

X_{3j} = water depth (fathoms) for the j^{th} set,

X_{4j} = categorical variable indicating a port effect ($X_4=1$ if the observer's port station for the j^{th} set was Monterey, and $X_4= 0$ otherwise),

X_{5j} = categorical variable indicating a prior-notification effect ($X_5=1$ if the set net vessel for the j^{th} set was notified of observation responsibilities prior to setting the nets, $X_5=0$ otherwise),

X_{6j} = categorical variable indicating a gear effect ($X_6=1$ if the net for the j^{th} set was made up of multiple pieces with different characteristics, $X_6=0$ otherwise).

Parameter estimates were obtained using ordinary least squares. A test of the hypothesis that there was no prior-notification effect is equivalent to a test of the hypothesis that $\beta_5=0$. Test statistics for this hypothesis and a test of the overall significance of the model (i.e., a test of the hypothesis that all coefficients except the intercept are zero) were based on the usual F statistic (e.g., Draper and Smith, 1981).

Density differences of California sea lions and harbor seals between central and southern California (south of Point Conception, Channel Islands excluded) were considered as a potentially important factor affecting incidental take rates of these species in the set net fishery. Due to the large number of zero-mortality sets (particularly in southern California, see Discussion), the assumption of normally distributed errors made for the previous model was considered inappropriate here. Therefore, we chose to model the natural logarithm of the odds of taking at least one marine mammal as a linear combination of various explanatory variables, where the number of sets involving positive mortality (Y) is assumed to follow a binomial distribution (i.e., a logistic model for the probability of taking at least one marine mammal (p), where $Y \sim B(p,n)$, n assumed fixed). A test of the hypothesis that there was no areal effect on mortality of these species was formulated in terms of a test of an areal effect on the odds ratio. The odds ratio is defined as the probability of at least one marine mammal mortality in a set divided by the probability of no marine mammal mortality in a set (p/(1-p)). To evaluate the odds ratio binomial observations were constructed by grouping the mortality data into two categories: zero-mortality sets and non-zero mortality sets. Because of the limited number of non-zero mortality observations available, our choice of a logistic model restricted the number of explanatory variables that could be considered. Next to area, soak time was considered to be one of the more important factors likely to affect mortality. A soak time effect was included in the model to account for the potential affect of longer soak times on the odds ratio. Soak time was treated as a categorical variable because of the limited data available. The resulting model (with grand mean μ) was

$$\ln [p_i/(1-p_i)] = \mu+ \alpha X_{1i} + \beta X_{2i}, \ (i=1,...,4),$$

where

p_i = probability of taking at least one marine mammal in a set for the i^{th} binomial observation $y_i \sim B(p_i,n_i)$ (i.e., $p_i = (\exp(\mu+\alpha X_{1i}+\beta X_{2i}))/(1+\exp(\mu+\alpha X_{1i}+\beta X_{2i})))$,

X_{1i} = categorical variable indicating a soak time effect ($X_1=1$ if odds ratio is for sets with soak times ≥ 27 hours, $X_1=0$ otherwise), and

X_{2i} = categorical variable indicating an areal effect ($X_2=1$ if odds ratio is for sets made in central California, $X_2=0$ otherwise).

Parameter estimates were obtained by maximising the log likelihood of the parameters given the data, using the technique of iteratively reweighted least squares. A test of the hypothesis that there was no areal effect is equivalent to a test of the hypothesis that $\beta=0$. A test statistic for this hypothesis was constructed as the difference in deviances (a measure of discrepancy formed from the logarithm of a ratio of likelihoods) between models fit with and without the parameter of interest (McCullagh and Nelder, 1983). A similar statistic was constructed to test for a soak time effect. Adequacy of the model was assessed using a chi-square goodness of fit test (McCullagh and Nelder, 1983).

MORTALITY ESTIMATION

Because total fishing effort was measured in days, total mortality (M) for each species was estimated as

$$\hat{M} = D \cdot \hat{r}_d,$$

where D = total number of fishing days (assumed known), $\hat{r}_d$ = estimated mortality/day = $(\Sigma_i k_i)/(\Sigma_i d_i)$, k_i=total mortality for trip i, d_i=number of days for trip i and i=1,...,n where n=number of observed trips. The variance of total mortality was estimated as

$$\hat{\sigma}^2_M = D^2 \cdot \hat{\sigma}^2_r,$$

where $\hat{\sigma}^2_r$ = estimated variance of $\hat{r}_d$.

Observers collected data on every set made during a trip. As a result, trips represented clusters consisting of one or more sets. For the purpose of computing variance estimates, each trip was considered a data unit, assumed to be independent (and identically distributed). In addition, observed trips were assumed to be the result of a simple random sample.

Except for two trips from southern California, no other multi-day set net trips were observed. For single-day trips, the sampling unit, a trip, was equivalent to a day. Because of the predominance of single-day trips, $\hat{r}_d$ was assumed to be equivalent to a mean per unit estimator. In this case, an estimate of the variance of $\hat{r}_d$ is given by

$$\hat{\sigma}^2_r=(fpc/n)\ (1/(n-1))\ \Sigma_i(r_i-\bar{r})^2,$$

where r_i=kill on day (trip) i, $\bar{r}$=average kill per trip ((1/n) $\Sigma_i\, r_i$) (in this case, $\hat{r}_d=\bar{r}$), n=number of observed trips, and fpc=finite population correction factor (=1–f, f=sampling fraction). In order to calculate the finite population correction factor, it was assumed that the sampling fraction of trips was equivalent to the sampling fraction of days because the total number of trips was unknown.

Driftnet

MORTALITY ESTIMATION

For the driftnet fishery, $\hat{r}_d$ was equivalent to mortality per set, since driftnet vessels make only one set per twenty-four hour period. (Typically, the net is set in the late afternoon or early evening and pulled the following morning.) Because driftnet trips often last more than one day, the number of days per trip was itself random and $\hat{r}_d$ had to be treated as a ratio estimator (e.g. Cochran, 1977). An estimate of the variance of $\hat{r}_d$ was obtained by the linearisation (or delta) method (e.g., Efron, 1982),

$$\hat{\sigma}^2_r = (fpc/n)(1/\bar{d}^2)(\hat{r}_d^2\ \hat{\sigma}^2_d + \hat{\sigma}^2_k - 2\hat{r}_d\hat{\rho}\hat{\sigma}_d\hat{\sigma}_k),$$

where fpc and n are defined as above, $\bar{d}$ is the average number of days per trip, $\hat{\sigma}^2_d$ is an estimate of the variance of the number of days per trip (= $(1/(n-1))\ \Sigma_i(d_i - \bar{d})^2$), $\hat{\sigma}^2_k$ is the estimate of the variance of mortality per trip calculated in the same manner as σ^2_d, and $\hat{\rho}$ is the estimated correlation coefficient between mortality per trip and number of days per trip.

Analysis/Fishing effort

Estimates of the total fishing effort for July through December 1990 were made in order to estimate total marine mammal take during this time period. A unit of effort was defined as one boat having retrieved a minimum of one net on a given day (i.e., one day of fishing effort). Retrieval of more than one net was counted as one unit of effort if the nets were retrieved on the same day, and the target species were the same.

The primary source of effort data was the commercial gillnet fishers' daily fishing logs. Fishing logs are required by state law and are submitted monthly to the CDFG. The gillnet logs specify the area fished by CDFG block number (numbered rectangular quadrants (Appendices 1a and b)), type of gear fished, number of sets made, and the species of fish caught. Although most fishers complete logs for each net set, some fishing activity goes undocumented. To account for fishing effort not recorded in the gillnet logs, data from landing receipts of fish sales were incorporated into the total effort estimate. Landing receipts from licensed fish dealers are required by state law for each boat landing fish. Data collected by NMFS observers were used to verify gillnet log entries and to help identify fishing activity associated with landing receipts.

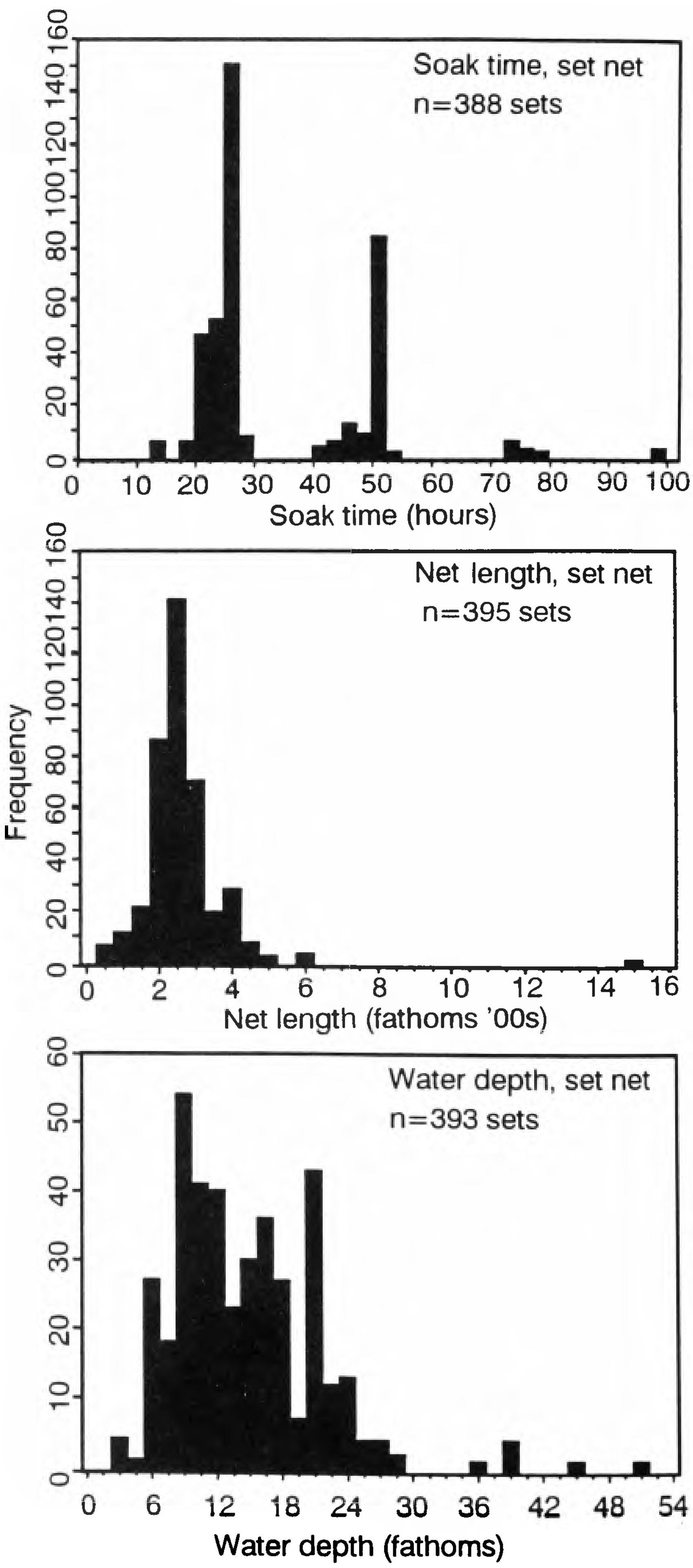

Fig. 1. Frequency distributions of soak time (hrs.), net length (fathoms), and water depth (fathoms) by set for the set net fishery, 1990.

Computer programs developed by the CDFG were used to verify target species against catch and gear data, and then to combine gillnet log data with landing receipt and observer data. One unit (a day) of fishing effort was tallied for each date which had a log entry, and/or an observation. Landing receipts that lacked corresponding log or observer entries three days before or after the landing date were also counted as one day of effort (it was assumed that the associated fishing effort was unlogged). The number of days fished per boat was tallied for each target species in a given area (CDFG block).

RESULTS

Set net

A total of 153 trips involving 406 sets were observed for the halibut and angel shark fisheries between mid-July and December 31 1990. A total of 60 trips involving 140 sets was observed in the central California area. Fifty-eight percent of the observed nets were single panel trammel nets; the remainder were non-trammelled set nets. Ninety-eight percent of the observed nets were constructed of monofilament material (single fiber nylon); the rest were constructed of multi-filament twine (nylon and other material). Ninety-nine percent of all observed halibut and angel shark nets had a mesh size of 8.5in (21.59cm). Partial observations were made on 10 sets, generally as a result of observations made from another vessel. Nine of these sets occurred in the Morro Bay area. The average number of sets per trip was 2.7 (SD=1.3). The average number of soak-hours per set was 31 (SD=13.82, n=388). The average net length was 253 fathoms (SD=103.8, n=395), and the average water depth per set was 14.1 fathoms (SD=6.59, n=393). Frequency distributions are presented in Fig. 1.

Scatter plots did not reveal any obvious relationships between marine mammal mortality and soak time, net length, or water depth. With the exception of the estimated by-set correlation between soak time and California sea lion mortality (central California, 0.42), estimated by-set correlations between marine mammal mortality (by species) and soak time were all less than 0.4 in absolute value. No preferable measure of fishing effort was evident for predicting marine mammal mortality, although weak relationships between California sea lion mortality and soak time and elephant seal mortality and soak time (estimated by-trip correlation coefficients were 0.32 and 0.31 (central California), respectively) were found.

Observed mortality

Total observed set net mortality was four harbor porpoises (*Phocoena phocoena*), three southern sea otters (*Enhydra lutris* subsp.) and 113 pinnipeds, including 67 California sea lions (*Zalophus californianus*), 30 harbor seals (*Phoca vitulina*), 13 northern elephant seals (*Mirounga angustirostris*), one unidentified otariid and two unidentified pinnipeds. Biological data collected from one harbor porpoise are summarised in Table 1. Otter and pinniped data are summarised in Table 2. The locations of observed sets and associated cetacean mortality are shown in Figs 2 and 3, sea otter mortality is shown in Fig. 3, and pinniped mortalities are displayed in Figs 4 and 5.

An additional 35 sets involving stretched-mesh sizes between 6.0 ins (15.2cm) and 6.5 ins (16.5cm), and target species other than halibut or angel shark were coincidentally observed. One harbor porpoise mortality was observed in a 6.25in (15.9cm) mesh net in the Monterey Bay area.

Table 1

Composition and life history of cetaceans incidentally killed in California Category I gillnet fisheries: July through December, 1990. Length is in centimeters. Maturity codes: U = unknown, analyses pending, M = sexually mature, P = pregnant. Comment codes: * = maturity and age determination pending, ** = age determination pending.

Map Code	Species	Location (N/W)	Sex	Length	Maturity	Comments
Driftnet						
1	*Delphinus delphis*	32°27.9 117°58.9	M	190	U	*
2		37°01.0 122°51.0	F	169	P	**
3		35°53.2 122°10.9	M	168	U	*
4		34°38.1 121°25.6	M	164	-	
4		34°38.1 121°25.6	F	163	P	**
5		32°34.5 117°29.2	M	153	U	*
6		31°59.0 118°08.1	M	-	M	**
7		32°49.2 120°02.1	M	-	-	
4		34°38.1 121°25.6	M	-	-	
8	*Lagenorhynchus obliquidens*	35°04.0 121°16.0	M	188	U	*
9		36°54.8 122°05.6	M	180	U	*
10		34°02.3 122°36.4	F	-	-	
11	*Globicephala macrorhynchus*	35°53.0 122°10.6	-	--		
12	*Phocoenoides dalli*	40°20.6 125°49.1	-	-	-	
13	*Mesoplodon* spp.	34°18.8 122°38.0	F	-	-	
Setnet						
S1	*Phocoena phocoena*	35°19.6 120°53.2	F	152	-	
S2		36°42.8 121°50.4	-	-	-	
S2		36°42.8 121°50.4	-	-	-	
S3		37°00.5 122°14.5	-	-	-	

Table 2

Summary of pinniped life history information collected from California Category 1 gillnet fisheries: July through December, 1990. Sex: M = male, F = female, U = unknown. Length: K = known, E = estimated, U = unknown. Age/maturity: A = age material collected, M = reproductive material collected.

	No.	Sex	Length	Age/maturity
Setnet				
Z. californianus	24	8F,3M,13U	12K,10E,2U	1A,1M
P. vitulina	19	4F,3M,12U	8K,8E,3U	3A,2M
M. angirostris	9	9U	2K,7E	-
E. lutris	2	2M	2K	2A,2M
Driftnet				
Z. californianus	2	1F,1M	2K	1A,1M
P. vitulina	1	1F	1K	1A,1M
M. angirostris	4	1F,2M,1U	3K,1U	1A,1M

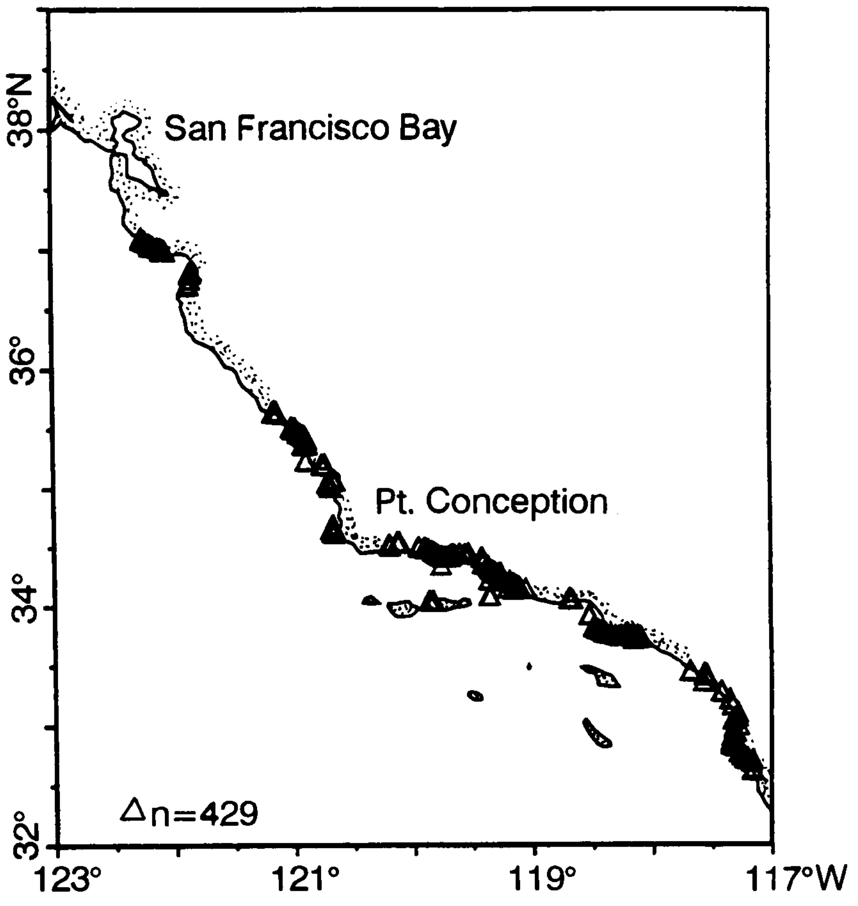

Fig. 2. Locations of observed sets (n=429) for the set net fishery, 1990.

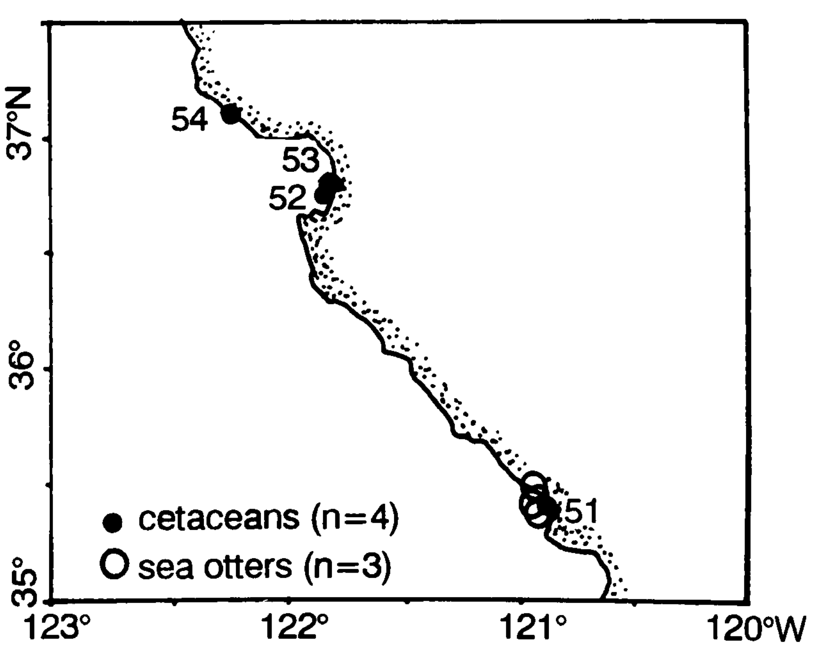

Fig. 3. Locations of observed cetacean and sea otter mortality by set: set net fishery: 1990. n=number of sets. Numbers next to filled circles refer to map codes given in Table 1.

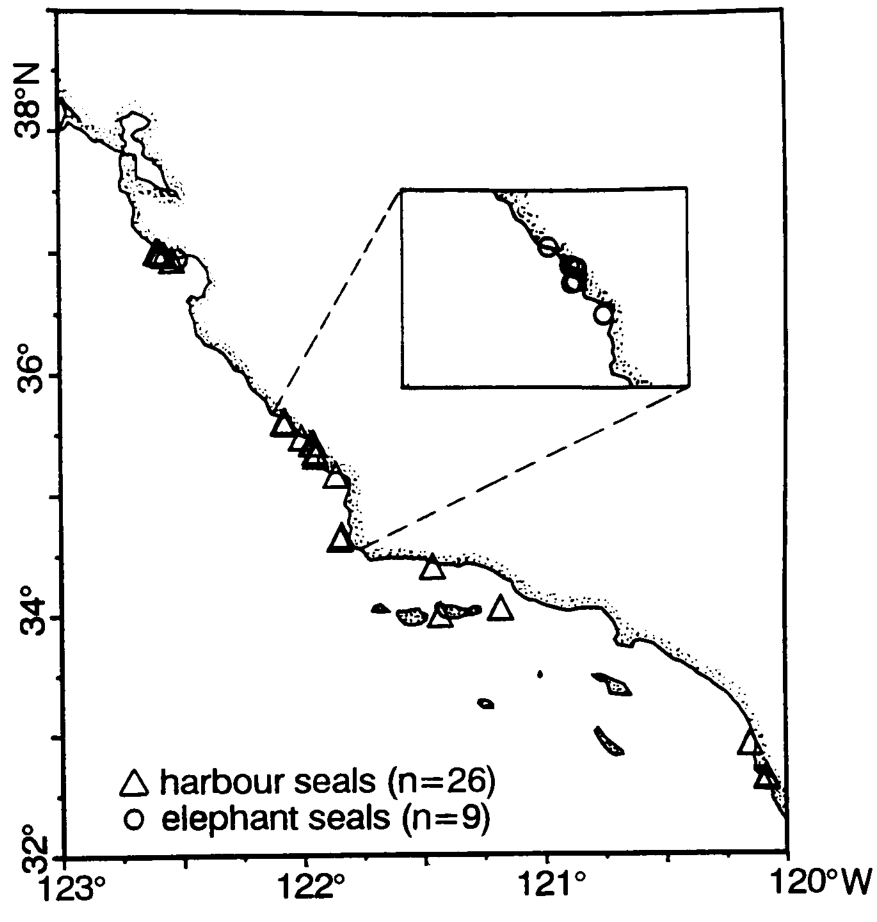

Fig. 4. Locations of observed harbor and elephant seal mortality by set: set net fishery: 1990.

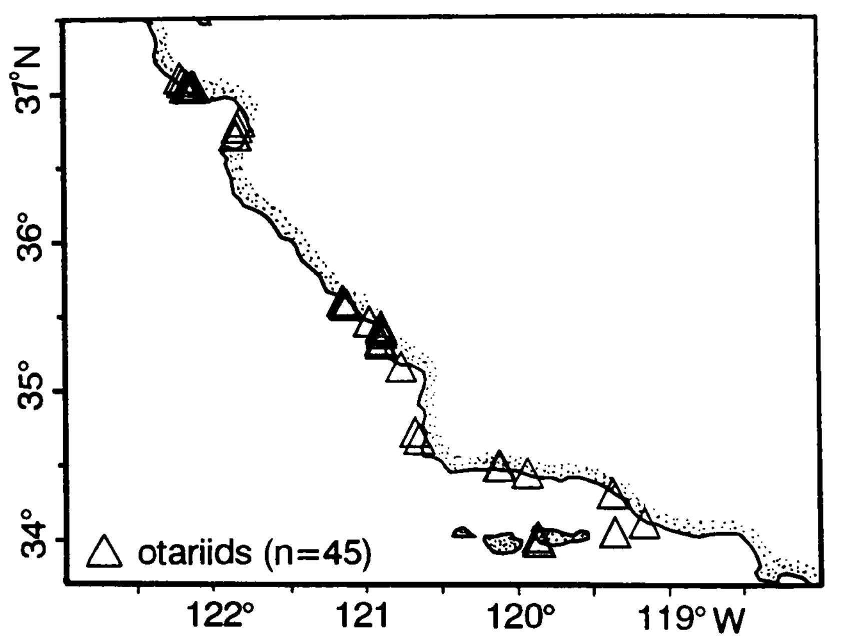

Fig. 5. Locations of observed otariid mortality (California sea lions and unidentified otariids combined by set): set net fishery: 1990.

Post-stratification

We were unable to detect an effect of prior-notification on pinniped mortality (p= 0.36); however the linear model proposed was significant ($p < 0.005$, R^2=0.21). The significance of this model was due largely to the coefficient for soak time which was significantly different from zero ($p < 0.005$). All other coefficients were not significantly different from zero ($p > 0.10$ for individual tests of each coefficient). A plot of residuals versus predicted values suggested that the natural logarithm transformation helped to stabilise the variance; however, a normal probability plot of the residuals showed some degree of skewness with respect to a normal distribution. Following these results, the data were not stratified by prior– versus post-notification.

Table 3

1990 (July through December) kill statistics for marine mammals involved with California Category I gillnet fisheries. Numbers in parentheses indicate standard errors; σ_b is the bootstrap estimate of the standard error. The drift-net and set-net (southern California) take rates for California sea lions includes unidentified otariids. CC = Central California, SC = Southern California, CI = Channel Islands.

Species	Observed killed	Kill/day		Total kill
Setnet				
Phocoena phocoena (central California)	4	0.067	(0.0382)	44 (25)
Enhydra lutris (central California)	3	0.05	(0.0269)	33 (18)
Zalophis californianus	67	CC=0.90	(0.1589)	
		SC=0.055	(0.0279)	847 (134)
		CI=0.75	(0.3202)	
Phoca vitulina	30	CC=0.400	(0.1013)	
		SC=0.044	(0.0211)	392 (83)
		CI=0.167	(0.0868)	
Mirounga angustirostris (central California)	13	0.217	(0.0876)	144 (58)
Driftnet				
Delphinus delphis	9	0.05	(0.0202) (σ_b=0.0207)	203 (82)
Lagenorhynchus obliquidens	3	0.017	(0.0093) (σ_b=0.0092)	68 (38)
Globicephala macrorhynchus	1	0.006	(0.0053) (σ_b=0.0052)	23 (22)
Phocoenoides dalli	1	0.006	(0.0053) (σ_b=0.0049)	23 (22)
Mesoplodon spp.	1	0.006	(0.0054) (σ_b=0.0053)	23 (22)
Mirounga angustirostris	4	0.022	(0.0106) (σ_b=0.0105)	90 (43)
Z. californianus	2	0.022	(0.0153) (σ_b=0.0155)	90 (62)
P. vitulina	1	0.006	(0.0053) (σ_b=0.0051)	23 (22)

The postulated areal effect on the mortality odds ratio for California sea lions and harbor seals was found to be significant (change in deviance=38.6 (d.f.=1), $p < 0.005$); however, the soak time effect was not significantly different from zero (change in deviance=3.4 (d.f.=1), p=0.07). There was no indication of a significant lack of fit for this model (goodness of fit test, chi-square, p=0.22), although one cell described by the logistic model involved less than five sets. Following these results, California sea lion mortality and harbor seal mortality were stratified by area (central California (Morro Bay and Monterey), and mainland California south of Pt. Conception), but not by soak time.

Mortality rates

In accordance with observed data and the known distributions of harbor porpoise and sea otters, estimates of the take rates for these animals in set nets were based on data from central California (Monterey and Morro Bay areas). Estimated take rates for elephant seals were also based on central California data as that was the only area where incidental mortality was observed. Cetacean and pinniped mortality rates are given in Table 3. The estimated mortality rate for California sea lions in southern California was based on observed mortality of both California sea lions and a single unidentified otariid.

The incidental take of marine mammals at the Channel Islands was estimated separately due to historical treatment of these data (Hanan *et al.*, 1988; Hanan and Diamond, 1989). No tests for significant differences between island and mainland rates were done. There were a total of 14 sets (three trips) observed near the Channel Islands (Fig. 2). Incidental marine mammal take associated with these three trips was nine California sea lions, two harbor seals, and one unidentified pinniped (one trip lasting 10 days accounted for 10 of the 14 sets and 10 of the 12 mortalities). Estimated standard errors for California sea lion and harbor seal mortality were obtained from variance estimates for take rates in each of the three areal strata (central California (c), mainland southern California (s), and Channel Islands (i)) according to the formula for variance of a sum (assuming covariance terms are zero): $\hat{\sigma}^2_M = D^2_c\hat{\sigma}^2_{rc} + D^2_s\hat{\sigma}^2_{rs} + D^2_i\hat{\sigma}^2_{ri}$.

Effort and total mortality

Observer placement at the six port stations began in mid-July, with the exception of the Los Angeles office, which was staffed by mid-September. Observer coverage was considerably lower than the targeted level of 20%; an estimated five to six percent of all set net fishing effort was observed between July and December 31, 1990. Observer coverage for central California was slightly better than for southern California; an estimated 10% of all fishing effort was observed. Coverage of the set net fisheries was not uniform because some boats were 'unobservable' due to safety considerations. The fraction of unobservable vessels differed by area. In particular, very few observations were made on vessels fishing near the Channel Islands or on vessels making multi-day trips from the Morro Bay area. It is estimated that one or more observations were made on 33% of all active vessels between July and September 30, increasing to 40% between October 1 and December 31. (Active vessels were defined as those vessels for which the CDFG had some record of fishing activity for halibut or angel shark).

The total number of days fished for the halibut and angel shark fisheries during July through December 1990, was estimated at 3,041. Fishing effort tallies for central California were estimated as the sum of effort within CDFG blocks 500 to 650. Fishing effort for the Channel Islands was estimated as the sum of effort in CDFG blocks 684–690, 707–713,760–762, 765, 806, 807, 813, 814, 829, 849, 850, and 867. Fishing effort for mainland southern California was estimated as the sum of effort from all blocks south of Point Conception (block numbers greater than 650) with the exception of effort in blocks included in the Channel Islands tally (Appendices 1a and b). Total fishing effort for the Monterey and Morro Bay areas was estimated at 664 days; effort for mainland southern California was estimated at 2,206 days. Total fishing effort for the Channel Islands was estimated at 171 days with 98% of the effort occurring around the northern islands. No variance estimate was available for total fishing effort. Under the assumption that kill rates on unobserved trips were the same as kill rates on observed trips, these measures of total fishing effort were used to estimate total take of marine mammals in the set net fishery between July and December for each species for which observed incidentally take occurred (Table 3).

Driftnet

A total of 54 trips involving 181 sets were observed between late July and December 31, 1990. Seventy four percent of the observed sets involved nets made of multi-filament twine (nylon and other material); the remainder were made of twisted monofilament material. There was only one partial observation (an estimated 80% of the net retrieval was observed). The average soak time per set was 12.1 hours (SD=2.45, n=180). Average net length and mesh size (stretched measurement) per set were 973.5 fathoms (SD=37.14, n=180), and 20.7 inches (SD=1.54, n=180), respectively. Average water depth per set was 1206.3 fathoms (SD=651.56, n=168). Frequency distributions are given in Fig. 6. The average number of sets (or equivalently days) per trip was 3.35 (SD=2.048).

Estimated by-set correlations of mortality with soak time, net length, water depth and mesh size were close to zero. Similarly, estimated by-trip correlations between marine mammal mortality and number of days, soak time, length of net and number of sets were low and approximately equivalent (less than 0.2 in absolute value). No preferable measure of fishing effort for predicting marine mammal mortality was evident for either cetaceans or pinnipeds.

Observed mortality

Fifteen cetaceans and nine pinnipeds were observed killed in driftnets. Cetacean species incidentally taken included nine common dolphins (*Delphinus delphis*), three Pacific white-sided dolphins (*Lagenorhynchus obliquidens*), one short-finned pilot whale (*Globicephala macrorhynchus*), one Dall's porpoise (*Phocoenoides dalli*), and a single, unidentified mesoplodont beaked whale (*Mesoplodon* spp.). Life history data were available for 13 of these animals (Table 1). Incidental pinniped take included four northern elephant seals, two California sea lions, a single harbor seal, and two unidentified otariids. Pinniped life history data are summarised in Table 2. The locations of observed driftnet sets are shown in Fig. 7. Locations of sets involving cetaceans and pinniped mortality are displayed in Fig. 8.

Mortality rates

Mortality per day (equivalently mortality per set) for the driftnet fishery was calculated for each species of marine mammal incidentally taken by the fishery (Table 3). The estimated take rate of California sea lions was based on observed mortality of both California sea lions and unidentified otariids (two animals).

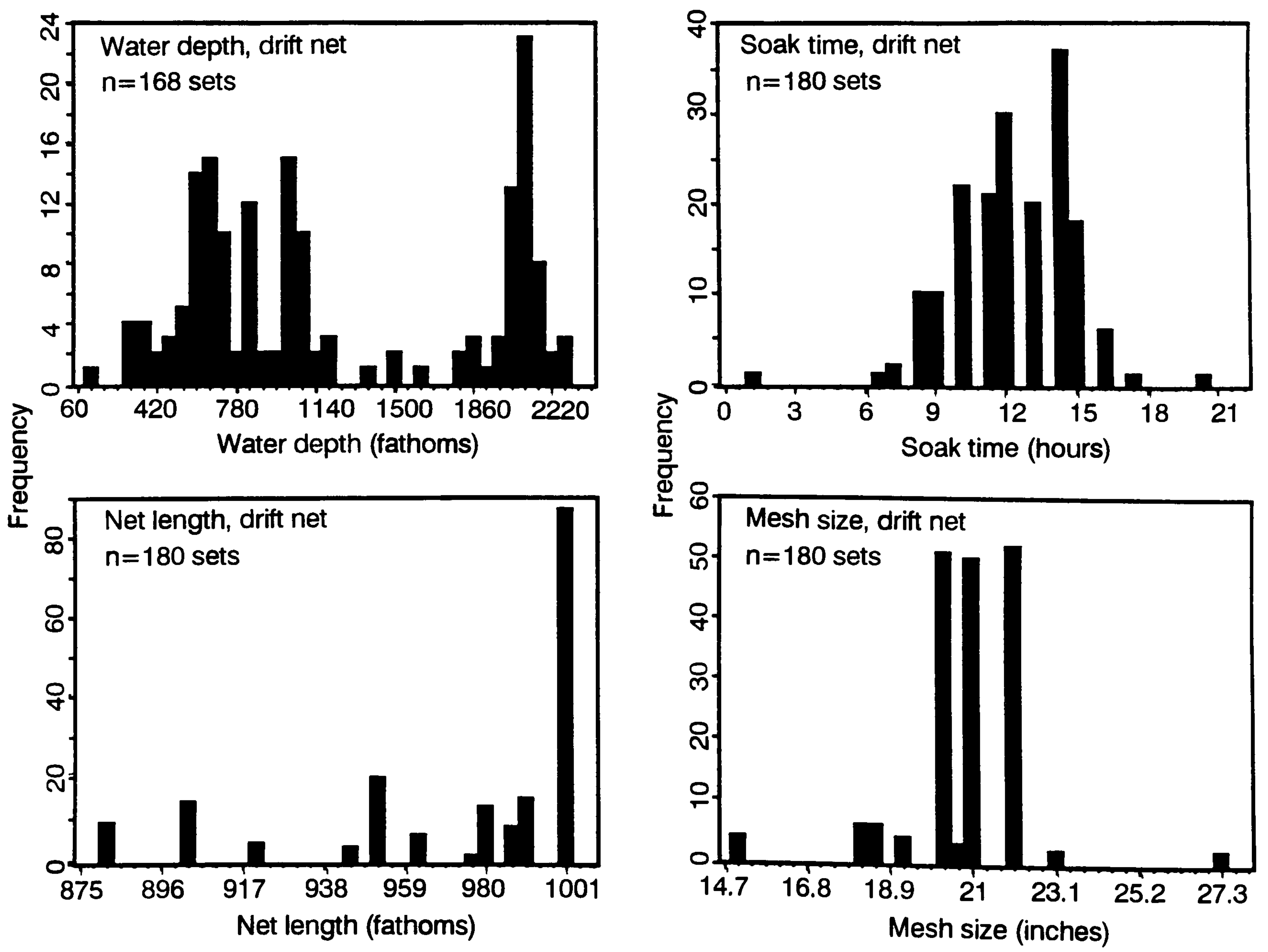

Fig. 6. Frequency distributions of soak time (hrs), net length (fathoms), water depth (fathoms), and mesh size (inches) by set for the driftnet fishery, 1990.

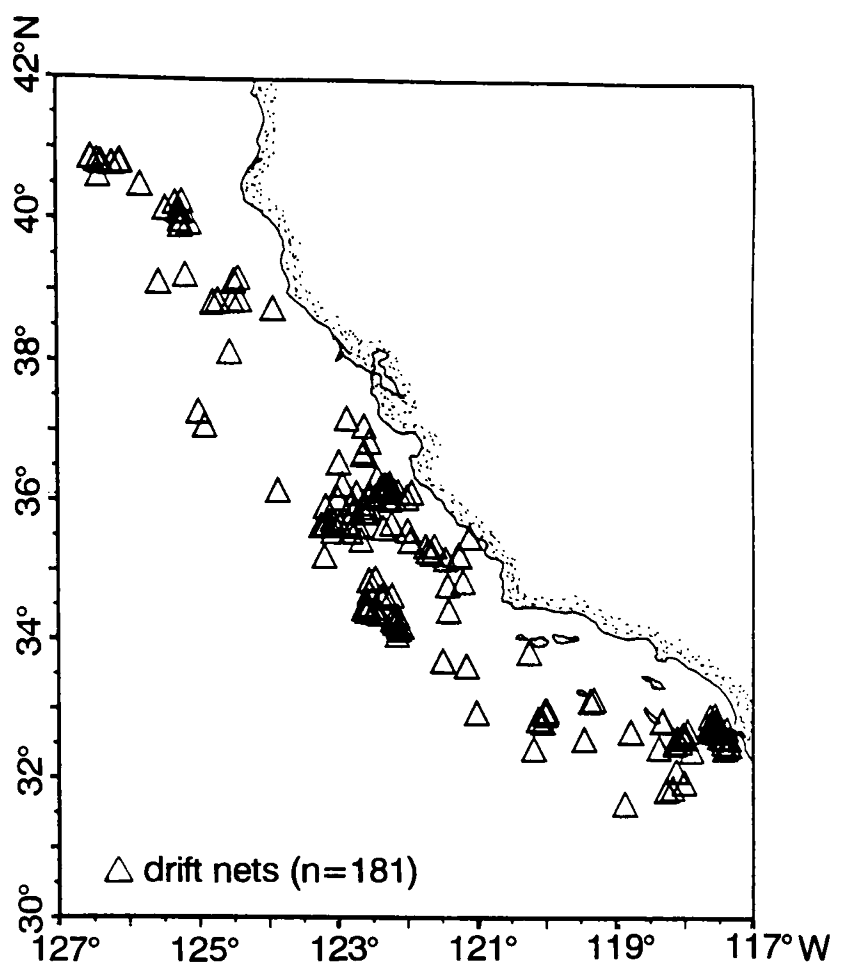

Fig. 7. Locations of observed sets (n=181) for the driftnet fishery, 1990. n=number of sets.

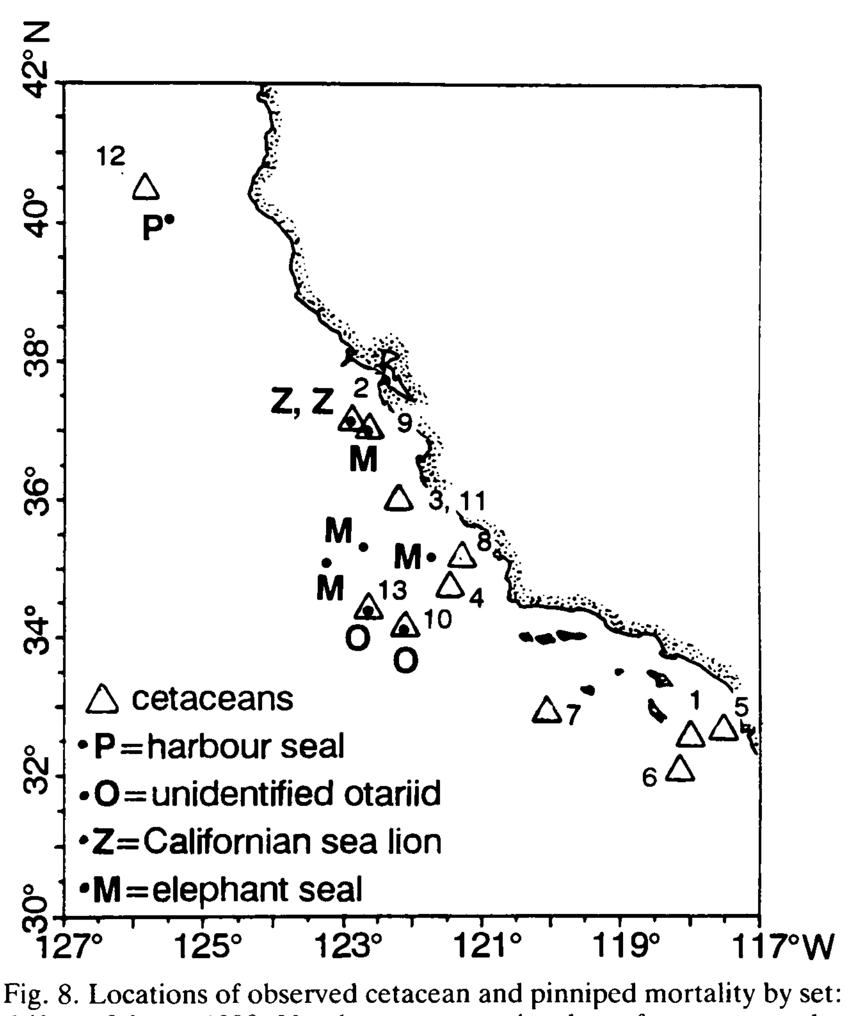

Fig. 8. Locations of observed cetacean and pinniped mortality by set: driftnet fishery: 1990. Numbers next to triangles refer to map codes given in Table 1. P=harbor seal, O=unidentified otariid, Z=California sea lion and M=elephant seal.

Effort and total mortality

As for the set net fishery, observer coverage was well below the targeted level of 20%; an estimated four percent of all driftnet fishing effort was observed. The 'unobservability' of many vessels prevented uniform coverage across the fishery. It is estimated that one or more observations were made on 16% of all active vessels between July and September 30, increasing to 27% between October 1 and December 31. (Active vessels were determined from CDFG effort data). Total fishing effort for the driftnet fishery for July through 31 December 1990 was estimated at 4,078 days. As with the set net estimates of total fishing effort, no variance estimate was available for total effort. Under the assumption that kill rates on unobserved trips were the same as kill rates on observed trips, this estimate of total fishing effort was used to estimate total kill of marine mammals for each species with incidental observed take between July and December 31 1990 (Table 3).

DISCUSSION

Life history

Life history data collected during the 1990 gillnet fishing season were too limited to draw any meaningful conclusions on the age and sex structure of species incidentally killed. As additional data are obtained, studies of reproductive parameters (e.g. Barlow, 1984; Hohn *et al.*, 1985; Myrick *et al.*, 1986) and stock structure will be initiated for species involved in these fisheries.

At least four of the cetacean species incidentally killed in California's gillnet fisheries are thought to be represented by several distinct geographical stocks. These animals include common dolphins (Banks and Brownell, 1969; Evans, 1975; 1982), Pacific white-sided dolphins (Walker *et al.*, 1986), Dall's porpoise (Kasuya, 1978; Winans and Jones, 1988) and harbor porpoise (Calambokidis and Barlow, 1991). Sufficient materials for stock identification were not obtained for most of the animals killed because of logistic problems involved with specimen collection at sea. Data collection protocols have been modified to mitigate these logistic difficulties so that sufficient specimen materials to assess stock structure will hopefully be obtained in the future.

The two female common dolphins collected (169 and 163cm in length) were pregnant. These animals are considerably shorter than the average length of sexually mature *Delphinus* reported from the eastern tropical Pacific (196cm) (Perrin and Reilly, 1984), but are within the range (164–193cm) reported for the short beaked form from coastal California (J.E. Heyning, pers. comm.). One male was sexually mature. Its length was not measured. Testes from three additional specimens were collected, but have not been examined to date.

Length and maturity data were collected from two male Pacific white-sided dolphins killed in gillnets during 1990. These animals were 188 and 180cm long – slightly less than the average length of sexually mature animals (190cm) reported by Walker *et al.* (1986). Determination of the reproductive condition of these two animals is pending.

Two male sea otters (124 and 93cm) were killed. The smaller of these animals was determined to be sexually immature (J. Ames, pers. comm.).

Relatively few life history data were collected from entangled pinnipeds. California sea lions are sexually dimorphic. Mature males average 220cm, and females 180cm (Odell, 1981). All of the sea lions observed killed between July and December were shorter than these figures and therefore were probably immature (Table 2).

The longest harbor seal reported was a 109cm female taken in the set net fishery. Bigg (1981) reports that average lengths of sexually mature *Phoca vitulina* are 161cm for males and 148cm for females (sample from British Columbia). It is probable that all of the harbor seals observed killed and measured this year were immature.

According to Le Boeuf (1979), the average length of sexually mature northern elephant seals is 360cm for females and 450cm for males. Reported lengths of elephant seals entangled this year ranged from 152 to 237cm. It is probable that no mature elephant seals were taken.

In spite of the small sample, it appears that the pinniped bycatch may be biased towards small or immature animals. Age biases in rates of gillnet entanglement have been suggested for harbor porpoise (Hohn and Brownell, 1990), Hector's dolphins, *Cephalorhynchus hectori* (Dawson, 1991) and Risso's dolphins, *Grampus griseus* (Kruse *et al.*, 1990). Additional data on age and reproductive status are necessary to assess bycatch characteristics more accurately.

Mortality rates

Comparability with historical estimates

Although the marine mammal mortality estimated here represents only six months, it is possible to make crude comparisons with annual estimates made for previous years. Our six-month set net mortality estimates for California sea lions, harbor seals, and harbor porpoise were 847, 392 and 44 respectively. These compare with average *annual* estimates of 2,597, 1,267 and 197 for the same species in fishing years 1983/4 through 1987/8 based on the CDFG observation program (data averaged from Diamond and Hanan, 1986; Hanan *et al.*, 1986; 1987; 1988; Hanan and Diamond, 1989; and Konno, 1990). Current estimates appear to be less than half the previous estimates. Given that more fishing typically occurs in the second half of the calendar year, total marine mammal mortality in set nets appears to be less than in previous years. However, average kill-per-day rates in set nets are similar between the data from 1990 (0.279, 0.129, and 0.066 for sea lions, harbor seals and harbor porpoises) and the average kill-per-day rates from 1983/4 through 1987/8 (0.266, 0.130, and 0.066, respectively for the same species). If mortality is truly decreasing, it would seem to be more related to a decrease in fishing effort than a decrease in kill rate. No estimates were made for northern elephant seal mortality in previous years.

Our six-month driftnet mortality estimates for California sea lions and harbor seals were 90 and 23 respectively. The corresponding average *annual* estimates for fishing years 1983/4 through 1987/8 were 328 and 50 (data averaged from Hanan *et al.*, 1988; Hanan and Diamond, 1989; Konno, 1990). Again current estimates are less than half the previous estimates. Average kill-per-day rates in driftnets in 1990 were 0.022 for sea lions and 0.006 for harbor seals, compared with average kill rates of 0.033 for sea lions and 0.005 for harbor seals for years 1983/4 through 1987/8. Effort for the July-December period (which represent the majority of the fishing season) was 4,078 days, compared to an average annual effort of 9,841 days in previous years. As with the set net fisheries, if mortality is truly decreasing, it would seem to be related to a decrease in fishing effort. No estimates were made for cetacean or elephant seal mortality in previous years.

Bias

Marine mammal mortality rates reported here may be unrepresentative of true take rates for several reasons. Unstratified (driftnet) or minimally stratified (set net) estimates of total mortality were computed for most species because it was felt that there were inadequate data to assess many factors considered likely to have affected marine mammal mortality. Additional data and more detailed analyses may indicate that these data should have been stratified and that our estimates are therefore biased estimates of actual take rates. We discuss several particular sources of bias below.

PRIOR-NOTIFICATION

Because of the nature of the set net fishery, it has been suggested that prior-notification of set net fishers of their obligation to carry an observer would result in a biased sample. That we were unable to detect any bias in these data due to prior-notification may indicate that set net fishers do not alter their fishing behavior substantially when an observer is onboard. On the other hand, our inability to detect any bias in the data may be due to the fact that vessel selection was not always based on random sampling. In areas where set net fishers were observed on approximately every fifth trip, the schedule for observation may have been better known than we would have preferred. More importantly, our inability to detect any bias due to prior-notification of fishers may have been a result of the model we used, the unbalanced nature of the data, or low sample size. More data would allow for construction of a more precise model to better describe sources of nuisance variation (e.g., inclusion of 'vessel effects') and increase statistical power. Because mortality data are positive, integer-valued data, and in this case, involved many zeros (60% of the 129 sets used in this analysis involved no pinniped mortality), formulation of this testing problem in terms of a generalised linear model analysis (e.g., natural logarithm link with Poisson-like variation) might well result in a better (and more theoretically sound) treatment of these data.

SOAK TIME

A potential relationship between soak time and marine mammal mortality in the set net fishery was demonstrated using a linear model for the natural logarithm of pinniped mortality per set. These results would conflict with the lack of significance found for the soak time effect on the mortality odds ratio for sea lions and harbor seals (based on a logistic regression analysis). There are several factors likely to be contributing to this disagreement. The two analyses were done on different data sets; the linear model for the logarithm of kill used all pinniped data from central California, the logistic model for the probability of at least one mortality only used sea lion, harbor seal and unidentified otariid data from central and southern California. Although there was a suggested positive relationship (albeit weak) between mortality for some species (in particular elephant seals and California sea lions) and soak time (from estimated correlation coefficients), other species showed no relationship at all (harbor seals were one such species). In addition, data for the logistic regression were grouped by zero kill versus positive kill and soak time (less than 27 hours versus 27 or more hours (following inspection of Fig. 1)). The occurrence of a few high mortality sets with soak times of 72 hours or more may have exerted considerable influence on the results of the linear model for the logarithm of kill. Moreover, interactions between soak time and area (central versus southern California) may exist but were not included in the logistic model because of inadequate data (however, in general, take rates in southern California were much lower than in central California regardless of the time the net soaked). The paucity of observations involving mortality make identification of factors affecting marine mammal mortality difficult (e.g., in the case of the data set for the logistic regression, less than 15% of the data involved non-zero mortality sets).

AREA

Observer data indicate that take rates of marine mammals for the set net fishery at the Channel Islands may be considerably higher than those for mainland southern California (Table 3). Pinniped rookeries at the Channel Islands tend to cluster animals geographically. Unfortunately our sample size of three trips, while accounting for approximately 7% of the total estimated fishing effort, may not be representative, severely biasing our estimates of take rates for pinnipeds at the Channel Islands. These data only add emphasis to the importance of increasing efforts to monitor fishing activity near the Channel Islands.

Although Monterey and Morro Bay set net data were grouped together as one areal strata, there appeared to be notable (although not statistically significant) differences between the set net fisheries operating in the two areas. The average soak time in Monterey Bay was considerably longer than the average soak time for Morro Bay, although the average number of sets per trip was considerably less (Table 4). Daily rates of cetacean mortality (harbor porpoise) for Monterey and Morro Bay were 0.115 (SD=0.4315) and 0.033 (SD=0.1826), respectively. We were unable to detect a difference in kill rates between the two areas (Student's t test (unequal variances), t=0.9028, d.f.=32, $p > 0.10$).

Table 4

Number of trips and sets and the average number of sets/trip, soak time/set, net length/set and water depth/set reported from the Monterey and Morro Bay-based set-net fisheries: July through December, 1990. Standard deviations are in parentheses. Data are from sets made with nets with stretched-mesh lengths ≥ 8.0 inches (20.3cm). Average soak time, net length and water depth for the Morro Bay area are based on 97 sets due to missing data.

Characteristic	Monterey	Morro Bay
No. sets	32	108
No. trips	26	34
No. sets/trip	1.2 (0.43)	3.2 (1.14)
Soak time (hrs.)	51.8 (16.24)	35.1(13.48)
Net length (fathoms)	352.5(65.17)	235 (26.26)
Water depth (fathoms)	21.7 (1.18)	17.4 (2.25)

OBSERVED VERSUS UNOBSERVED FISHING ACTIVITY

We have assumed that take rates based on observer data are representative of the fisheries as a whole, even though certain segments of both set net and driftnet fisheries were never observed (i.e., small vessels and distant fishing areas). Initial inspection of CDFG gillnet log data has revealed some differences between the log data and NMFS observer data. For example, 43% of the mesh sizes reported in the driftnet log data were between 14 and 19 inches (35.5–48cm); only 8% of NMFS driftnet observer data have comparable mesh sizes (Fig. 6). The distribution of water depths recorded in the gillnet log data for the set net fishery in Morro Bay area is bimodal with 19% of the sets made in water depths less than or equal to 11 fathoms; only 2% of the set net observer data for the Morro Bay area have comparable water depths (Fig. 9). It is clear that further analysis on the CDFG log data in connection with the observer data is necessary. Such analysis may suggest that take rates based on observer data collected under the present methods are not representative of unobserved set net or driftnet activity. In addition, we have estimated total mortality for July 1 through December 31 1990, even though data for estimating take rates were not available from some areas for July and August.

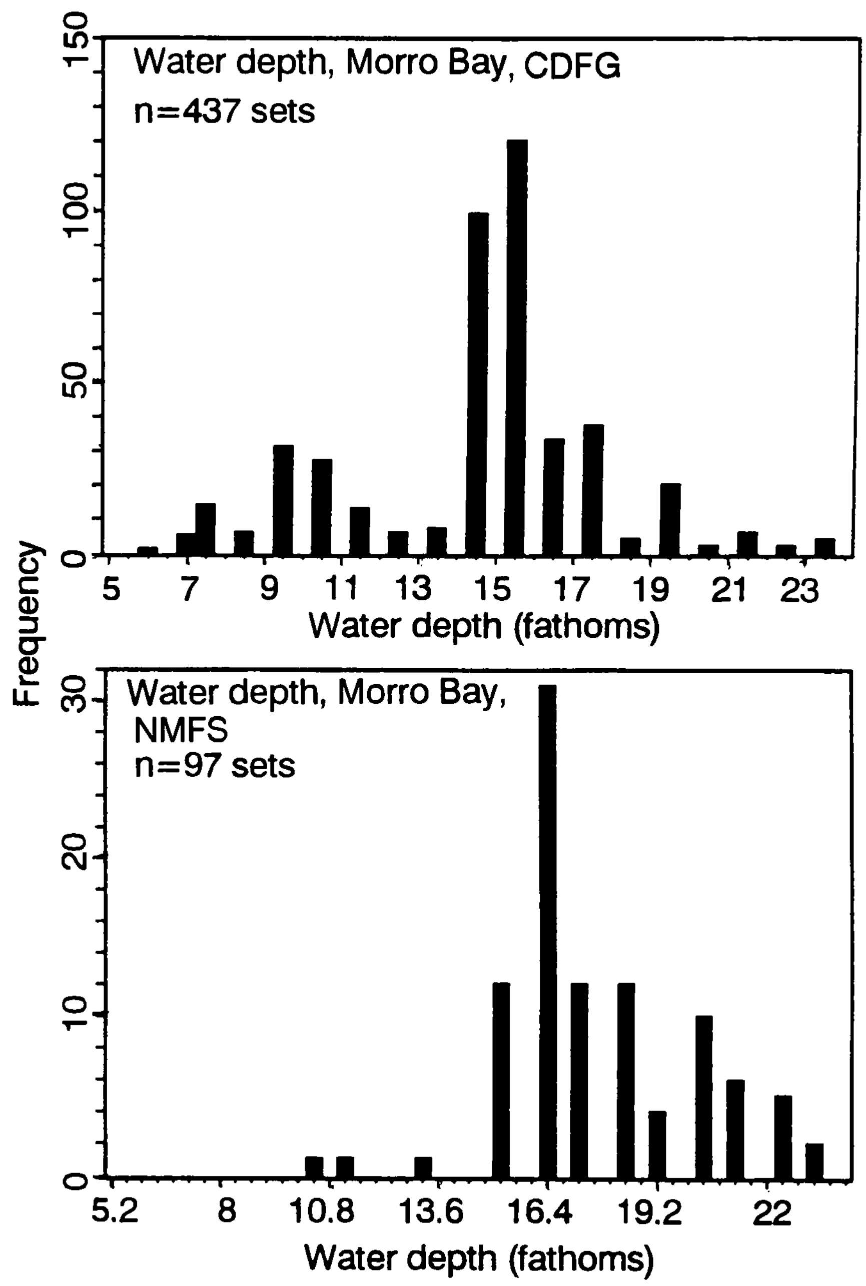

Fig. 9. Comparison of water depths for Morro Bay area set net fisheries, observed vs. non-observed trips: 1990.

Data collection/sampling

Identification of vessels actively participating in these three Category I fisheries has been an ongoing problem. With the exception of the set net fishery in Monterey (a result of previous CDFG programs), fishers are not required by law to notify NMFS personnel regarding their fishing status. In particular, driftnet vessels fishing up and down the coast of California may never visit the same port twice. While cooperation of some vessels has been good, port coordinators may only become aware of active vessels by way of CDFG effort data (which are only available after a three month time lag). The inability of NMFS personnel to identify and track all active fishing vessels affects the percentage of fishing effort observed as well as their ability to obtain a representative sample of data from the fleet. This problem is compounded by the fact that, once identified as active, some vessels are 'unobservable' except from an alternate platform. As opposed to reports of entanglement of baleen whales in driftnets and set nets off the California coast (Heyning and Lewis, 1990), no entanglements for these species have been reported by our program to date. It is possible that more species were taken by gillnets than were documented by our program. Small sample sizes and/or biases resulting from constraints imposed on the sampling program could result in mortality of certain species never being observed. Clearly, mitigation of logistic sampling problems is crucial to the quality of data that can be obtained through this program.

Estimation methods

Because the only source of total fishing effort for these gillnet fisheries is in terms of days fished, total mortality was estimated using the estimator kill per day. However, for the driftnet data, there was effectively no correlation between marine mammal mortality and number of days fished. It would seem that the number of days fished may be a poor predictor of incidental marine mammal take. In addition, the number of days fished would seem to be a poor measure of effort for the set net fishery because it is not uncommon for more than one net to be pulled in a day. Identifying other measures of fishing effort showing substantial positive correlation with marine mammal take would likely allow for improvement of both the precision and the accuracy of estimated total take of marine mammals.

In this analysis we have treated these data as though they were the result of a simple random sampling scheme. This is not the case for either fishery. In many cases, random selection of vessels in the set net fisheries was considered to be unworkable because of the number of active vessels on any given day, the limited cooperation of some fishermen with NMFS personnel, and the perceived inequity of any particular vessel carrying an observer on more than one consecutive trip. Non-random selection of set net vessels often followed a system similar to that used for sampling driftnet vessels (i.e., every fifth trip). Calculation of variance estimates did not reflect the structure of the data and may be under or over-inflated due to dependencies within the data which were not taken into consideration.

Given the sampling assumptions made, we believe the linearisation method provided a reasonable estimate of the variance for the ratio estimate of kill per day for the driftnet data, even though estimated coefficients of variation exceeded guide lines provided in Cochran (1977). As a heuristic measure of the adequacy of the linearisation technique (as regards truncation of the Taylor series expansion used to estimate the variance function), estimates of the variance of kill per day were computed following a resampling method for finite populations proposed by Sitter (1992b) (Appendix 2). Variance estimates obtained from this procedure were very similar to those obtained using the linearisation procedure (Table 3).

Fishing effort

The estimated total gillnet fishing effort for July through December 31 1990 presented here is only preliminary. Even when the gillnet log data are complete, estimated fishing effort may be biased. It is not clear exactly what percentage of effort goes unlogged. Landing receipts can account for some unlogged effort, but the actual fishing effort associated with each landing receipt may vary considerably from the one day allotted. In addition, the landing receipt database is itself incomplete. Incomplete fishing logs may influence regional effort estimates; gillnet fishers occasionally neglect to record the specific location fished and the effort is subsequently assigned to a general area. Variance estimates for total days fished are currently not available. Inclusion of variability of the estimated total effort would increase the variability associated with estimated total marine mammal mortality.

Our treatment of fishing effort lacking a specific CDFG block assignment undoubtedly affected our estimate of total mortality for the set net fishery because we used a stratified estimator (by three areas). While it seemed unlikely that effort assigned by the CDFG to the general areas of Monterey or Morro Bay would be from fishing occurring in southern California (south of Pt. Conception), unspecified effort for the Los Angeles/Ventura area may have represented some fishing effort that occurred at the Channel Islands. Twenty percent of the fishing effort assigned to southern California was only assigned a regional area (34 days to San Diego and 401 days to Los Angeles/Ventura). Given our uncertainties as to the most appropriate method for prorating this unspecified effort, we chose to use the regional areas to stratify the effort according to our three areal strata (central California, southern California or Channel Islands).

While available data are limited, we can do little other than assume that gillnets fish indiscriminately and that when placed in areas of known marine mammal concentration, are likely to incidentally kill a wide variety of these animals. Preliminary findings underscore the need to continue the gillnet observer program (preferably at an increased level of observer coverage) until adequate analysis of the impact of incidental mortalities on marine mammal populations can be made for all marine mammal species incidentally taken in these fisheries.

Postscript

The NMFS observer programme has now been running for over three years. A summary of the level of sampling coverage achieved, and of marine mammal mortalities for 1991 through 1993 can be found in Barlow *et al.* (1994) and references therein.

ACKNOWLEDGEMENTS

We are indebted to Peter Perkins for his invaluable comments regarding our statistical analyses and the organisation of this report, in addition to providing useful statistical discussions. Susan Chivers, Doug DeMaster, Karin Forney, Tim Gerrodette, Debra Palka, and Steve Reilly of the Southwest Fisheries Science Center (NMFS), Dick Butler and Norm Mendes (NMFS – Southwest Regional Office), and Doyle Hanan (CDFG) kindly reviewed our manuscript and strengthened it with their useful comments and suggestions. Nancy Lo and Bruce Wahlen of the Southwest Fisheries Science Center provided critical reviews of our statistical analyses. We appreciate the cooperation of the California gillnet fishers who allowed observers access to their boats. We especially thank the NOAA observer-technicians and their port coordinators whose hard work and dedication to the California gillnet monitoring program made this report possible.

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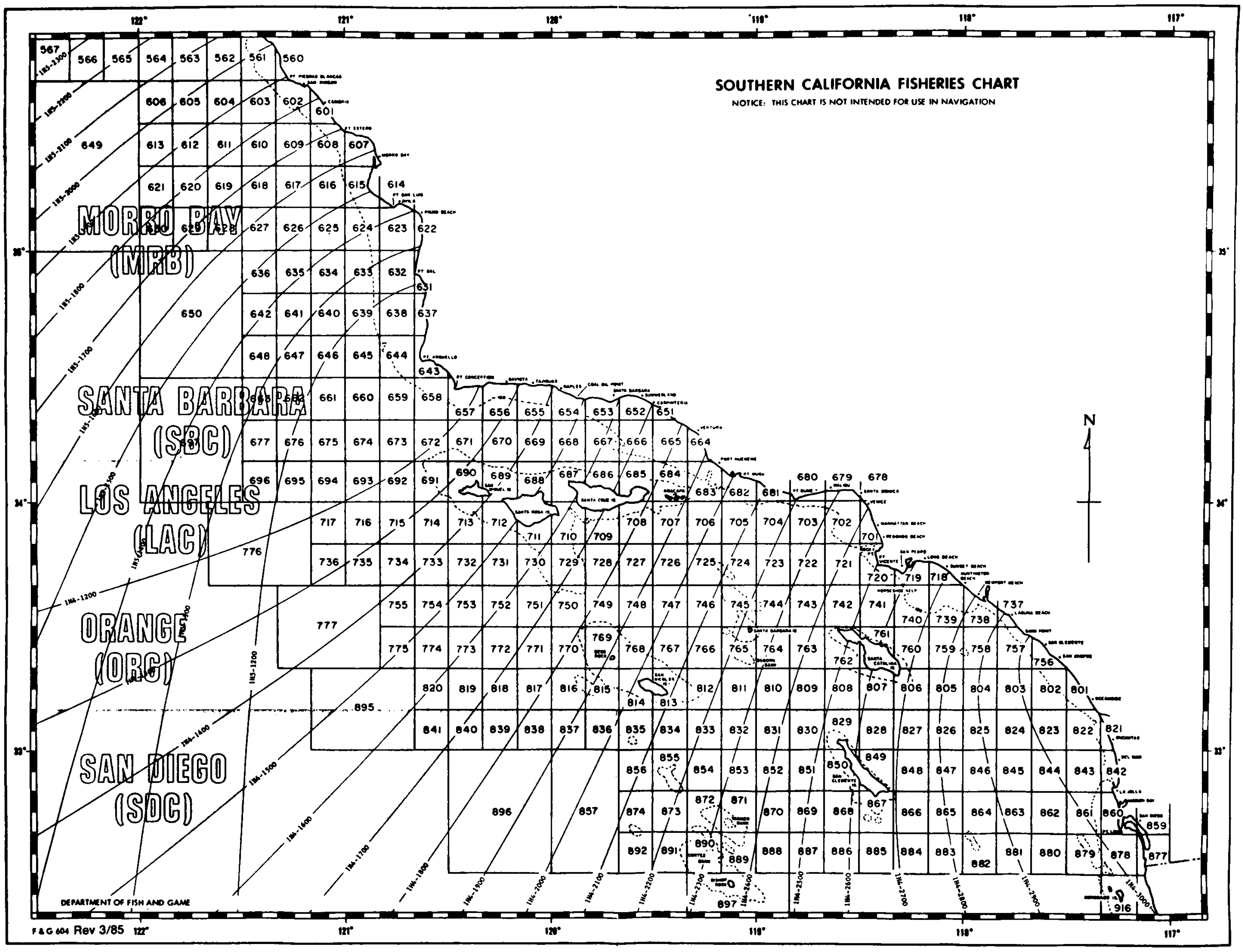
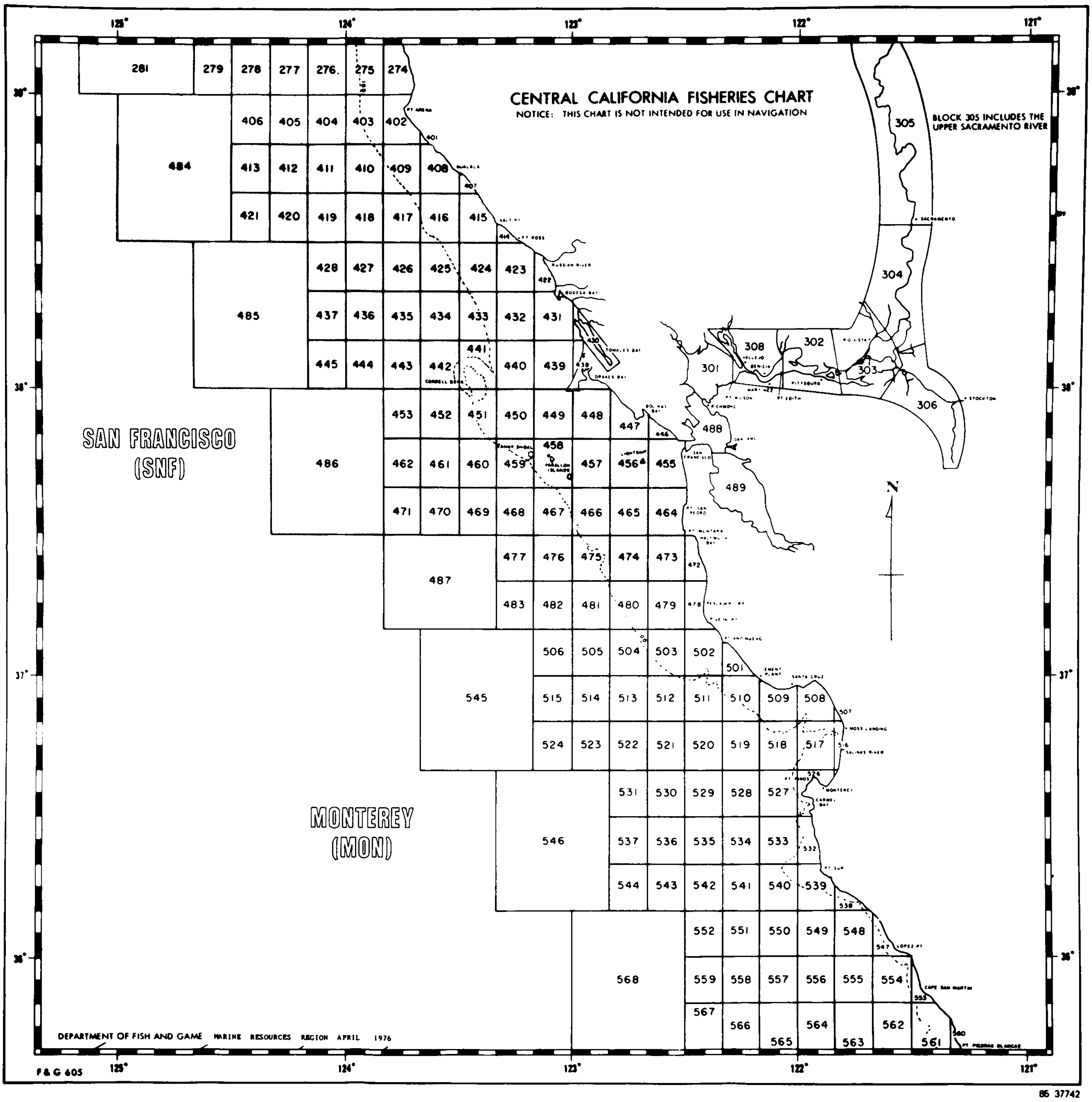
APPENDIX 1

CALIFORNIA DEPARTMENT OF FISH AND GAME FISHERIES MANAGEMENT BLOCKS





APPENDIX 2

Although our sample size from the driftnet fleet was not small (a sample of 54 trips was obtained), the estimated coefficients of variation for mortality per trip and number of days per trip were large. Cochran (1977) gives conditions under which the linearisation technique provides a reasonable estimate of the variance of the ratio. As a comparison against our estimates of variance obtained using the linearisation method, estimates of the variance of kill per day were computed following a resampling method for finite populations proposed by Sitter (1992b). In brief, for each of 1,000 bootstrap samples, trips were resampled without replacement m times where $m=f \cdot n$, f=sampling fraction for the true population, n=number of observed trips. Then k subsets of size m were drawn with replacement from the n observed trips, $k=n \cdot (1-f^*)/m \cdot (1-f)$, where $f^*=$ bootstrap sampling fraction. Both k and m were, in this case, non-integer, so randomisation between bracketing integers was used at each bootstrap sample (see Sitter, 1992b, for details). The variance of kill per day was then estimated using the usual Monte Carlo approximation $((1/B) \cdot \Sigma_i(\Theta_i-\Theta)^2$, where $\Theta_i=$ ith bootstrap replicate of kill per day, $\Theta = (1/B)\ \Sigma_i\ \Theta_i$, $i=1,\ldots,B$). Variance estimates obtained from this procedure were very similar to those obtained using the linearisation procedure (Table 3). However, estimates were based on the same sampling assumption: that the data were the result of a simple random sample. With additional data, a multi-stage bootstrap procedure which more closely mimicked the actual sampling procedures used in the field could be constructed (e.g., see Sitter, 1992a; 1992b; Rao and Wu, 1988; McCarthy and Snowden, 1985). In as much as the actual driftnet data sampling procedures were more involved than simple random sampling, such a resampling procedure (while computer intensive) would likely be easier to implement than an estimate based on the linearisation method.

Southeastern Pacific

SC/O90/G11

Gillnet Fisheries and Cetaceans in the Southeast Pacific

Julio C. Reyes[1]

Grupo Cetáceos-ECCO. Centro Peruano de Estudios Cetológicos, (CEPEC). Casilla 1536, Lima 18, Peru

and

Jorge A. Oporto

Centro de Investigación y Manejo de Mamíferos Marinos (CIMMA), c/o Instituto de Biología Marina Universidad Austral de Chile. Casilla 567, Valdivia, Chile

ABSTRACT

A general description of gillnet fisheries in the Southeast Pacific area (comprising the waters of Ecuador, Peru and Chile) is presented and their potential threat to cetaceans is discussed. Information was gathered mainly through a literature review and interviews with fishermen and fishery experts but direct observations are included where possible. Gillnets are the main fishing gear used in waters of the region. In Peru they represent around 60% of the fishing gear used. Mortality of small cetaceans in fishing nets is known to be high in Peruvian waters where a market for their meat exists. An unknown number of large and small cetaceans are taken incidentally in the gillnet swordfish fishery in Chilean waters. Some tens to a few hundred dolphins and porpoises die every year in southern Chile in an expanding coastal gillnet fishery for ratfish and sciaenids. The scanty information from Ecuador suggests that a few hundred animals may get entangled in fishing nets every year. No foreign driftnet fisheries operate in or off the waters of the region. Little specific information on gillnet fisheries is available as they are pooled with other fisheries as 'artisanal' by national agencies. It is recommended that national agencies institute studies to evaluate the impact of gillnet fisheries on small cetaceans and other marine organisms, including commercially exploited species. Research on alternative fishing methods should be considered in order to reduce cetacean mortality without damaging the fisheries.

KEYWORDS: INCIDENTAL CAPTURE; SOUTH PACIFIC; FISHERIES; BOTTLENOSE DOLPHIN; SPOTTED DOLPHIN; BURMEISTERS PORPOISE; DUSKY DOLPHIN; COMMON DOLPHIN; RIGHT WHALE DOLPHIN; SHORT-FINNED PILOT WHALE; RISSO'S DOLPHIN; KILLER WHALE; FALSE KILLER WHALE; PYGMY SPERM WHALE; DWARF SPERM WHALE; CUVIER'S BEAKED WHALE; LESSER BEAKED WHALE; HUMPBACK WHALE

INTRODUCTION

The Southeast Pacific is one of the richest marine environments of the world. Exploitation of marine resources is a major activity in countries such as Ecuador, Peru and Chile, and several projects have been implemented in the region to develop or improve fishing methods. Among these, the introduction of gillnets was preferred over others because of the relatively low cost and high yields of such fisheries. However, a disadvantage of such fishing gear is that it may take non-commercial fish species and other marine vertebrates, including marine mammals.

In this paper we review the gillnet fisheries in the Southeast Pacific area (Fig. 1) in an attempt to characterise each of them and document their interactions with cetaceans. The extent of the area and the lack of research on these fisheries is reflected in our report, which is based on a literature review, interviews with fishermen and fishery experts, and direct observations in Peru and Chile. For Ecuador, the only available information to us was that from correspondence with fishery experts. Since our review was completed, new information has been provided in papers included in this volume (pp. 475–83).

LITERATURE REVIEW

Entanglements of cetaceans, in particular small cetaceans, in the Southeast Pacific area have been reported in the literature since the 1960s. Incidental mortality of small cetaceans in Peruvian waters was reported by Clarke (1962), Grimwood (1969) and Clarke *et al.* (1978). More recently the exploitation of small cetaceans in Peruvian

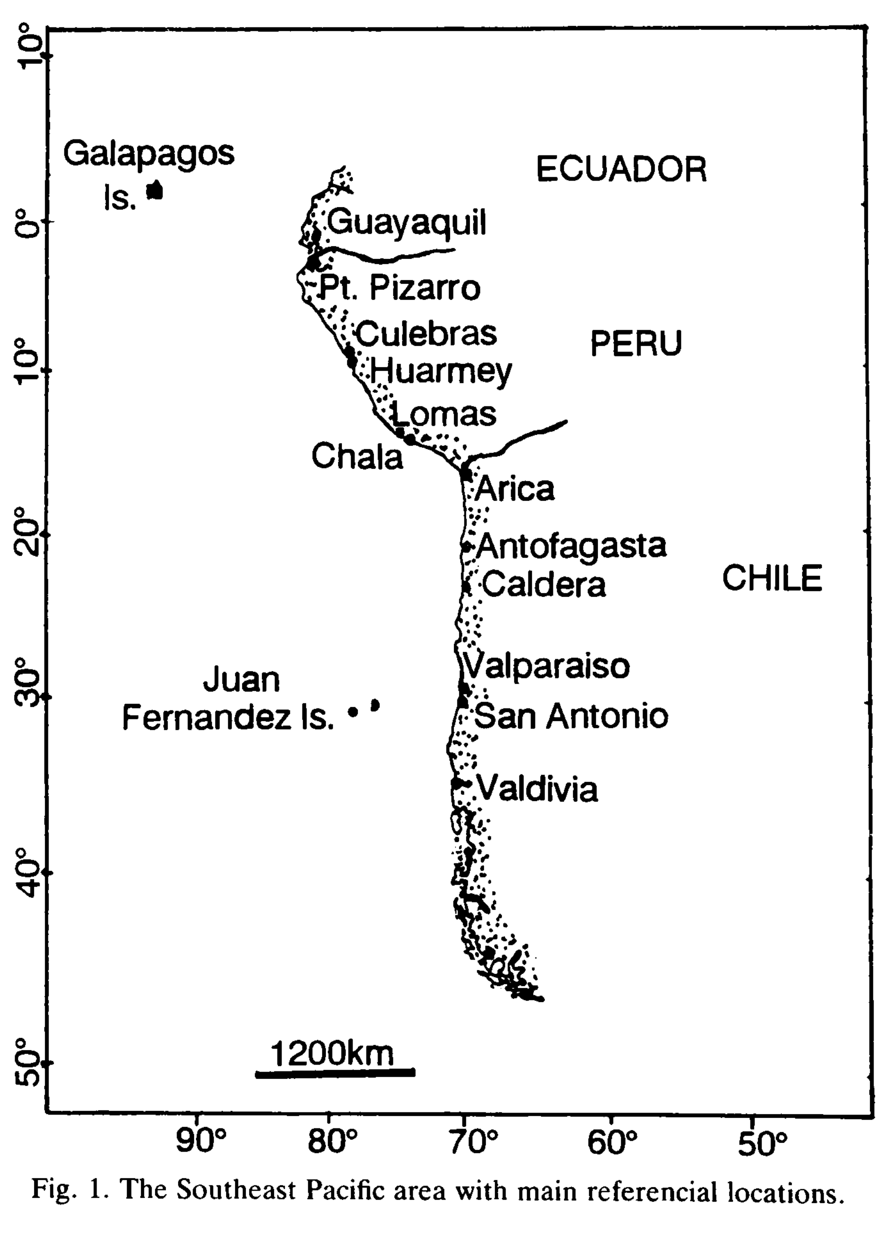


Fig. 1. The Southeast Pacific area with main referencial locations.

[1] Present address: *Casilla 392, Talcahuano, Chile*

waters has been documented in several studies (Read *et al.*, 1988; Van Waerebeek *et al.*, 1988; Van Waerebeek, 1989; Van Waerebeek and Reyes, 1990; 1994; Reyes and van Waerebeek, 1991). For Chile there is information from Norris (1968), Aguayo (1975), Torres *et al.* (1979), Cárdenas *et al.* (1986), Guerra *et al.* (1987) and Oporto (1989). For Ecuador information was lacking until very recently and remains unpublished (B. Haase, *in litt.*, 21 July 1990; K. Van Waerebeek, pers. comm.). Fishery interactions and exploitation of cetaceans in the Southeast Pacific has been reviewed by Mitchell (1975) and Northridge (1984).

Gillnet fisheries have not been the subject of specific studies. Most of what is known has been gleaned from the reports on artisanal fisheries that are released by national agencies throughout the area (Ancieta, 1976; Arana, 1976; Campos, 1976; Instituto Nacional de Pesca, 1976; Herdson *et al.*, 1985; Martínez *et al.*, 1987; Wosnitza-Mendo *et al.*, 1988). The swordfish gillnet fishery in Chile may be the only one under current study (Pesquera Catalina, 1982; Barbieri, 1988b; Bustos, 1990 and pers. comm.).

DESCRIPTION OF FISHERIES AND CETACEAN BYCATCHES

Ecuadorian gillnet fisheries

Location of ports
There are about 60 fishing centres along the Ecuadorian coast within the four coastal provinces, and in most of them gillnets and trammel nets are used (Herdson *et al.*, 1985).

Target species
The main target species are billfishes (*Istiophorus platypterus*, *Tetrapterus audax*, *Makaira* sp. and *Xiphias gladius*), sharks (*Carcharhinus* sp., *Alopias* sp., *Mustelus* sp., *Isurus oxyrhinchus*, *Prionace glauca*, *Sphyrna* sp.), sciaenids (*Cynoscion* sp., *Isopisthus* sp.), tripletails (*Lobotes pacificus*), jacks (*Caranx* sp.), catfish (*Bagre* sp., *Arius* sp.) and shrimps and lobsters.

Area of operation
Although no detailed information is available, it seems that most gillnet fishing occurs in waters close to the coast, within 20–30 n.miles from shore (Herdson *et al.*, 1985; Massay, 1987; Anon., 1989a; b).

Vessels and crew
Fishing boats are made mainly of wood, although some are made of fibre-glass. The most common vessel is the dug-out canoe (6–11m long) powered by an outboard engine. Similar sized boats called '*balandra*' and '*lancha*' are also used in the net operations. Most boats lack basic navigational equipment (Montano, 1987). Nets are hauled by hand; very few boats are equipped with hydraulic winches. The crew usually consists of three Ecuadorian fishermen, but can be as high as five in larger boats. Fish capacity ranges from 1–5 metric tonnes. Fish is handled fresh. Some boats may have facilities to add ice to the fish products (Instituto Nacional de Pesca, 1976; Herdson *et al.*, 1985; Massay, 1987; Montano, 1987).

There are about 230 boats in Manabi Province. In El Oro and Esmeraldas Provinces there are around 1,040 and 287, respectively (Anon., 1989a; b; c). There is no information on how many boats use gillnets.

Gear
Most nets are of nylon, but there are still some cotton nets in use (Instituto Nacional de Pesca, 1976). Trammel nets may be 72m long and 1.8m deep, while gillnets may range from 72 to 216m long and 3.6 to 14m deep (Instituto Nacional de Pesca, 1976; Martínez, 1987). According to Martínez (1987), the total net length may be as high as 3,000m. From information on the length of each panel given by Herdson *et al.* (1985), the number of panels set by vessels may range from 3–40. Mesh sizes in trammel nets are usually 23cm (first net) and 11cm (second net). Gillnets nets have mesh sizes ranging between 5–20cm, depending on the target species (Instituto Nacional de Pesca, 1976). Floats are made of cork, light wood or plastic. The space between floats varies according to the depth at which the net is meant to operate. In the case of large gillnets for sharks, the mean distance may be 1m (Instituto Nacional de Pesca, 1976; Martínez, 1987).

Operations
Trips last from 12 hours to 1–2 days, depending on the type and availability of target species, although in some cases trips may last as long as five days (Herdson *et al.*, 1985; Anon., 1989c). Depth in fishing areas can vary from 80m to 250m (Herdson *et al.*, 1985).

Trammel nets are usually set on the bottom to catch shrimp, lobster and some demersal fish species. Gillnets and trammel nets are left to drift to catch catfish, jacks and tripletails in midwater and billfish and sharks at the surface (Herdson *et al.*, 1985).

Economics and history
Most fishery products are consumed locally (Herdson *et al.*, 1985); billfish are exported to the USA, Japan and Korea (Martínez, 1987). In general, fishery products receive no special processing. Fish are eviscerated and kept fresh by the addition of ice. Part of the billfish catch is smoked (Herdson *et al.*, 1985; Martínez, 1987; Massay, 1987). The only information on fish landings is for 1982 (Herdson *et al.*, 1985) when 3,734.3 tonnes were landed by a variety of fishing methods, including nets (sharks – 279.4; dolphinfish – 1,797.4; billfishes – 4.5; and scombrids – 1,653.0). These numbers refer to fish. There is no information on the levels of fishing effort.

Interactions with cetaceans
The species most likely to be involved with fisheries are bottlenose dolphins (*Tursiops truncatus*) and pantropical spotted dolphins (*Stenella attenuata*), the most common species in coastal areas in Ecuador. There are no direct observations of fishery interactions, but some stranded animals have shown signs of entanglement (B. Haase, *in litt.*, 21 July 1990). Ecuador has legislation protecting cetaceans: tuna vessels are not allowed to set their nets on dolphin schools and the waters surrounding the Galápagos Islands have been declared a whale sanctuary (Hurtado, 1991). Small cetaceans are not utilised and animals captured in nets are released or discarded. The number of animals caught has been roughly estimated, on the frequency of stranded animals with signs of entanglement, at about 100 a year (B. Haase, *in litt.*, 21 July 1990; K. Van Waerebeek, pers. comm.).

Discussion
Although cetacean by-catches have been reported along the Ecuadorian coast, no information is available about the magnitude of the interactions with fisheries. However,

experience elsewhere suggest that gillnets and trammel nets may represent an important source of mortality. There is no information that foreign fleets operate gillnet fisheries off Ecuador.

Peruvian gillnet fishery

Location of ports

This fishery operates in ports and small villages all along the Peruvian coast. Three main zones can be recognised: a northern zone between Puerto Pizarro (03°29′S) and Culebras (09°55′S); a central zone between Huarmey (10°03′S) and Lomas (15°34′S); and a southern zone between Chala (15°50′S) and the Chilean border.

Target species

The target species vary with season and availability. During the summer, the main species are the bonito (*Sarda chiliensis*), the blue shark (*Prionace glauca*), the hammerhead sharks (*Sphyrna* sp.) and the shortfin mako shark (*Isurus oxyrhynchus*); the dolphinfish (*Coryphaena hippurus*) and the thresher shark (*Alopias vulpinus*) may comprise an important part of the catch on the northern coast. In winter, a large fishery for blue sharks and dolphins, particularly dusky dolphins (*Lagenorhynchus obscurus*) takes place off the central Peruvian coast. Other species may be taken throughout the year, e.g. eagle rays (*Myliobatis* sp.), small sharks (*Mustelus* sp.), sciaenids and other teleost fishes.

Area of operation

Artisanal fishermen are requested to operate within 30 n.miles from shore. However, this regulation is difficult to enforce and fishermen may venture as far as 100 n.miles from shore.

Vessels and crew

Boats are mainly made of wood and are of three basic types (Cano *et al.*, 1979; Guerrero, 1989): San José, double pointed and San Andrés.

(a) The San José type is common on the northern coast. They are relatively large, flat-sterned boats, 6–17m long by 3m wide with a fish capacity of 1–30 tonnes. They are powered by a permanent diesel engine located at the centre of the vessel and also have a mast for a sail.
(b) The double-pointed type is one of the most common along the Peruvian coast. The vessels are 5–11m in length by 1.8–2m wide, with a fish capacity of 1.5–8 tonnes. Both the bow and the stern are pointed; these boats may or may not have a deck. The permanent engine is located at the centre of the vessel.
(c) The San Andrés type vessels are smaller (up to 7m long by 2m wide, capacity 1.2 tonnes) with a low bow and flat stern, lacking a deck. They are powered by outboard engines.

Some of the larger boats may carry an echosounder and a few more may use a compass. Most boats, however, have neither basic navigational equipment (Arana, 1976) nor fish handling facilities. Larger boats, especially of the San José type, have a small winch to haul the net. In the other types the net is hauled by hand. A Peruvian crew of 2–3 men is the rule in smaller boats, whereas larger boats may have up to a five man crew. Information on number of boats can be grouped by areas: on the northern coast the number of boats operating in the gillnet fishery is 785; on the central coast it is 1,741 while on the southern coast it is only 43 (S. Ludeña, pers. comm.). These numbers may vary as some fishermen may switch from one gear type to another, or even move to other ports, depending on resource availability.

Gear

Most nets are made of nylon multifilament. Monofilament gillnets are rare and are used mainly to fish for mullet (*Mugil* sp.) or, in some ports of the northern coast, for bonito (Wosnitza-Mendo *et al.*, 1988; S. Ludeña, pers. comm.).

Information on the dimension and number of panels per vessel and mesh size is given in Table 1 for the various target species.

Floats are made of cork. The basic float used is one designed for purse seines: cylindrical and 8cm long by 11cm in diameter. Most artisanal fishermen slice these floats to obtain several smaller floats for their gillnets. The distance between floats may vary from 30cm to almost 1.5m.

Operations

In general, trips last one day, but, depending on the catch, may extend to two days. Fishing mainly occurs between the shore and the 200m isobath, usually at the surface, but in some instances a few metres below the surface. The nets may be used in two forms, depending on the target species. For small sharks (*Mustelus* sp.), rays (especially *Myliobatis* sp.) and sciaenids, nets are set at the bottom, held down by stones.

In the case of the fishery for pelagic sharks, dolphins, jack, mullet and silverside, nets are left to drift either at the surface or in mid-water. Nets are set between late afternoon (for most species) and early morning (for silverside and some sciaenids), left to soak for 4–12 hours and retrieved at dawn.

Economics and history

At present (1990) the price of shark, ray and dolphin meat is the same (values from Pucusana, in central Peru). Fishermen receive US $0.23 per kilogram for these species. This is within the range of prices obtained in 1986 (Read *et al.*, 1988). There is no constant price for other fishery products. Depending on availability and demand, the price paid to fishermen may vary widely. Most fish are consumed

Table 1

Information on the Peruvian gillnet fishery.

Target species	Length(m)	Depth(m)	No. of panels	Mesh size(cm)
Sharks, rays and dolphins	86-270	2.8-19.0	2-30	10.2-44.0
Sciaenids	74-180	2.8-20.0	2-30	6.3-17.5
Bonito and horse mackerel	90-263	6.8-27.0	3-32	11.0-18.0
Jack	108-263	8.8-20.0	3-11	14.6-19.0
Mullet	108-126	2.2- 8.4	6-8	7.0- 9.0
Silverside	72-115	2.9- 5.0	2-8	2.9- 3.3

fresh domestically. Processing is reduced to evisceration at the fishmarket and, in the case of sharks, separation of fins that are sold separately. Rays may be salt-dried and sent to the markets in Lima and other departments.

It is not known exactly when gillnets were introduced in Peru. However, the fishery developed in the early 1970s, after the collapse of the anchoveta fishery. Many fishermen turned to work in the artisanal fishery, that at present provides 60–80% of the marine products consumed fresh by Peruvian people (Espino and Wosnitza-Mendo, 1988). Today the gillnet fishery is carried out by nearly 60% of the artisanal boats operating along the Peruvian coast (S. Ludeña, pers. comm.).

Total landings

Table 2 shows the total landings of species that are taken in gillnets, although the values include all catches of those species, whatever the fishing methods (gillnets, purse seines, shore seines, longlines and harpoon). Total landings for the gillnet fishery alone cannot be estimated.

Effort data

In a study of the artisanal fishery in 11 ports along the Peruvian coast, gillnets showed the highest fishing effort, representing 38% of the total effort. The CPUE for gillnets was 14% (average) of that for other fishing methods (Espino and Wosnitza-Mendo, 1988). The CPUE was estimated as catch per fishing trip, with the catch given in weight units.

Interactions with cetaceans

Cetacean species taken in this fishery include the Burmeister's porpoise (*Phocoena spinipinnis*), dusky dolphin (*Lagenorhynchus obscurus*), bottlenose dolphin (*Tursiops truncatus*), common dolphin (*Delphinus delphis*), pantropical spotted dolphin (*Stenella attenuata*), southern right whale dolphin (*Lissodelphis peronii*), short-finned pilot whale (*Globicephala macrorhynchus*), Risso's dolphin (*Grampus griseus*), killer whale (*Orcinus orca*), false killer whale (*Pseudorca crassidens*), pygmy and dwarf sperm whales (*Kogia breviceps* and *K. simus*), Cuvier's beaked whale (*Ziphius cavirostris*), lesser beaked whale (*Mesoplodon peruvianus*) and humpback whale (*Megaptera novaeangliae*) (Read *et al.*, 1988; Van Waerebeek *et al.*, 1988; Majluf and Reyes, 1989; Van Waerebeek and Reyes, 1990; 1994; Reyes *et al.*, 1991). Although most of these species are taken as a by-catch, a directed catch existed for dusky dolphins until recently. There is no information on how entanglements occur. Small animals, likely less than 4m long, are hauled aboard and removed by rolling the net in an opposite direction to that of the entanglement.

Larger animals may be towed to port where a combination of net-rolling and cutting is used. In general, live animals are not released and are sometimes landed in that state (Read *et al.*, 1988). In a single recorded case a humpback whale entangled in a gillnet off San Juan, southern Peru and was towed to port and then released (Majluf and Reyes, 1989).

Small cetacean landings are compiled in official statistics as total weight of 'marine mammals'; there is no information on species composition. Total landings of small cetaceans (in metric tonnes) for the period 1981–8 are shown in Table 3. It should be stressed that these statistics do not discriminate among capture methods (gillnets, purse seines or hand-thrown harpoons). The meat is used for human consumption, either fresh or salt-dried (Read *et al.*, 1988; Van Waerebeek and Reyes, 1990; 1994). Until recently legislation protecting cetaceans covered only those large whales that were the target species of commercial whaling (Reyes, 1990). Small cetaceans, except for river dolphins, were not covered by legislation until November 1990, when a decree of the Peruvian Ministry of Fisheries prohibited the take, processing and trade of small cetaceans (Anon., 1990).

Brownell and Praderi (1982) reviewed the early data on incidental captures of small cetaceans in Peruvian waters (and see Clarke, 1962; Grimwood, 1969; Mitchell, 1975). They believed that the estimated annual catch of small cetaceans, mainly Burmeister's porpoises, suggested by Norris (in Mitchell, 1975) was a conservative estimate. No other reports on this fishery were published until the development of systematic studies in the mid 1980s, when the take for 1985 was estimated at 10,000 animals (Read *et al.*, 1988). In these later studies, the directed fishery for dusky dolphins contributed to the rise in small cetacean

Table 2

Total landings (metric tonnes) of fish products - Peru. Source: Ministerio de Pesquería, 1970-1988.

Year	Sharks	Rays	Bonito	Mullet	Silver-side	Jack	Sciaenids
1970	14,419	4,540	57,371	992	4,496	6,974	
1971	10,010	1,437	73,043	2,082	2,530	13,666	13,089
1972	10,347	1,223	64,161	4,610	1,799	11,005	10,664
1973	20,348	1,251	34,805	6,871	923	10,370	30,054
1974	15,176	1,813	7,404	7,394	6,053	9,370	26,716
1975	13,023	1,868	4,887	5,843	10,297	7,868	19,089
1976	9,523	1,292	4,057	3,218	3,341	18,257	12,068
1977	12,331	1,596	5,747	6,035	3,313	23,336	20,532
1978	13,656	1,979	4,741	7,824	1,429	19,246	20,856
1979	9,369	2,866	5,302	13,391	4,909	9,416	16,869
1980	10,965	2,655	6,838	18,194	4,387	10,740	16,480
1981	2,646,696	400,099	1,904,572	2,713,090	668,302	4,325,776	3,214,334
1982	15,274	3,595	13,888	15,241	8,078	30,250	27,254
1983	11,182	3,826	14,696	16,264	131	2,296	14,233
1984	29,938	4,614	20,995	21,243	53	5,315	18,936
1985	11,292	5,496	2,349	15,269	1,015	11,161	41,647
1986	15,971	7,276	3,318	17,004	3,930	35,551	25,590
1987	15,219	7,922	18,032	24,475	3,953	43,358	21,856
1988	18,417	8,251	33,986	16,827	5,620	21,514	27,710

Table 3

Small cetacean landings (in metric tonnes) in Peru, by regions. NA=not available. Source: Statistics Department, Peruvian Ministry of Fisheries (MIPE) except 1980 (source: IMPARPE, Statistics Department).

Year	North	Central	South	Total
1969	18	29		47
1970	2	7		9
1971	3	125		128
1972	20	646	15	681
1973	39	569	45	653
1974	168	681	105	954
1975	120	562	34	716
1976	153	513	47	713
1977	154	446	8	608
1978	218	928	26	1,172
1979	270	1,102	36	1,408
1980	NA	NA	NA	685
1981	169	411	44	626
1982	183	714	89	986
1983	146	237	53	436
1984	105	316	94	515
1985	105	607	44	756
1986	171	372	30	573
1987	133	330	7	470
1988	85	339	2	426

landings (Van Waerebeek and Reyes, 1990; 1994). At present the impact of these catches on small cetacean populations remains unknown.

Pinniped bycatches

Incidental catches of sea lions (*Otaria byronia*) and South American fur seals (*Arctocephalus australis*) are known to occur but their magnitude is unknown. In some parts of Peru the meat of these animals is used for human consumption.

Discussion

There have been several studies of artisanal fisheries in Peru (Ancieta, 1976; Arana, 1976; Wosnitza-Mendo *et al.*, 1988), but they were mostly socioeconomic studies of the development of fishing communities, and aspects related to fishing operations were treated in a global context. It is thus difficult to obtain detailed information about gillnet fisheries in Peru. Collection of specific data on mortality of small cetaceans only began five years ago. Paradoxically, obtaining information may become more difficult with the present more strict regulations, since fishermen are now more reluctant to release any information.

There is no information about foreign fleets involved in gillnet or driftnet fishing off the Peruvian coast. Until recently, Soviet trawlers fished for demersal species such as hake (*Merluccius gayi*) and some pelagic species including the horse mackerel (*Trachurus murphyi*). Dolphins, mainly bottlenose dolphins, were reportedly taken by this fishery, although the number of animals taken may have been small (J. Cox, pers. comm.).

Chilean swordfish fishery

Location of port(s)

Ports are located between Caldera (27°04'S) and Valdivia (39°48'S).

Target species

The target species is the swordfish (*Xiphias gladius*).

Area of operation

The artisanal fishery operates from 15 to 120 n.miles offshore, although a few (but an increasing number) boats may operate up to 150 n.miles offshore. Some larger boats dedicated to the industrial fishery are authorised to operate between 120 and 200 n.miles from shore (E. Bustos, unpublished data).

Vessels and crew

Most boats are wooden, although some may be of ferro-cement or fibre glass. Boats are usually between 12–20m long, but about seven boats range from 20–28m. The mean displacement is 16 tonnes and fish capacity ranges from 12–20 tonnes. Crews comprise 3–5 Chileans. Boats are either of the 'American type' (with a cabin near the bow) or the 'Norwegian type' (with a cabin near the stern). As basic equipment, boats carry a magnetic compass, sounder and radar, as well as VHF and HF radios. Most boats have a satellite navigation system and a few may have a fax machine to receive information on water temperature (J. Brito and E. Bustos, pers. comm.). Approximately 18% of the boats have a hydraulic power block winch. In the others net-hauling is done by hand. Fish is kept fresh by the addition of ice.

There is no information on the exact number of boats for each port. The location of fishing grounds may change every season, and consequently the boats move along the coast. Approximately 250 boats are registered in San Antonio, but in 1988 around 160 moved north to Caldera (Barbieri, 1988b; J. Brito, pers. comm.). Nearly 800 boats are involved in this fishery along the Chilean coast. Permits for operation of more boats in this fishery are at present under consideration by the government. It is essentially a small-scale fishery with only about 50 larger commercial vessels participating (E. Bustos, unpublished data).

Gear

Nets are nylon multifilament, consisting of 12 to 25 panels. The mean panel length is 54m and depth ranges from 29 to 45m. The average net length is 1,440m, but some nets reach 2,160m. Mesh size varies from 45–56cm. Floats are made of plastic, 48.5cm in diameter on average, with a mean distance of 45m between them (Pesquera Catalina, 1982).

Operations

Trips may last from 3–5 days with an average of four trips each month during the fishing season, giving a total of some 30 trips per season. Usually a single net set occurs, during the night and in waters 4,000 to 5,000m deep. Depending on the sea state, almost all panels are set. In general, fishing is performed at the surface, where nets are left to drift, but in some cases, depending on the vertical distribution of fishes, the nets may be placed at midwater. Fishing takes place from mid-afternoon to the next morning, with a soak time of 12 to 14hrs. The whole net may be retrieved in 3–4hrs or 2hrs if there is no fish. Usual catches are 1–3 fish per panel.

The fishing season has been extended since the introduction of gillnets to the fishery. When only harpoons were used, the fishing season was set between January and March, mainly because good visibility was an important aspect of the harpoon fishery. With the introduction of gillnets, the fishing season has been extended until September (Barbieri, 1988a).

Economics and history
Nearly 80% of the catch is exported to the USA, Spain and France. At the beginning of the season, fishermen may receive up to US $5/kg, but depending on several aspects (fishing conditions, demand, etc.) the price may go down to around US $2/kg (E. Bustos, pers. comm.). The catch does not receive special treatment other than ice, since the product is sold fresh. A part called the 'neck' is cut off; the 'trunk' represents the final product. The neck is used for local consumption. Preparation of the final product for export is made mainly on the central Chilean coast, in areas such as Valparaiso, San Antonio and Santiago (Anon., 1988; J. Brito, pers. comm.). The 1990 value of the exported fish is about US $25,000,000.

The swordfish fishery in Chile dates back to the mid-1950s, although there is one catch record from 1943. Initially a harpoon fishery, gillnets were introduced in 1983. The introduction of gillnets and more boats, as well as the rise in international demand, has contributed to the increase of Chilean catches.

Total landings
Landings ranged from 342MT in 1983 to 5,824MT in 1989 (Table 4). It should be noted that the total landings refer to the weight of 'trunks' (fish with neither head nor tail). Present studies are addressing the estimation of total weight of animals from these trunks (E. Bustos, pers. comm.).

Table 4

Total annual landings (in metric tonnes) of swordfish in Chile:1980-9. Source:Servicio Nacional de Pesca (SERNAP). Anuarios Estadísticos de Pesca 1980-9.

Year	Landings	Year	Landing	Year	Landing
1980	104	1984	103	1988	4,445
1981	294	1985	342	1989	5,824
1982	285	1986	764		
1983	342	1987	2,059		

Effort data
A thorough study of this fishery is at present being developed by researchers at the Instituto de Fomento Pesquero (IFOP), Chile. Data on fishing effort and maximisation of the fishery, as well as other related aspects will be covered. The inclusion of observers on the commercial vessels was recommended to start in 1990 (Bustos, 1990).

Interactions with cetaceans
There are confirmed reports of entanglements of killer whales (*Orcinus orca*), sperm whales (*Physeter macrocephalus*) and southern right whale dolphins (*Lissodelphis peronii*) (J. Brito, pers. comm.). Large animals entangled are cut out and left to drift or sink. Small animals however may be taken to port or are consumed by fishermen (J. Brito, pers. comm.). There is no information about the number of cetaceans taken. No direct efforts to reduce the cetacean by-catch exist. However, in order to manage the swordfish fishery, a reduction in net size and fishing effort has been proposed (E. Bustos, pers. comm.).

Small cetaceans are protected by law in Chile (Torres *et al.*, 1979). The capture, possession and trade of small cetaceans is forbidden. However there are no provisions addressing the problem of incidental mortality.

Discussion
At present, swordfishing is one of the most important fishing activities in Chile, and the increase in the annual landing of cetaceans has been a cause of concern for authorities, researchers, fishermen and traders. In fact, some proposals to regulate the fishery have been made, e.g. reduction of net size and delay in the issuance of new fishing permits. The magnitude of by-catch of cetaceans in this fishery, however, remains unknown, since information on this subject has been gathered only from a few boats. Nearly 800 boats are involved in the fishery; the effort is particularly high off the central Chilean coast, where total landings for the period 1985–7 were higher than landings in the previous 30 years. With such an increase in fishing effort an increase in cetacean bycatch should be expected. The situation should be studied further. There are a few larger ships from other nations fishing for swordfish off Chilean waters, but they use longlines (Reyes, 1989).

Chilean ratfish and sciaenid fishery

Location of ports
This fishery is operated mainly from two small ports, Caleta Queule (39°23'S) and Bahía Mansa (40°34'S).

Target species
Ratfish (*Callorhinchus callorhynchus*) and the sciaenid corvina (*Cilus montti*) are the target species.

Area of operation
Fishermen from Queule operate between Playa Larga (38°40'S) and Punta Manquillahue (39°27'S), while fishermen from Bahía Mansa fish between Punta Dehui (40°15'S) and Bahía San Pedro (40°55'S). Fishing takes place between 2 and 12 n.miles of shore.

Vessels and crew
All boats are made of wood, with length ranging from 7.7 to 11m. The 'Norwegian type' predominates in Queule, but in Bahía Mansa a smaller, outboard powered boat called a '*chalupa*' is used. Most boats have basic navigational equipment (light and compass) and around 20% may carry VHF radios. Fish capacity ranges from 3.5 to 4 tonnes in the Norwegian type and from 2 to 2.5 tonnes in the *chalupa*. The crew of 2–5 is Chilean. There is no net-hauling gear and the fish is handled fresh.

Gear
Nets are nylon multifilament. Each net comprises 2–14 panels, 100m long by 4–6m deep. Mesh size is 15cm.

Operations
Trips may last 12–24 hrs. In Queule, the number of trips may be 108–112/year, while in Bahía Mansa fishermen may complete 180–228 trips/year. Nets are bottom set in waters ranging from 10–217m in depth. Fishermen from Queule set their nets at depths between 15 and 18m in the summer and between 38–45m during winter. Off Bahía Mansa nets are set at 60–80m. Usually setting of nets occurs during the morning or late afternoon, and the soak time is about 10–12 hrs. Retrieval takes 1–4 hrs, depending on the catch. Catch per set ranges from 0.4–3 tonnes.

Economics and history

This fishery sustains a domestic market. Fishermen receive US $ 0.13–0.16/kg for ratfish and US $ 1.00/kg for corvina. The fish are eviscerated and sold fresh. Addition of ice occurs when fish products are shipped to Santiago. Ratfish is sent to fish meal plants located in Puerto Montt and Talcahuano.

The exact date for the beginning of this fishery is unknown, but it was well established by 1962. In the last six years it has been substantially improved with the introduction of better boats and engines and the increasing use of gillnets. Fishermen believe catches may triple in the future.

Total landings

Total catches in Queule are approximately 4,106 tonnes/year, with corvina representing 20%. In Bahía Mansa, corvina represents 15% of 9,216 tonnes/year. There is no information on effort.

Interactions with cetaceans

Cetacean species involved are mainly Burmeister's porpoise and Chilean dolphin (*Cephalorhynchus eutropia*). Sporadically Peale's dolphins (*Lagenorhynchus australis*) are also taken. Entanglements occur during the night or early morning. Animals are hauled into the boats, eviscerated upon arrival at port and used as bait for conger eel fishing. On very rare occasions the meat may be consumed by the fishermen.

The cetacean catch at Queule is given in Table 5 (J. Oporto, unpublished data).

Table 5

Catches of cetaceans at Queule.

Year	*P. spinipinnis*	*C. eutropia*	*L. australis*
1988	62	63	2
1989	57	51	-
1990*	40	32	1

* Until October.

According to one fisherman, the number of animals entangled every year in Bahía Mansa is between 300–400. Apparently the majority are Burmeister's porpoises. The impact of this fishery mortality on the affected populations remains unknown.

No market for dolphin meat exist in Chile because there is legislation protecting all species (Torres *et al.*, 1979).

Discussion

The expansion of this fishery expected to occur within the next few years will pose a potential threat to coastal small cetaceans in southern Chile. It is necessary to monitor operations from both fishing locations in order to determine the impact of the fishery on small cetacean populations in the area.

Other fisheries

Gillnets are one of the most important types of fishing gear used in the coastal waters of the Southeast Pacific region. Other fisheries include those for lobsters and deep sea fish in the Juan Fernandez archipelago (around 33°S) off mainland Chile. The fisheries in the waters surrounding the Galápagos Islands do not use gillnets due to local regulations. Lobsters are taken by diving, and fish such as sea bass are taken with longlines (Barragán, 1987; Rodriguez, 1987). We found no evidence of the use of fishing weirs except those used in the shallow waters of Ecuador to catch shrimp. However the operation of foreign fleets using driftnets in or off the waters of the countries involved (Ecuador, Peru and Chile) should be investigated.

DISCUSSION

Despite the widespread utilisation of gillnets in the region, there are few studies being carried out on the development of these fisheries, except for the so called 'artisanal' swordfish fishery in Chilean waters and the incipient studies in Peru and Ecuador mentioned above.

Swordfishing in Chile sustains an important industry within the frame of economic development through the export of local products adopted by the government. The situation in northern Chile is quite different. There, an industrial fishery for fish meal production is the government's main interest and studies on artisanal fisheries are almost nonexistent (J. Oliva, pers. comm.). Although driftnets were introduced into the fishery in the early 1980s, information on cetacean mortality has only recently become available. The size of the fleet, its area of operation and the total surface of fishing nets, together with actual records of mortality, suggest that the entanglement of cetaceans in this fishery may be substantial. It is necessary to collect more information about the interactions of cetaceans and the swordfish fishery. This information could be gathered through the observer programme that is now in operation.

Entanglement of cetaceans in gillnets off Peru has been documented for a number of years. The recently adopted legislation, however, may significantly reduce the possibility of estimating the number of animals taken incidentally in the fishery. Effort should be made to reduce this incidental mortality. In particular, studies should include observations to determine factors such as distances from the coast and depths to which the gillnet fishery operates, information that could be used if temporal and spatial restrictions are to be considered in the future. Also, modification of fishing gear or replacement by other fishing methods (e.g. longlines) should be considered as potential alternatives. This could help to reduce the proportion of gillnets (today estimated at around 60% related to other fishing methods) used in the Peruvian artisanal fishery.

Relatively little information is available on gillnets and cetacean interactions in Ecuador.

More detailed studies should be implemented by the countries of the region in order to understand the evolution and development of artisanal fisheries and to assess the impacts that gillnet fisheries have on cetaceans and other marine organisms, not in the least the commercially exploited species. Research on alternative fishing methods for a progressive replacement of those gillnets known to be a threat to small cetaceans should be included in fishery research programmes currently undertaken by national fishery agencies throughout the region.

Finally, if the impact of incidental mortality of cetaceans is to be assessed, studies of the stock identity and abundance of the affected species must be undertaken.

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SC/46/O 6*

Incidental Catches of Small Cetaceans in the Artisanal Fisheries of Ecuador

Fernando Félix and Jorge Samaniego

Fundación Ecuatoriana para el Estudio de Mamíferos Marinos (FEMM), PO Box 09–01–6637, Guayaquil, Ecuador

ABSTRACT

During 1993, a study was carried out to try to estimate the incidental mortality of small cetaceans in gillnets of artisanal fishermen along the coast of Ecuador. Two ports were selected as convenient study sites: Puerto López and Santa Rosa. In both ports, a sample fleet of six boats was chosen. From December 1992 until December 1993 the two fleets made a total of 2,764 fishing trips and they caught 217 small cetaceans as bycatch. The Santa Rosa sample index (0.1042±0.012 (SE) dolphins/boat/trip) was significantly larger ($P<0.01$) than that for the Puerto López sample fleet (0.038±0.007 (SE)). The estimated total catch for the entire Santa Rosa fleet is 1,150 (CI 95% 874–1,426) dolphins/year and that for the entire Puerto López fleet is estimated to be 156 (CI 95% 99–213). If the results are extrapolated to two similar ports nearby the estimated total bycatch is 3,741 (CI 95% 2,784–4,698) dolphins caught in 1993. If similar capture rates apply to the rest of the country, the total national bycatch would be 2 or 3 times higher. By far the most frequently captured species was the common dolphin (86%) followed by the short-finned pilot whale (9%). Occasionally, spotted dolphins (2%) and dwarf sperm whales (1%) are caught.

KEYWORDS: EASTERN TROPICAL PACIFIC; INCIDENTAL CAPTURE; FISHERIES; COMMON DOLPHIN; PILOT WHALE - SHORT-FINNED; SPOTTED DOLPHIN; DWARF SPERM WHALE

INTRODUCTION

Cetacean species are subjected to a number of human induced mortalities, including direct capture, incidental capture, competition for food resources and habitat pollution (IWC, 1992). Of these, perhaps the most important for affected species is the incidental capture in fishing activities which can result in high mortality rates, particularly for coastal species and river dolphins (e.g. Northridge, 1984; Brownell *et al.*, 1989; IWC, 1994).

Almost no published information on the incidental mortality of cetaceans during fishing activities in Ecuador exists. Only the bycatch of cetaceans in the industrial tuna fishery has garnered attention from the fishing authorities. Current regulations forbid fishing on tuna associated with dolphins in Ecuadorian waters[1]. As in other developing countries, the potential problem of incidental catches in artisanal fisheries has largely been ignored.

In 1993, a study was undertaken along the coast of Ecuador to determine the magnitude of the small cetacean bycatch in artisanal fisheries. The study was financed by the United Nations Environmental Program (UNEP) as part of the Action Plan for the Conservation of the Marine Mammals of the Southeast Pacific (PNUMA, 1992). The study found that at least four dolphin species become entangled in surface gillnets: the common dolphin, *Delphinus delphis*, the short-finned pilot whale, *Globicephala macrorhynchus*, the spotted dolphin, *Stenella attenuata*, and the dwarf sperm whale, *Kogia simus* (Samaniego and Félix, 1994). Bottlenose dolphin (*Tursiops truncatus*) interactions with deep gillnets set for shrimps and other species in the Gulf of Guayaquil (South of Ecuador) were reported by Van Waerebeek *et al.* (1990) and by Félix (In press). It is unknown whether other small cetacean species are involved in interactions with other fisheries in Ecuador.

This paper presents the results from the above study with respect to small cetaceans and artisanal fisheries.

DESCRIPTION OF THE ARTISANAL FISHERY

Artisanal fishing represents a major part of Ecuador's economy. In 1992, the total catch for the eight most important ports of the country was 38,633 tonnes (Villón and Balladares, 1993). In the last decade the fishing fleet has increased dramatically, being ten times higher than in 1982 (Contreras and Revelo, 1992). Overall there are about 50,000 artisanal fishermen found in over 70 fishing communities (Campbell *et al.*, 1991). Since 1989, the National Institute of Fisheries (INP) has made a complete inventory of the artisanal fisheries in eight of the most important ports of the country: Esmeraldas, Manta, San Mateo, Santa Rosa, Anconcito, Engabao, Playas, and Puerto Bolívar (Fig. 1) (Martínez *et al.*, 1991; Contreras and Revelo, 1992; Villón and Balladares, 1993). These ports account for some 75% of the total national fishing effort (Carlos Villón[2], pers. comm.).

Vessel types

The fleet comprises some 7,000 vessels of various types (Campbell *et al.*, 1991), ranging from small rafts for 2–3 fishermen, through long wooden canoes with 25–50HP outboard motors for 3–4 fishermen, to open boats made of wood or fibreglass of up to 10m long equipped with 75–100HP outboard motors (Massay, 1987).

Target species

The target species are mainly large pelagic fish including the 'dorado' (*Coryphaena hippurus*); tuna (*Thunnus albacares*, *T. obesus*, *Katsuwonus pelamis*); swordfish (*Xiphias gladius*); 'picudos' (*Makaira* sp., *Isthiophorus albicans*); sharks (families Alopiidae, Carcharhinidae, Lamnidae, Sphyrnidae and Triakidae) and deep water fish (families Bothidae, Carangidae, Lutjanidae, Serranidae,

* The paper presented to the meeting originally had two parts. The second part is now Haase and Félix (1994).

[1] Ministerial Agreement No. 203, May 10, 1990. Ministerio de Industrias Comenrcio Integración y Pesca (MICIP).

[2] Instituto Nacional de Pesca INP, Fisheries Resources Department.

Sciaenidae). Crustaceans (Penaeus sp.) and various species of molluscs are also taken (Herdson *et al.*, 1985; Martínez, 1987). Artisanal fishing takes place within 40 n.miles of the coast (Martínez, 1987).

Techniques

Longlines (palangre or espinel)

These comprise a large number of down hanging sublines with hooks (100–1,500) connected via a horizontally placed, long thick nylon mother line of between 4.5–11km in length, with signal flags and floats on each end (Cedeño, 1987; Martínez *et al.*, 1991). The use of longlines and handlines is more common along the north coast of Ecuador (Cedeño, 1987; Campbell *et al.*, 1991).

Gillnet (red agallera or trasmallo)

Two types of gillnets are used: (1) surface gillnets of up to 3km in length and 15m in depth, with a large mesh size (7.5–13cm); (2) deep gillnets between 300–400m in length, used to catch deep water species such as slabs, lobsters and shrimps (Cedeño, 1987; Martínez *et al.*, 1991). Gillnets are used mostly by fishermen in the central and southern part of the country.

MATERIAL AND METHODS

By mid-November 1992, all ports in the four coastal provinces had been visited to determine the use of gillnets along the coast. We selected two ports to be representative (Fig. 1): Puerto López, in the province of Manabí (01°34′S, 80°W) and Santa Rosa, in the province of Guayas (02°12′S, 80°54′W). Fishermen in these ports showed interest in the project and in general cooperated willingly.

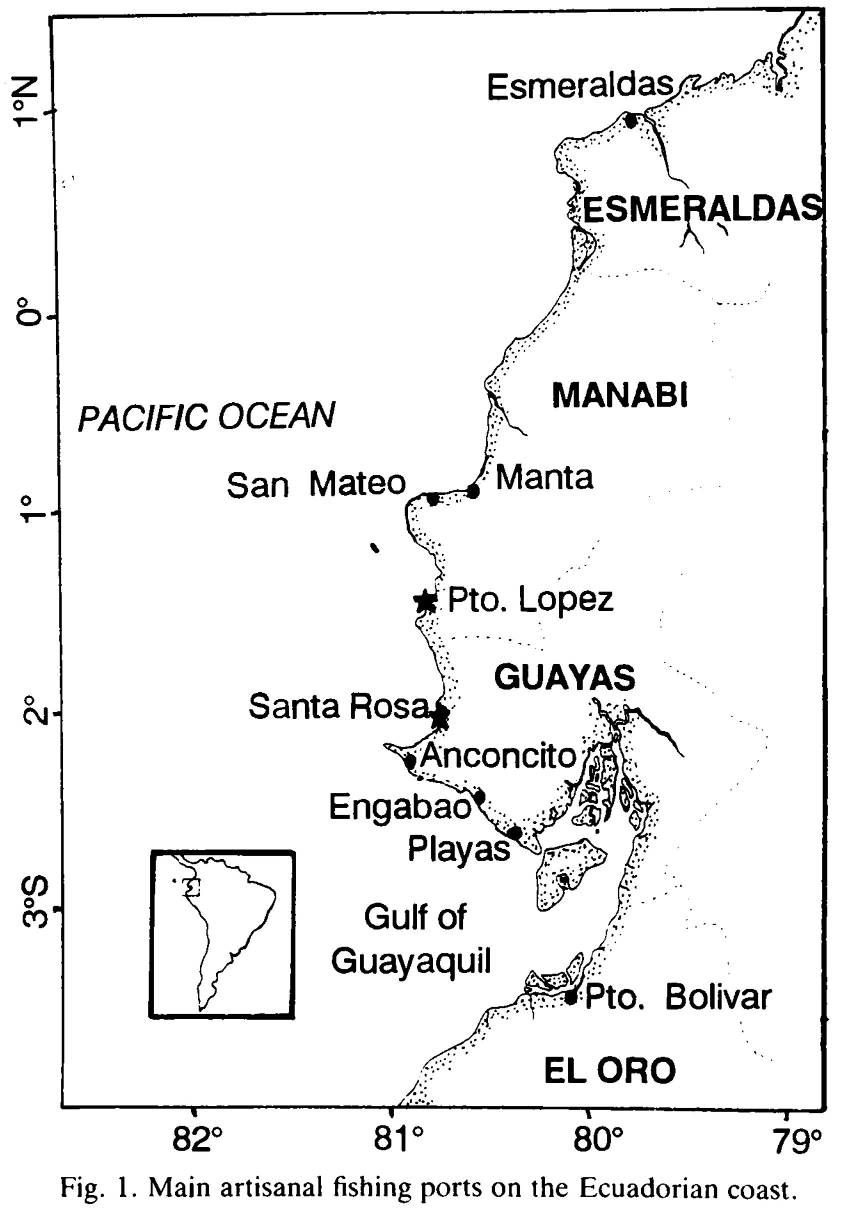

Fig. 1. Main artisanal fishing ports on the Ecuadorian coast.

In order to obtain an idea of the bycatch levels, six boats that used surface gillnets were selected for each port. Between them, the twelve boats made a total 2,764 trips between 15 December 1992 and 15 December 1993. The boats (fibreglass, 7m in length, outboard engine of 75–85HP) and their gear (polyfilament nylon nets, 1,500m long and 15m wide) were similar. Fishing techniques were also similar with the boats leaving port in the afternoon and returning on the following day in the early morning. The nets were set at night for a period of 8–10 hours.

Once back in the port, each crew member was asked to report any interaction with dolphins. Information on the number of captured animals, the species, the distance off the coast where they had been fishing and general information on the journeys was recorded. For 64 trips (2.3%) J.S. and volunteers of the Ecuadorian Foundation for the Study of Marine Mammals (FEMM) were on board as observers. The information obtained from these trips is compared to that for trips without observers later in this paper.

The relevant authorities gave special permission for the fishermen participating in the study to bring the bycatch to land. The animals were photographed and examined, and biological data and other information recorded, including species, sex, weight and external measurements. In addition, the animals were sampled for teeth, reproductive organs, stomach contents and parasites, etc. The samples are being analysed at present.

For practical reasons, not all the dolphins were brought to port. At the beginning of the project the animals were identified on return to port from photographs shown to the fishermen, and quite soon they were able to identify most cases without problems. These animals were not measured and their total length was estimated by the fishermen; this information was excluded from statistical analysis. However, the common dolphins (*Delphinus delphis*) and spotted dolphins (*Stenella attenuata*) were subdivided as: (1) calves, small animals of less than 1.2m; (2) immature of between 1.2m and 1.8m; and (3) adults animals > 1.8m.

Information on the number of artisanal boats, the number of operative boats and the fishing techniques used in Santa Rosa and seven other ports during 1993 were provided by the INP (Table 1). This information was based on comments by nearly 10,000 fishermen interviewed during 1993 and was used to extrapolate the results of our study to the entire fleet in order to obtain estimates of dolphin mortality rate for each port. Non-active boats and those using different techniques were subtracted from the total fleet (Table 1). In addition, as no boats operated

Table 1

Fishing methods of the artisanal fleet in eight ports during 1993.

Ports	Total fleet	Operative fleet (%)	Fishing gear: Longline (%)	Fishing gear: Gillnet (%)
Esmeraldas	196	21	95	5
Manta	563	36	60	40
San Mateo	210	12	100	-
Santa Rosa	235	41	60	40
Anconcito	370	43	60	40
Engabao	163	6	100	-
Playas	96	48	100	-
Puerto Bolivar	383	87	10	90

Source: Artisinal Fishing Project INP/CISP/MLA. National Institute of Fisheries (Instituto Nacional de Pesca). 1994.

Table 2

Number of monthly trips made by the sample fleet of Santa Rosa, 15 December 1992 - 15 December 1993.

Boat	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
I	14	24	20	23	24	24	22	24	22	20	24	23	11	275
II	15	24	20	24	26	26	26	26	24	22	26	26	11	296
III	14	23	19	23	24	24	22	24	20	20	24	22	11	270
IV	15	24	20	24	26	26	26	26	25	23	26	26	11	298
V	14	23	20	24	26	26	26	26	24	22	26	26	11	294
VI	14	20	20	23	22	24	22	21	22	20	24	23	11	266

Table 3

Number of monthly trips made by the sample fleet of Puerto Lopez, 15 December 1992 - 15 December 1993.
G: Gillnet/L: Longline.

Boat	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
												G/L	G/L	
A	10	16	15	16	15	14	16	18	14	15	13	04/10	05/06	171
B	10	17	15	15	17	16	18	19	12	20	12	10/07	00/10	181
C	10	16	16	18	18	17	17	19	13	17	14	09/10	05/06	189
D	10	17	14	17	16	16	17	18	9	17	13	08/09	04/07	176
E	9	16	14	16	17	16	16	19	10	16	14	09/09	05/06	177
F	9	16	15	16	16	16	14	17	14	16	13	04/12	05/06	171

every day of the year, it was assumed that the average number of fishing days in the year for the sample fleet could be applied to the entire fleet.

The number of boats of the Puerto López fleet that used gillnets was determined by the authors. The percentage of operative boats in that port was considered the same as that for Santa Rosa.

RESULTS

Fishing effort

Fishing effort from both ports occurred in all months of the year (Tables 2 and 3) although the mean numbers of trips differed by port. The fishing grounds for the two ports differed considerably. Boats of the Puerto López fleet operated between 11 and 33 n.miles offshore (mean=22.2, SD=5.8), while those from Santa Rosa generally operated further offshore, between 14 and 56 n.miles off the coast (mean=32, SD=7.5).

Santa Rosa

INP data revealed that the Santa Rosa fleet comprised 235 boats, of which 96 (41%) were operative. On average throughout the year, around 38 (40%) used surface gillnets (Table 1). As shown in Table 2, the six sample boats operated for an average of 283 days in the year (SD 14.4). Thus the total number of trips estimated for this fleet is 10,754.

Table 4

Incidental catch for the sampled Santa Rosa fleet.

Boat	No. of trips	Dolphin catch	Capture index dolphins/boat/trip
I	275	21	0.0764
II	296	39	0.1318
III	270	27	0.1000
IV	298	38	0.1275
V	294	32	0.1088
VI	266	20	0.0752
Totals	1,699	177	0.1042

Puerto López

Our census of Puerto López revealed that the entire fleet comprised 89 boats of which 56 (63%) used surface gillnets. Assuming, as for Santa Rosa, that 41% of the fleet operated implies that 23 boats operated using gillnets in 1993. The Puerto López sampled boats carried out an average of 178 trips in 1993 (SD 6.8). Thus the total estimated fishing effort for 1993 is 4,094 trips.

Mortality of small cetaceans

Santa Rosa

The Santa Rosa sample fleet caught 177 dolphins in 1993 (Table 4), with between 21 and 39 dolphins per boat, giving an annual average per boat of 29.5 (SD=8.2). The average capture rate per trip was 0.1042±0.012 (SE). The capture rate from boats carrying observers on board (n=35, 2%) was 0.286±0.131 (SE), 2.7 times higher than the boats without observers (Table 6). The species caught were the common dolphin (*Delphinus delphis*) 90%, the short-finned pilot whale (*Globicephala macrorhynchus*) 7%, the dwarf sperm whale (*Kogia simus*) 1%, the spotted dolphin (*Stenella attenuata*) 0.6% and unidentified dolphins 1% (Fig. 2).

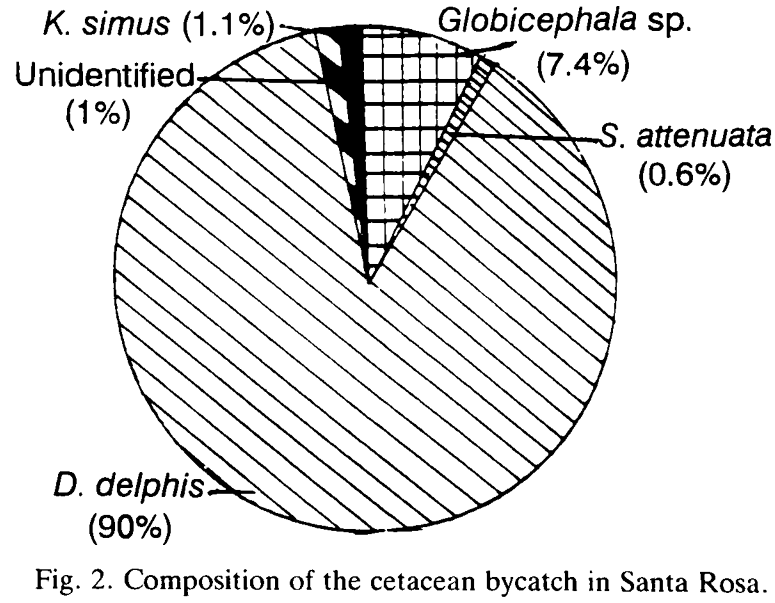

Fig. 2. Composition of the cetacean bycatch in Santa Rosa.

Using the estimated numbers of trips for the entire fleet obtained above gives a total estimated bycatch of 1,150 (CI 95% 874–1,426) dolphins assuming the total average capture rate or 3,157 (CI 95% 320–5,994) dolphins if the capture rate for boats with observers is used.

Puerto López

During 1993, the crew of the Puerto López sample fleet reported a bycatch of 40 dolphins (Table 5). The number of animals caught per vessel varied between 2 and 12, with an annual average of 6.7 (SD=3.4). The mean capture rate per trip was 0.038±0.007 (SE) dolphins (Table 5), was significantly lower than in Santa Rosa (ANOVA, $F_{1,5}=30.35$, $P<0.01$). The capture rate from boats carrying observers on board ($n=29$, 2.7%) was similar to that for boats without observers 0.034±0.033 (SE) (Table 6). The species composition was: common dolphin 67.5%; short-finned pilot whale 17.5%, spotted dolphin 10%; and non-identified 5% (Fig. 3). Using the estimated number of trips for the Puerto López fleet obtained above gives an estimated total bycatch of 156 (CI 95% 99–213) dolphins in 1993.

Other ports

No direct study of the incidental mortality of dolphins for other ports was made. However, we believe that it is instructive to extrapolate the Puerto López and Santa Rosa data for two other important nearby ports: Manta and Anconcito. Manta is situated 70km to the north of Puerto López and Anconcito is 12km south of Santa Rosa. Both ports have similar characteristics to the monitored ports in terms of gillnet use and operative boats. Their locality suggests that they probably exploit the same fishing area. To give an idea of possible mortality we used the Puerto López data for Manta and the Santa Rosa data for Anconcito. The resultant mortality estimates are 548 (CI 95% 350–746) and 1,887 (CI 95% 1,461–2,313), respectively. Despite the large number of assumptions involved, the potential scale of bycatches indicates the need to monitor the problem in Ecuador.

Table 5

Incidental catch for the sampled Puerto Lopez fleet.

Boat	No. of trips	Dolphin catch	Capture index dolphins/boat/trip
A	171	9	0.053
B	181	12	0.066
C	189	7	0.037
D	176	7	0.040
E	177	2	0.011
F	171	3	0.017
Totals	1,065	40	0.038

Table 6

Incidental catch of small cetaceans of boats with observers.

Port	No. of trips	Dolphin catch	Capture index dolphins/boat/trip
Puerto Lopez	29	1	0.034
Santa Rosa	35	10	0.286
Totals	64	11	0.172

Seasonality of the bycatch

Both ports exhibited a similar pattern in incidental captures with two peaks in the year. In Puerto López the bycatch increased between March and August, decreased from September to November and then increased again in December and January (Fig. 4). In Santa Rosa, catches increased between May and September, decreased in October and November and then increased again in December (Fig. 5). Although the study began in December, the first bycatch by the Santa Rosa sample fleet was not reported until February 1993, possibly because the fishermen were initially suspicious. If this is the case, our estimated bycatch for that port may be an underestimate.

Use of the bycatch

All but two (0.9%) dolphins that were released alive, were found dead. They were usually not taken on board, but were freed or cut loose outside the launch and left behind.

However, from July until November in Puerto López, some boats (not of the sampling fleet) brought the bycatch

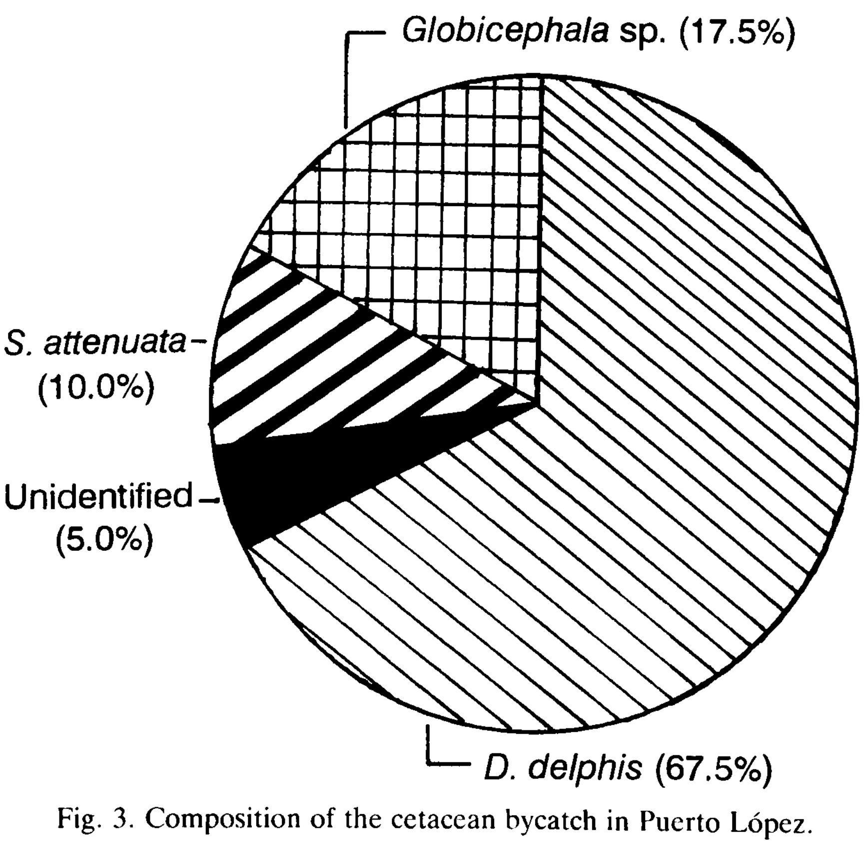

Fig. 3. Composition of the cetacean bycatch in Puerto López.

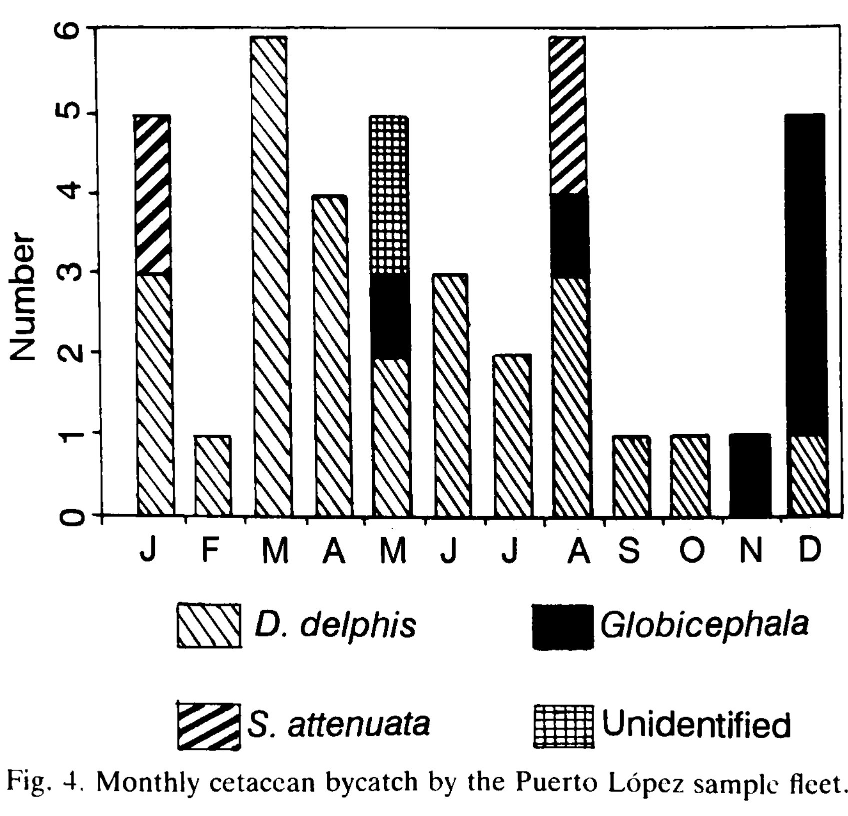

Fig. 4. Monthly cetacean bycatch by the Puerto López sample fleet.

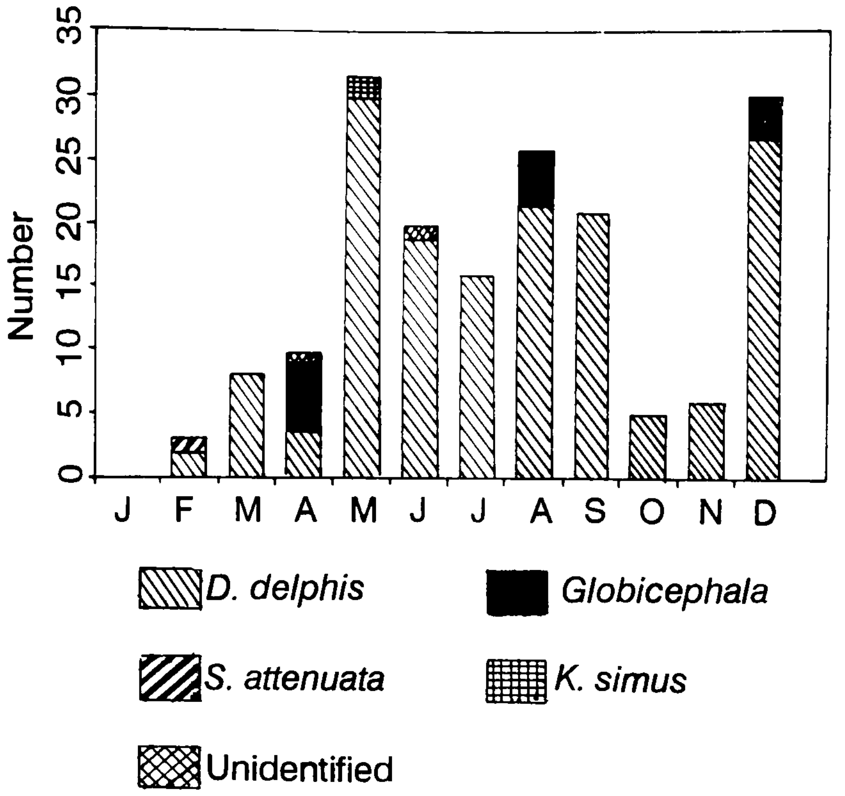

Fig. 5. Monthly cetacean bycatch by the Santa Rosa sample fleet.

Table 7

Composition of the bycatch per age class in Santa Rosa.

Species	Calves n	Calves %	Young n	Young %	Adults n	Adults %
Delphinus delphis	79	49	52	33	28	18
Globicephala sp.	2	15	6	46	5	39
Stenella attenuata			1	100		
Kogia simus					2	100
Unidentified			1	50	1	50

Table 8

Composition of the bycatch per age class in Puerto Lopez.

Species	Calves n	Calves %	Young n	Young %	Adults n	Adults %
Delphinus delphis	13	48	11	41	3	11
Globicephala sp.			2	29	5	71
Stenella attenuata	1	25			3	75
Unidentified			2	100		

to shore and sold it to longline fishermen for bait. This appears to be an increasingly common phenomenon with prices of US $75 for large carcasses being mentioned. Although the harbour authorities were informed and some boats were inspected, there are no clear regulations forbidding this practice. Local fishermen informed us that this trade had begun soon after the arrival at Puerto López of two visiting launches from Puerto Bolívar (in the south of the country), who seemed often to use dolphin and whale meat as bait. This could not be confirmed because we have not surveyed the bycatch situation in Puerto Bolívar.

Fishermen consider both dolphins and whales as fish but not as food. However, the blubber is occasionally used as medicine to cure asthma and other illness.

Examined specimens

Of the 217 caught animals, 33 (15%) were taken ashore to be examined; 27 common dolphins, 5 spotted dolphins and the head of a dwarf sperm whale. Fig. 6 shows the lengths of the common dolphins examined (mean 1.25m, SD=0.32). Most corresponded to animals in their first year of life. The five spotted dolphins were slightly longer, measuring an average of 1.7m (SD=0.5). Tables 7 and 8 show the age class composition of the dolphin bycatch. However, this information is of limited value since only seven dolphins came from boats with observers and large

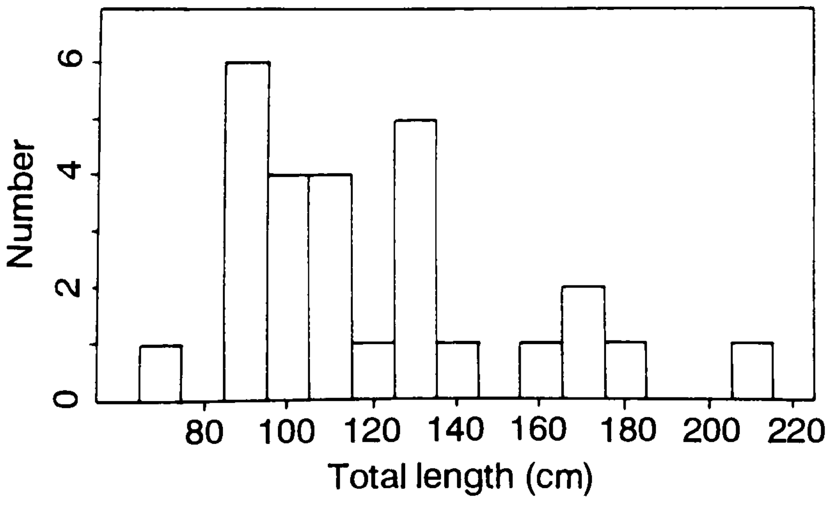

Fig. 6. Frequency distribution of the total length in the common dolphins examined (n=27).

animals were probably not brought back to port because of the effort of getting them on board and the fact that they would occupy space that could be used for fish.

DISCUSSION

This is the first survey of cetacean bycatches in Ecuadorian artisanal fisheries that attempts to quantify the incidental mortality. However, as only two ports in the centre of the country were sampled, it is not possible to provide a national estimate. It would be inappropriate to extrapolate the results from the sampled ports to the entire artisanal fleet, not the least because the capture rate was different in both sample ports and this could be true for other sites. To obtain better estimates more ports should be examined, especially in the south of the country where more gillnets are used. INP data (Table 1) show that Puerto Bolívar has both the highest number of gillnets and the highest percentage of its fleet operating. The potential is there, therefore, for the incidental capture of dolphins from this port to be high and an investigation of that fleet should be given high priority. By contrast, the artisanal fishermen of the north's fishing ports use fewer gillnets and more longlines, and one would expect the incidental capture of cetaceans to be less.

Despite the problems in the extrapolation procedure, the estimated bycatch in 1993 for the fleets in Puerto López and Santa Rosa, and the other two ports (Manta and Anconcito) shows that the incidental mortality of cetaceans is high, perhaps between 2,500–5,000 animals. If mortality levels are similar in other artisanal ports in Ecuador, the total bycatch in 1993 may have been 2–3 times greater than this, i.e. greater than the annual capture in Perú, where a directed dolphin fishery has existed for many years (e.g. Read *et al.*, 1988). In Perú some species of dolphins show signs of being over exploited due to the high bycatch levels (Van Waerebeek *et al.*, 1994).

Our study has only included boats for the pelagic fishery that used wide mesh surface gillnets. However, interactions of small cetaceans (e.g. the bottlenose dolphin, *Tursiops truncatus*) with other types of nets used in Ecuador, such as the nylon monofilament nets used for catching shrimp and other benthic species in coastal waters, have been reported by Van Waerebeek (1990) and Félix (In press). In this regard it should be noted that the Puerto López sample boats that used both longlines and gillnets in November and December did not report any capture of small cetaceans in longlines.

The two peaks in incidental captures reported (March-September, December-January) coincide with the peaks in catches of small pelagic fish (French *et al.*, 1988; Aguilar and Santos, 1993). This suggests that the dolphins may be more abundant at those periods due to food availability. Unfavourable environmental conditions such as turbid water, swell and current could affect the ability of the small cetaceans to detect and to avoid nets (Jefferson *et al.*, 1991). The highest bycatch of the sample fleet was recorded in August and October when the south trade winds occur and produce strong surf (on one occasion 10 dolphins were caught in one net). The number of dolphins (as reflected by capture rate) also seems to vary geographically but it is not clear if this reflects greater abundance in the south (Santa Rosa) or offshore (Santa Rosa boats operated further from shore).

Variation in bycatch composition was also seen. Although the most affected species was the common dolphin (*Delphinus delphis*) for both fleets, the Puerto López fleet caught proportionally more spotted dolphins (*Stenella attenuata*) and pilot whales (*Globicephala macrorhynchus*) than the Santa Rosa fleet. The Puerto López fleet is more active in coastal waters i.e. where the coastal spotted dolphin is more frequently found (Perrin *et al.*, 1985). Although pilot whales are a deep water species, the higher bycatches at Puerto López can be explained as most occurred when the fleet made longer and (probably) more distant trips in December 1993.

It is noticeable that the trade of (incidentally caught) dolphins was discovered during the time when the whitebait that is used by longline fishermen was scarce. The fishermen know that dolphin meat is excellent bait on their longlines and they are willing to pay a lot of money for bycatch. Haase and Félix (1994) report that sperm whale meat is occasionally used for bait in Ecuador. They note that this might result in deliberate capture of this species unless action is taken by the authorities.

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SC/46/O 6*

A Note on the Incidental Mortality of Sperm Whales (*Physeter macrocephalus*) in Ecuador

Ben Haase and Fernando Félix

Fundación Ecuatoriana para el Estudio de Mamíferos Marinos (FEMM), PO Box 09–01–6637, Guayaquil, Ecuador

ABSTRACT

Between 1987 and October 1994, twenty strandings of the sperm whale (*Physeter macrocephalus*) were recorded along the Ecuadorean continental coast. In eleven cases an interaction with some type of fishing gear (usually gillnets) had occurred. Although the total number of interactions is unknown, fisheries may play an important role in the mortality of these animals. In at least three cases, the animals were taken to the beach by fishermen in order to obtain some profit. The meat and the fat may be used for bait and other parts of the animal such as the teeth and bones have an increasing market value. Although whales are protected by law in Ecuador, this additional income may provide a motive for some fishermen to enter a directed, but illegal fishery.

KEYWORDS: EASTERN TROPICAL PACIFIC; SPERM WHALES; INCIDENTAL CAPTURE; STRANDINGS

INTRODUCTION

The sperm whale (*Physeter macrocephalus*) is widely distributed in Ecuadorian waters. Its presence at these latitudes was known by the 19th century whalers who hunted them throughout the year along the continental coast and around the Galapagos Islands (Clarke, 1962; Whitehead and Hope, 1991). Investigations on the sperm whales found around the Galapagos Islands have been carried out since 1985 and have recently been extended towards continental waters (e.g. Arnbom and Whitehead, 1989; Whitehead, 1989; Whitehead and Kahn, 1992; Kahn *et al.*, 1993).

Compared to other species, the sperm whale does not appear to be as affected by fisheries interactions. In his extensive review, Northridge (1984) noted that it is only from the Mediterranean Sea that there are reports of sperm whale mortality in fishing gear. Since 1987, we have recorded twenty sperm whale strandings on the Ecuadorean coast. In at least eleven cases the stranding appears to be the result of an interaction with fishing gear, mainly artisanal gillnets.

MATERIALS AND METHODS

The information given here is part of the strandings database of the Ecuadorian Foundation for the Study of Marine Mammals (FEMM) developed and collected between 1987 and 1994. It was obtained from villagers at the strandings sites and FEMM members. In eight of the 20 cases at least one of the authors was present. For the remainder of cases photographic evidence, bones or both were assessed. Other possible cases were ignored due to the lack of physical evidence.

The total length of the examined animals was determined in the standard way i.e. in a straight line from the tip of the head to the central notch of the flukes. Age was estimated from the teeth which were cut longitudinally, sandpaper polished and put in formic acid (10%) for 30 hours. The number of growth layer groups formed in the surface of the dentine (Perrin and Myrick, 1980) was counted.

* This was originally an Appendix to SC/46/O 6. The main paper is also published in this volume.

THE STRANDINGS

The available data are summarised in Table 1. The stranding locations are shown in Fig. 1.

Strandings occurred almost throughout the year (10 months), apparently with no seasonal tendency. For those strandings for which it could be obtained, the age/sex distribution was young males (6 cases), adult females (3), adult males (1) and calves (1). For the other nine cases although the sex could not be determined their size meant that they were young animals or adult females. This is in accord with the view that females with calves and the immature males remain in tropical/temperate waters throughout the year, while adult males make seasonal migrations to polar waters (e.g. Clarke, 1962; Whitehead, 1987).

In nine cases, cables and/or other parts of nets were found on the stranded animals, sometimes around the flukes and/or mandible. These animals had thus become entangled in some sort of net, probably artisanal gillnets. Usually these nets have a mesh size of 4" (10cm) and are used to catch large pelagic fishes such as tuna, marlin and sharks. In two cases, the interaction occurred with a tuna purse seiner, which had presumably accidentally caught the sperm whale during fishing activities.

DISCUSSION

For the 11 cases of proven interaction with some type of fishery, the subsequent stranding of the animals appeared to be the direct result of the interactions. Interactions of sperm whales with fisheries have been reported from the Mediterranean by Di Natale and Mangano (1983, in Northridge, 1984; Di Natale and Di Sciara, 1994) and most of the sperm whales died in the Italian driftnet fishery. They suggest that this may play an important role in the mortality of sperm whales in that area. Although the number of sperm whales caught incidentally off Ecuador is unknown, the information presented here suggests that fishery interactions may also play an important role in the mortality of this species in Ecuador.

Most of the stranding records occurred in the most accessible coastal zone of the southwest and central provinces, Guayas and Manabí. It is not known whether

Table 1

Sperm whale strandings recorded on the Ecuadorian coast (1987-1994).

Site	Position	Date	Length (m)	Sex	Remarks	Source
1. Valdivia	01°56'S, 80°55'W	1987	10	?	Skull collected by a resident and brought to Montanita	This report
2. Punta Carnero	02°20'S, 80°55'W	12 Jun. 1988	11	?	Entangled in a gillnet	This report
3. Chanduy	02°25'S, 80°42'W	22 Mar. 1989	13.6	M	Caught by a tuna purse seiner and brought to the shore	Prieto & Bravo, 1991
4. Muisne	00°35'N, 80°03'W	Jun. 1990	?	?	Unknown details	*El Universo* 3 June 1990
5. Engabao	03°34'S, 80°28'W	09 May 1991	11.4	M	Entangled in a gillnet and brought to the shore to remove the net. Estimated age 12 years	This report
6. Salango	01°35'S, 80°52'W	02 Jul. 1991	10.8	M	Entangled in a gillnet	This report
7. Punta Carnero	02°20'S, 80°55'W	15 Aug. 1991	12.6	F	With the maxilaries broken	This report
8. Rio Chico	01°37'S, 80°52'W	12 Oct. 1991	11.8	F	Entangled in a gillnet. Estimated age 25-30 years	This report
9. Bahia de Caráquez	00°36'S, 80°26'W	Nov. 1991	?	?	Stranding reported to FEMM by Mr. Juan Jose Bernal	This report
10. Salinas	02°12'S, 81°00'W	Mar. 1992	3.5		Skull found on the beach	This report
11. Los Frailes	01°28'S, 80°46'W	15 Nov. 1992	11.4	M	Found stranded on the beach	This report
12. Puerto Rico	01°38'S, 80°50'W	09 Feb. 1993	8.4	F	Entangled in a gillnet	This report
13. Anconcito	02°22'S, 80°47'W	16 Jun. 1993	10	F	Entangled in a gillnet and brought to shore to remove the net	This report
14. San Vicente	00°35'S, 80°24'W	28 Oct. 1993	6.5	M	Entangled in a gillnet. Flukes were cut to remove the net. Estimated age 7-8 years	This report
15. Puerto Bolívar	03°16'S, 80°01'W	01 Dec. 1993	10.12	?	Floating 2 days in the channels near to harbour	This report
16. Sucre	00°14'S, 80°20'W	Feb. 1994	?	?	Skull found on the beach	This report
17. Las Manchas	00°45'N, 80°05'W	Apr. 1994	?	?	Skull found on the beach	This report
18. Chanduy	02°25'S, 80°42'W	17 May 1994	13.5?	M	Caught by a tuna purse seiner	Frias *et al.*, 1994
19. Briseño	00°32'S, 80°27'W	15 Aug 1994	11.6	M	Entangled in a gillnet. Estimated age 12 years	This report
20. Engabao	03°34'S, 80°28'W	04 Oct. 1994	10.11	?	Entangled in a gillnet. Estimated age 16 years	This report

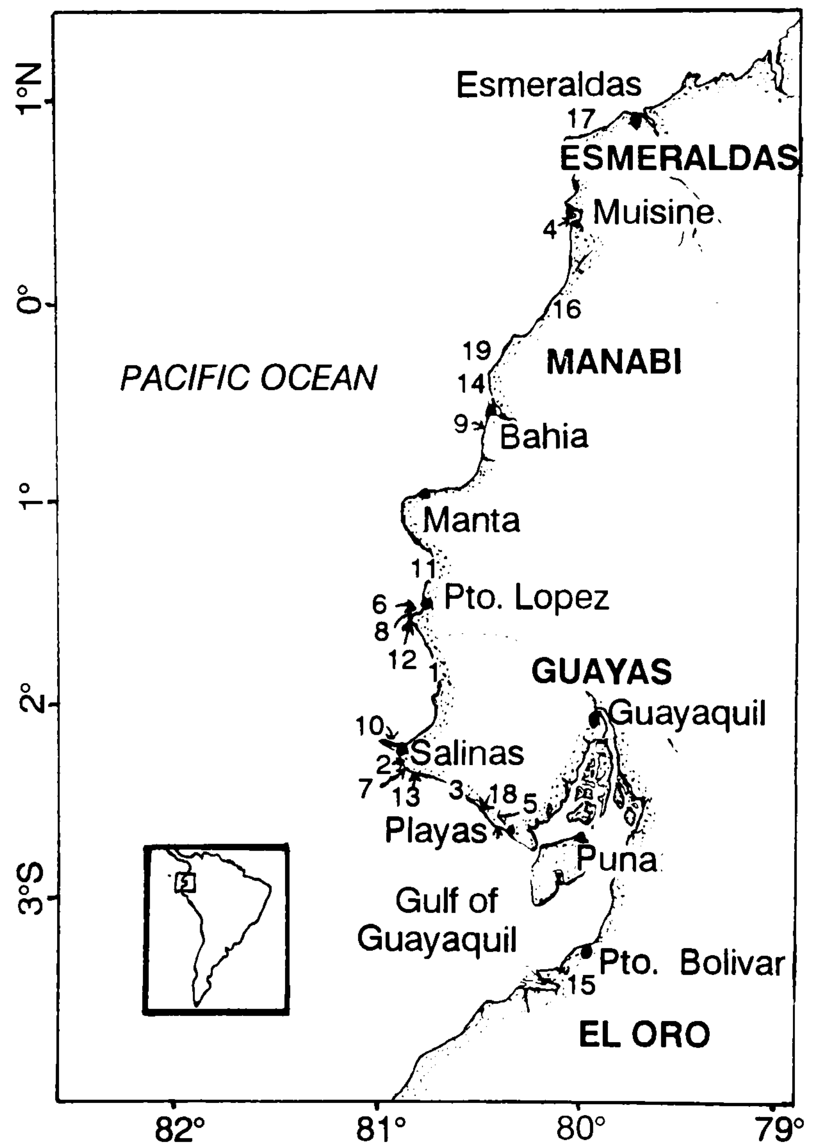

Fig. 1. Sites where sperm whale strandings occured on the Ecuadorian coast during 1987–1994

strandings occur with the same frequency in the northernmost province, Esmeraldas. It should be noted that the use of gillnets in that area is less common (Cedeño, 1987). There are no recorded fishery interactions and/or strandings of sperm whales in the inner estuary of the Gulf of Guayaquil. This part is relatively shallow, mostly less than 100m depth and sperm whales rarely visit such shallow waters (e.g. Leatherwood and Reeves, 1983). However, north of the Gulf, where the continental platform is narrower, artisanal vessels might operate in waters where sperm whales are found. The lack of stranding records for the southern Gulf may also reflect the fact that most of its coast is covered with mangrove trees, with few beaches. The only recorded case of a dead sperm whale in that part of the Gulf (No. 15) was for an animal that did not wash ashore but rather floated for several days in the channels near Puerto Bolívar.

The incidental capture of sperm whales in the nets of artisanal fishermen represents a danger for both the whale and the fisherman. If the drifting net is not free but tied to the boat this may endanger the lives of the fishermen. For example local fishermen believe that animal no. 5 had been responsible for the loss of a launch and its crew a few days before.

Although up until now incidental catches appear to have occurred as an unwanted bycatch during normal fishing operations, it is possible that in the future things might change. In three cases it was proved that fishermen purposefully dragged the incidentally caught animals to shore in order to make some profit out of the event, either to recover the net or to sell parts of the body (e.g. teeth, meat and bones, especially the cranium). The meat and the fat are occasionally used for bait by artisanal fishermen and by the industrial tuna fishery. The value of a sperm whale tooth has reached a high price (US$50.00 each). It is not inconceivable that this might cause some fishermen to view this species as an alternative source of income and even lead to a 'directed' fishery, despite the fact that sperm whales are protected by law in Ecuador. The situation requires continued monitoring.

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SC/46/SM11

Mortality of Small Cetaceans and the Crab Bait Fishery in the Magallanes Area of Chile Since 1980

Anne-Catherine Lescrauwaet and Jorge Gibbons

Casilla 527, Punta Arenas, Chile

ABSTRACT

Since 1974, species of small cetaceans, fur seals, sea lions, sea birds and to some extent sea otters, have been taken deliberately each year for bait in the Chilean artisanal fishery for centolla, southern king crab (*Lithodes santolla*) and centollón, false king crab (*Paralomis granulosa*). We describe the socio-economic context of this fishery and we review official fishery statistics and unpublished data in order to estimate the magnitude of this direct take between 1980 and 1992. We find that the need for bait in the crab fishery has continually decreased from a peak value of 950 tonnes in 1986 to a minimum of 450 tonnes in 1992. In recent years, three new trends are contributing to alleviate mortality pressure on marine mammals in Magellanes; a change in fisheries legislation, an increased diversification of the artisanal fishery and an increasing public awareness of the values of marine wildlife.

KEYWORDS: INCIDENTAL CAPTURE; DIRECT CAPTURE; FISHERIES; SOUTH PACIFIC; PINNIPEDS; SEA OTTERS; COMMERSON'S DOLPHIN; BLACK DOLPHIN; DUSKY DOLPHIN; RIGHT WHALE DOLPHIN; BURMEISTER'S PORPOISE; MANAGEMENT.

INTRODUCTION

As several authors have reported (e.g. Goodall, 1977; Sielfeld *et al.*, 1977a; b; Torres, 1977; Sielfeld and Venegas, 1978; Cárdenas *et al.*, 1987; Goodall and Cameron, 1980; Goodall *et al.*, 1988b; Leatherwood *et al.*, 1988), small cetaceans have been taken deliberately each year since 1974 in the Magellan region of Chile for use as bait in traps set for centolla or southern king crab (*Lithodes santolla*) and centollón or false king crab (*Paralomis granulosa*). However, no thorough examination of the development of the crab fishery, its geographic expansion or the demand for marine mammal bait has been presented previously. In this paper, we discuss the socio-economic background to the fishery, the historical sequence of relevant political and economic events, and attempt to estimate the numbers of cetaceans that would have been required to support the crab fisheries in recent years.

This work is predicated on the assumption that, to conserve populations in the Patagonian and Fuegian channels, one needs to have: (a) better information on the status of the populations affected by activities related to crab fishing, (b) better information on the numbers of cetaceans killed and (c) a basic management plan for presentation to the Chilean government and the fishing communities.

MATERIALS AND METHODS

We have reviewed the literature on the crab fisheries in southern Chile with respect to the use of bait and the social and economic factors affecting or influencing the fisheries. We especially sought information on cultural elements, ethnic structures and population transitions within the fishing communities of the Magellan region.

Written sources included annual statistics from port authorities, the Servicio Nacional de Pesca (SERNAP), the Instituto de Fomento Pesquero (IFOP), the Servicio Agricola y Ganadero (SAG), the Corporación Nacional de Fomento a la Producción (CORFO), the Instituto Nacional de Estadisticas (INE) and a published socio-economic profile of a part of the artisanal fishing community (Henriquez, 1990). We also checked every issue of the regional newspaper *La Prensa Austral*, from 1987 to early 1993, for articles related to the taking of wildlife for bait, the over exploitation of crab etc. This newspaper search gave us an indication of what information has been made available to the community and the perceived importance of these issues at the regional level.

We conducted extensive interviews with fishermen (approx. 60), 16 of 25 company managers, scientists, representatives of the Chilean Navy and personnel in the fisheries service. Company managers completed questionnaires designed to elicit their views on the condition of the crab fisheries, suggested solutions to problems and likely obstacles to implementation of regulatory measures. The Secretary of Fisheries kindly cooperated with a 'written interview' regarding new policies.

We used the region's 14 fishing areas (IFOP, publications 1979–1990) to identify fishing grounds with the highest catch effort. Annual catch effort values per area are given as fractions of the total annual catch effort. The seasonal and geographical distribution of catch effort was compared with the available information on distribution of small cetaceans.

In this paper, the term 'catch effort' refers only to the effort directed at the trapping of crabs. It does not encompass the effort involving nets or diving gear. We calculated effort using IFOP methods, with the following assumptions:

(a) a 40% loss in active fishing days due to poor weather or technical difficulties;
(b) an average submersion time per trap set (cast) of 72 hours for centolla (one third of the traps are set per cast);
(c) an average submersion time of 48 hours for centollón (one half of the traps are set per cast).

The monthly catch effort per vessel was thus calculated by multiplying the number of traps on board by the number of fishing days per month and then dividing by either 2 (centollón) or 3 (centolla).

Partial monthly and yearly information on crab catch effort was available for 1979–1986 from SERNAP and IFOP. Catch effort for 1987–1989 was calculated from daily fishing activity as recorded by harbour personnel, who noted the arrival and departure of vessels and the areas from which crabs were harvested (fishing Regions I-XIV, see Fig. 3). Files kept by the port authorities provided each vessel's length. By knowing the average number of traps carried by different length classes of vessels, we were able to estimate the total number of traps deployed from a particular port.

Our estimates of catch effort for centolla and centollón, combined, during 1990–1992 are based on the total estimated number of traps available in the region and the number of effective fishing days. The total catch effort, multiplied by a 'bait unit', gives an indication of the total amount of bait used (both wildlife and legal). Since in reality bait units may vary in size by as much as 1.5kg, the use of a single value is arbitrary. We chose 0.5kg, the minimum amount of bait needed for a single trap, to generate conservative estimates of total bait requirements.

We identified potential legal sources of bait in the region (e.g. slaughterhouse waste, waste from the industrial fishery) and reviewed official information to verify that this bait was being used for crabbing.

Finally, in our discussion we consider available data for 1993 and 1994 in our assessment of conclusions drawn from the main period of our work (i.e. up to 1992).

RESULTS

Government policy and national fisheries

Growth in fisheries has made fishing the second most important category in the Chilean economy, contributing 12% of the total value of national exports in 1990. In 1989, Chile exported a total catch of 6.6 million tonnes of fish, shellfish, crustaceans and algae worth US$930 million. Developments in the Chilean fishery industry occurred under a regime of free access to fisheries and major reductions in all forms of regulation and control. It had an extremely destructive impact on natural resources, with the exhaustion of mollusc banks and the overfishing of important pelagic fish and shellfish populations. Ten of the main fisheries, together contributing 85% of the total export value, showed signs of overexploitation (Couve, 1991).

Unmanageability of the crab fisheries

Chilean commercial fisheries for centolla and centollón are centred in the Magellan Region (49°S-56°S). This region supplies 97% of the national production of centolla and 100% of that of centollón. In 1976, accelerated and sustained growth began in this industry with increases in the sizes of the fleets, the processing companies, the geographical areas, annual landings and exports (Table 1, Figs 1 and 2).

Annual landings before 1976 fluctuated between 200 and 450 tonnes.

By 1986, crabbing had become unmanageable, as shown by the high percentage of illicit captures; Hernandez and Diaz (1986) estimated that 30–40% of the total landings were taken illegally (either undersized crabs, crabs obtained from closed areas or those obtained using illegal methods). Some company owners suggested that this may have reached up to 70% in later years.

Six factors are seen as contributing to the unmanageability of the Chilean crab fisheries.

(1) *Free access*

Little or nothing was required of entrants to the fisheries, resulting in an increase from nine processing plants in 1974 to 27 in 1988.

(2) *State support*

The Chilean government, through CORFO, provided extremely favourable terms for the acquisition of fishing boats and equipment. From 1976 to 1989, 90 beneficiaries in the artisanal sector received, in total, approximately US$600,000 of credit, while four enterprises in the industrial sector received a total of US$2,500,000 of credit from 1982 to 1986 (B. Bonifetti, CORFO, pers. comm.). The artisanal fleet grew from approximately 60 before 1970, to nearly 600 boats by 1988.

(3) *Growth in export demand*

Extremely favourable external market conditions arose in recent years for Chilean crab. In 1990, their export value reached approximately US$2,800 per tonne; 30 times greater than the average value for all other fishing products. This was partially due to the high prices of Alaskan king crab (*Paralithodes camtschatica*) which

Table 1

Characteristics of growth in crab fishery, Magallanes, 1974-1992. Key: (A) Centolla; (B) Centollón.

Year	Total catch	(A)	(B)	No. of companies	No. of fishing vessels		No. of transport vessels
					(A)	(B)	
1974	511			9			
1976		1,028					
1979	3,220	2,268	952	13	150	63	8
1980	1,810	1,381	429	14	105	26	8
1981	1,590	1,280	310	16	133	46	6
1982	1,782	1,473	309	14	138	18	8
1983	3,586	2,755	831	24	177	90	8
1984	3,597	2,746	851		220	123	8
1985	2,902	2,636	266		229	39	21
1986	3,586	2,593	993		282	130	45
1987	3,961	2,188	1,773	27	296		55
1988	4,491	2,161	2,330	27			
1989	4,250	2,297	1,953	27			
1990	3,699	1,834	1,865	25			
1991	5,127	1,738	3,389			550 total	
1992	2,494	1,173	1,321	21		550 total	

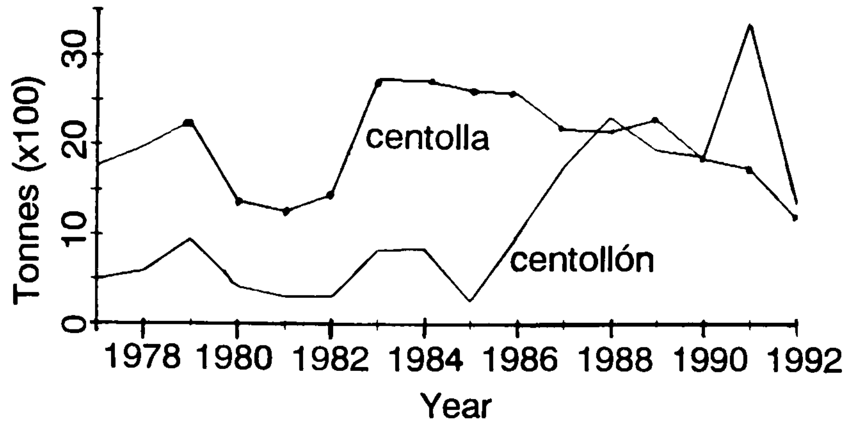

Fig. 1. Annual landings, centolla-centollón.

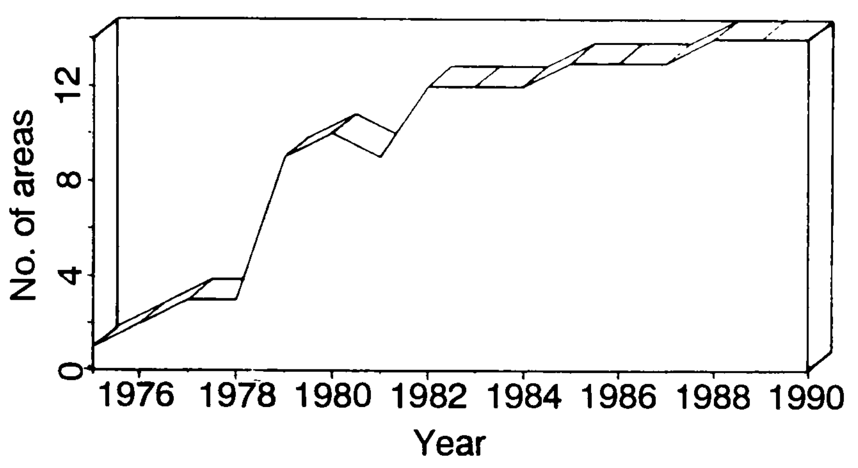

Fig. 2. Geographical expansion of centolla and centollón fishery.

encouraged the USA to import lower-priced crab products from the ex-USSR, Argentina and Chile. The Alaskan fishing grounds were closed from 1982 to 1988. This led to an increase in the number of processing plants in the Magallanes and seriously disrupted the balance between the artisanal fishing sector and the processing capacity of the industry.

(4) *Lack of regulation*
The free market economic policy focused on maximising short-term profits and neglected the government's responsibility for protecting the nation's marine resources. This is evident from the contrast between the major development of the fisheries and the simultaneous decline in SERNAP's work force. In 1973, the SERNAP regional office in Magallanes had 13 inspectors. This declined to between eight (in 1985) and ten (in 1992). The necessary infrastructure (proper vehicles, vessels, radio and office equipment) was not in place to support the staff of inspectors and the legal sanctions were too weak to deter illegal crabbing.

In 1987, only two of the 27 companies were supplied by their own vessels. The remainder of the regional fleet work as individuals, under highly competitive conditions. Crab is bought alive at low prices in the remote fishing areas by company boats that also bring in expensive supplies and gasoline or exchange them for fresh products, often at unfair rates. The increased competition for fresh crab together with poor working conditions has led to criminal activity among fishermen including stealing and sabotage.

(5) *Geography*
Until the mid-1970s, the centolla fishery was limited to nine companies operating only on the west coast of Isla Grande de Tierra del Fuego, around Isla Dawson, in Seno Otway and along the south coast of Peninsula Brunswick (52°S-54°S). Since 1976, the crab fishing grounds have expanded to cover approximately 25,000km of labyrinthian interior channels that are difficult, if not impossible to police. In 1981, the Porvenir area was closed to crab fishing in response to a study that revealed overfishing in this area (Campodonico, 1979). Seno Otway and Seno Año Nuevo were closed for the same reasons, but many fishermen admitted that they had fished in closed areas at one time or another. In 1990, about 20 boats were discovered fishing in Seno Año Nuevo, using camouflage against aerial surveillance (A. Roman, Director SERNAP-Magallanes, *La Prensa Austral*).

(6) *Cultural factors*
Crab fishing is extremely demanding in terms of physical effort, harsh climate (low temperatures, high precipitation, strong winds), exposure to dangerous circumstances and isolation. Most artisanal fishermen have come to the Magallanes from rural areas on Isla Chiloë (42°S-43°S). They generally come from low income backgrounds with limited employment alternatives other than in agriculture or fishing and have little or no formal education (Henriquez, 1990); crab fishing is by far the most lucrative option. For example, the average monthly wage of a shepherd is US$ 100, whereas crab fishermen could earn as much as US$ 1,000 per month in the 1980s.

During 1983–1984, a special effort was made by local authorities in Punta Arenas, with support from the Organisation of American States, to improve fishing techniques in the artisanal sector. Although courses (including training in the use of fishing gear, such as longlines, not represented in the Chiloë fishing culture) were offered free of charge, only 43 persons attended. Longlines are an important tool for obtaining fish as bait in the crabbing areas.

The few attempts to form labour unions or other labour organisations have failed, apparently because crab fishing is so profitable and individualistic (Mr J. Gonzalez – President of the Union of Artisanal Fishermen – Punta Arenas, pers. comm.).

Summary
In summary, the crab fisheries of Chile can be characterised by: (a) a lack of formal responsibility by the industry with respect to the working conditions and methods of the fishermen; (b) strong competition for raw material, which has stimulated illegal capture; (c) over-capitalisation of the fleet; and (d) a failure of governmental authorities to intervene and prevent resource depletion. The fisheries have become unmanageable in spite of a high degree of awareness among politicians, managers, scientists, fishermen and the general public. This awareness is evident from the abundant information in the media, numerous technical reports by IFOP, seminars and workshops organised by regional authorities and, finally, the number of regulations applied to the fisheries.

Between 1983 and 1986, the previously established 5-month closed season (February-June) was abolished. Later, to protect the centolla during its reproductive season, crabbing was suspended from December to February (1987–1991). A special decree in 1991 established a 7-month closed season (December-June) to protect the species from further overexploitation, but the closed season was shortened to five months in 1992 in view of the socio-economic crisis facing the artisanal sector. The December-January closed season for centollón remains unchanged.

Status of small cetaceans in southern Chile

Legal status

Under Decree No. 223, 1979, of the Ministerio de Economia, Fomento y Construccion, traps are the only type of fishing gear that can be used legally to catch crabs. These traps need bait. In 1977, after Torres (1977) had made the authorities aware of the fact that large numbers of small cetaceans were being taken for crab bait in the Magellan region, the Ministerio de Agricultura published Decree No. 381, prohibiting the catch, transport, commercialisation, possession or processing of small cetaceans. Special permits for scientific or cultural purposes have been issued on four occasions – three relating to the export of Commerson's dolphins (*Cephalorhynchus commersonii*) and one allowing the capture of Chilean dolphins (*Cephalorhynchus eutropia*) (SERNAP, Resolution No. 364, 1988).

Actual situation

In spite of the 1977 decree, many publications have referred to continued catches of small cetaceans along the southern Chilean coasts, specifically to support crab bait (Torres, 1977; Sielfeld *et al.*, 1978; Torres *et al.*, 1979; Goodall and Cameron, 1980; Sielfeld, 1983; Goodall and Jordan, 1986; Goodall *et al.*, 1988b; Crespo *et al.*, 1994; and others). Published estimates of the numbers of individuals or meat tonnages of small cetaceans and other marine wildlife are summarised in Table 2; these estimates range from 50 dolphins per week in 1976 (Torres, 1977) to 400 tonnes of marine and other wildlife (including cetaceans) during 1987 (Cárdenas *et al.*, 1987). The species of wildlife known to have been taken for crab bait are listed in Table 3. As to small cetaceans, Peale's dolphins (*Lagenorhynchus australis*), Chilean dolphins and Commerson's dolphins were most affected, while the presence of dusky dolphins (*Lagenorhynchus obscurus*), Southern right whale dolphins (*Lissodelphis peronii*) and Burmeister's porpoises (*Phocoena spinipinnis*) in the area suggest that they also would have been taken occasionally for bait.

Table 2

Estimates of illegal captures of small cetaceans.

Year(s)	Estimate	Source
1976 (6 months)	50 specimens/week	Torres, 1977
1978	2,400 specimens/year	Torres, 1979
1979	4,120 specimens/year	Torres *et al.,* 1979
1980-1983	240 tonnes/year	Sielfeld, 1983
[mainly Commerson's and Peale's dolphins, sea lions and sea birds]		
1987	400 tonnes/year	Cárdenas *et al.,* 1987
[species mentioned by Sielfeld (1983)]		

Table 3

Species of wildlife affected by crab bait fishery.

Most affected species	Species affected to lesser extent
Otaria flavescens	*Phocoena spinipinnis*
Arctocephalus australis	*Lagenorhynchus obscurus*
Lagenorhynchus australis	*Lissodelphis peronii*
Cephalorhynchus commersonii	*Phalacrocorax magellanicus*
Cephalorhynchus eutropia	*Phalacrocorax albiventer*
	Phalacrocorax atriceps
	Eudyptes crestatus
	Larus dominicanus
	Larus skoresbii
	Lama guanicoe
	Lutra felina
	Lutra provocax

Progress of knowledge on small cetaceans

There has been little scientific research on small cetaceans in Chile. During the last century, only three graduate theses on cetological subjects have been produced by Chilean Universities and only one project (for monitoring mortality of small cetaceans in Regions IX and X – in 1989) was entirely financed with national funds. A second project was partially supported by the Chilean Ministry of Agriculture (Clarke *et al.*, 1978).

In consequence, little is known about the general biology, distribution, trophic relations or reproductive habits of small cetaceans in Chile, or on the status of populations and their interactions with humans.

Estimation of illegal bait

Amount

Annual catch effort values and estimates of total amount of bait used in the centolla fishery (both legal and illegal) are summarised in Table 4a, while those for the centollón fishery from 1979–1986 are in Table 4b. Data for 1990–1992 in Table 4a refer to combined centolla and centollón catch effort. Centolla catch effort shows a substantial increase starting in 1983, with a peak value in 1986. Centollón catch effort values remain generally low but variable until 1986. Although no data on centollón catch effort after 1986 are included, the substantial increases in total annual landings (Table 1(B) of SERNAP annual statistics) indicate that the

Table 4a

Annual catch effort values for centolla fishery with estimated amounts of bait used (tonnes).

Year	No. of effective traps	Estimates bait used (tonnes)
1979	1,443,782	722
1980	649,487	325
1981	734,155	367
1982	974,864	487
1983	1,537,259	769
1984	1,445,568	723
1985	1,850,787	925
1986	1,900,000	950
1987	1,875,600	938
1988	1,860,000	930
1989	1,700,000	850
1990	1,600,000	800
1991*	1,800,000	900
1992*	900,000	450

* Data include both centolla and centollón catch effort values.

Table 4b

Annual catch effort values for centollón fishery with estimated amount of bait used, 1979-1986.

Year	No. of effective traps	Estimated bait used (tonnes)
1979	100,627	50
1980	44,225	22
1981	50,995	25
1982	48,814	24
1983	200,378	100
1984	272,646	136
1985	66,115	33
1986	282,272	141

Table 5a

Distribution of annual catch effort for centolla (1979-1990*), for the different fishing Regions (I to XII); catch effort per area is expressed as a fraction of the total annual catch effort.

Year	Region															Total
	I	I-A	II	III	IV	IV-A	V	VI	VII	VIII	IX	X	XI	XII	Undetermined	
1979	0.11	-	0.14	0.01	0.22	-	0.17	0.14	0.16	0.03	-	-	-	-	0.03	1.0
1980	0.03	-	0.15	0.00	0.22	0.00	0.02	0.18	-	0.06	-	0.31	-	-	0.00	1.0
1981	0.04	-	0.04	0.00	0.19	0.05	0.20	0.09	0.20	0.07	-	0.11	-	-	0.00	1.0
1982	0.00	-	0.05	0.05	0.08	0.05	0.28	0.02	0.09	0.05	-	0.10	0.22	-	0.00	1.0
1983	0.02	-	0.30	0.01	0.03	0.01	-	-	0.29	0.33	-	-	-	-	0.00	1.0
1984	0.04	-	0.52	0.00	0.02	0.00	0.04	0.01	0.31	0.05	0.00	0.00	-	-	0.00	1.0
1985	0.00	0.07	0.08	0.08	0.09	0.04	0.17	0.10	0.10	0.02	0.00	0.16	0.08	0.00	0.00	1.0
1986	0.01	0.05	0.06	0.08	0.16	0.04	0.16	0.06	0.09	0.05	-	0.17	0.07	-	0.00	1.0
1987	0.01	0.01	0.01	0.23	0.14	0.03	0.06	0.07	0.09	0.06	-	0.18	0.07	0.03	0.00	1.0
1988	0.00	0.01	0.02	0.17	0.18	0.01	0.07	0.00	0.19	0.02	-	0.31	-	-	0.02	1.0
1989	0.01	0.01	0.00	0.14	0.13	0.00	0.22	0.00	0.10	0.03	0.02	0.16	0.10	0.07	0.00	1.0
1990*	0.03	0.02	0.01	0.07	0.15	0.00	0.19	0.00	0.07	0.12	0.04	0.16	0.01	0.13	0.00	1.0
Total (%)	2	1	12	7	13	2	13	6	13	7	0	14	4	2		100%

* Based on data from January to June 1990.

catch effort for this species has increased appreciably since 1986. Our estimates of catch effort are similar to those made independently by Hernandez *et al.* (1986) for the period 1979–1984.

Evaluation of sources

The catch effort values published by IFOP are supplied by the companies, based on declarations by the fishermen. Harbour records generally confirm information on activity as given by the companies, but independent fishermen's reports on the number of traps used are likely to be underestimates.

In Table 4a we used only harbour activity records and independent methods to estimate the number of traps carried from 1987–1992. Thus these estimates should be little affected by biases in the fishermen's reporting. They are, however, biased by the fact that part of the crab catch has been made with illegal gear (e.g. nets) or by illegal means (e.g. diving). This bias is difficult to quantify, but IFOP publications generally correct estimates of bait requirements by subtracting 20% to account for it. There was noticeable increase in the last few years in the number of boats too small to carry a significant number of traps (IFOP, 1988). This trend is interpreted to indicate that netting and diving for crabs has increased. Crab nets are known to cause a significant amount of incidental small cetacean mortality due to entanglement (Goodall and Cameron, 1980).

The amount of bait used by fishermen within crab extraction areas is difficult to determine. The fishermen usually keep their camp sites stocked with about 15% of the total bait needed (Sielfeld, 1983).

Geographical distribution

CENTOLLA

For official management purposes, the centolla and centollón fishing grounds have been divided into 14 different fishing Regions (see map, Fig. 3). The distribution of catch effort for centolla from 1979–1990 is given in Table 5a. Fluctuations between seasons are due to the incorporation of new areas as well as the abandonment of others. Before 1976, the crab fishery was limited to the vicinity of Punta Arenas. From 1979–1989, the main activity was localised in the areas south of the Magellan Strait. Regions V and VII had very low catch effort during 1980–1981, but the crab fishery expanded to Region X during that season. In 1981–1982, Regions V and VII became important crabbing areas again, with no major changes in fishing activity near their northern limits. A further northwards expansion in Region XII occurred in 1987.

After 50 years of intense activity, the Porvenir area (Region I) was closed for four years beginning in 1983. Along with locations in Regions II, IV and VI, this area has been exploited almost continuously for centolla. Accumulative catch effort is highest in Regions II, IV, V, VI and X.

CENTOLLÓN

Region IX, where Commerson's dolphins are commonly observed (Goodall, 1994) has been the primary fishing area for centollón throughout the entire period (1979–1986). Regions II, VII and VIII were used less intensively during this period (Table 5b).

Table 5b

Distribution of catch effort for centollón, 1979-1986.

Year	Region						Total
	I	II	IV-A	VII	VIII	IX	
1979	-	-	-	6,500	-	94,127	100,627
1980	1,056	-	-	-	-	43,169	44,225
1981	-	12,219	-	-	17,151	21,625	50,995
1982	-	1,678	-	27,064	-	20,072	48,814
1983	-	-	-	80,483	31,610	88,285	200,378
1984	-	-	-	87,766	23,313	161,567	272,646
1985	-	-	-	-	27,361	38,754	66,115
1986	-	57,090	-	-	27,037	188,145	272,272
Total	1,056 (1%)	70,987 (6%)	-	201,813 (19%)	126,472 (12%)	655,744 (62%)	1,056,072

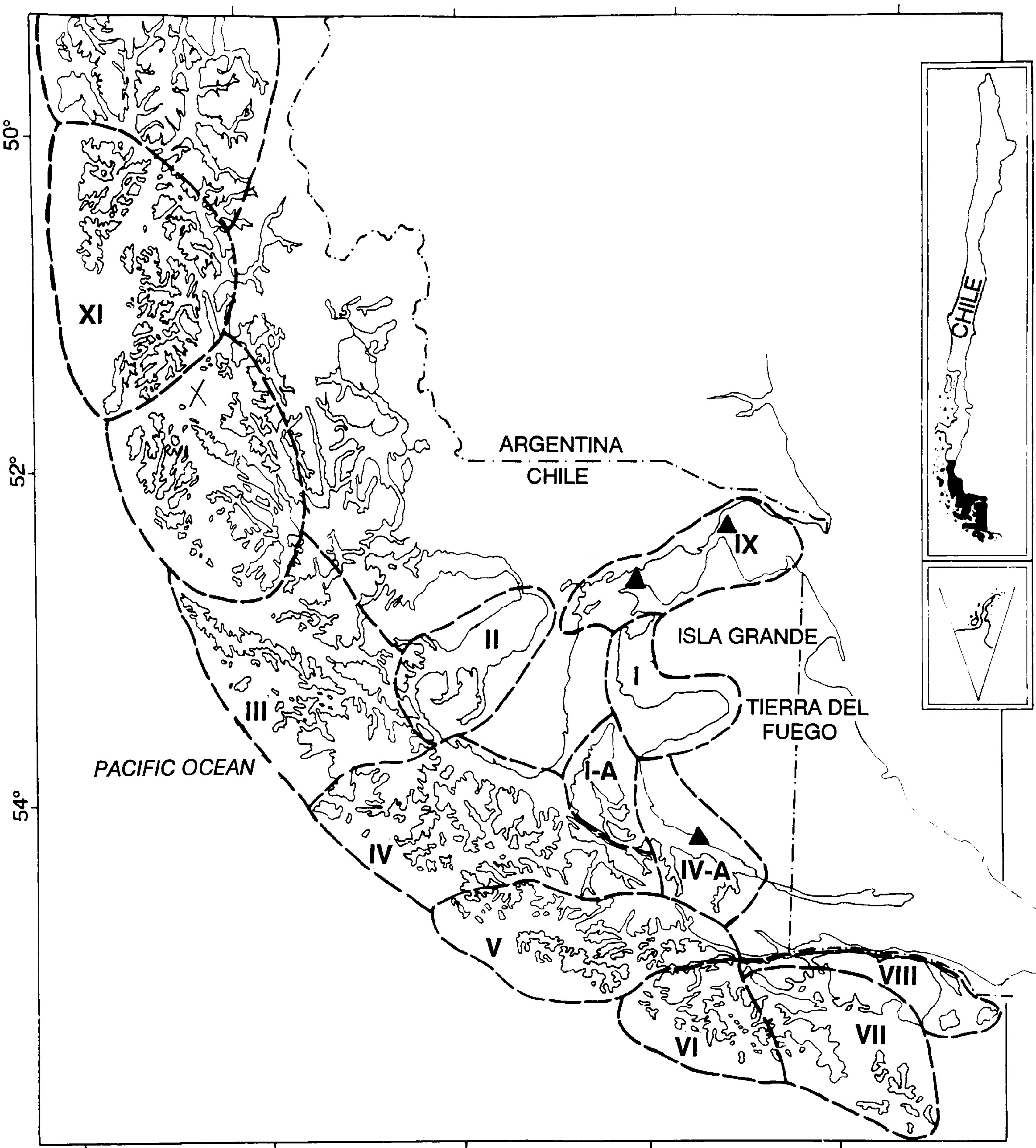

Fig. 3. Geographical location of fishing areas – centolla and centollon (XII Region – from IFOP).

Evaluation of sources

Information on capture sites has become less and less reliable with the growth in illegal crabbing activity, especially since certain areas have been closed. The fishermen are the exclusive sources of data on capture sites. We can therefore assume that there is a negative bias in the amount of catch effort assigned to closed areas and a corresponding positive bias in the amount assigned to areas still open to fishing.

Monthly variations

Table 6 shows monthly catch effort for centolla, 1979–1990. Catch effort for the centolla fishery was low during the first months of the calendar year and gradually increased towards the peak winter months. Data from IFOP show it was highest for the centollón fishery during the first half of the calendar year, with peak values from April to July.

Evaluation of sources

The monthly fishing activity (recorded as departure and arrival of boats in the harbour) information can be regarded as reliable, at least during the open season. During the closed season illegal fishing continues, although probably at relatively low levels.

Table 6

Seasonal variations in catch effort for the centolla fishery 1980-1990. Catch effort per month is expressed as a fraction of total annual catch effort. Key: CS = closed season.

	Month												
Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1980	0.25	CS	CS	CS	CS	CS	0.04	0.06	0.07	0.15	0.18	0.23	0.98
1981	-	CS	CS	CS	CS	CS	-	-	-	-	-	-	-
1982	-	CS	CS	CS	CS	CS	-	0.11	0.13	0.20	0.25	0.30	0.99
1983	0.01	0.01	0.04	0.12	0.17	0.20	0.16	0.12	0.07	0.03	0.02	0.02	0.97
1984	-	0.05	0.12	0.16	0.21	0.18	0.13	0.07	0.04	0.02	0.01	0.01	1.00
1985	0.08	0.08	0.06	0.05	0.05	0.07	0.08	0.09	0.10	0.12	0.11	0.11	1.00
1986	0.06	0.05	0.06	0.05	0.06	0.07	0.08	0.09	0.11	0.12	0.12	0.10	0.97
1987	CS	0.03	0.06	0.06	0.07	0.09	0.11	0.12	0.12	0.16	0.17	CS	0.99
1988	CS	0.04	0.08	0.06	0.09	0.11	0.13	0.12	0.14	0.08	0.09	CS	0.95
1989	CS	0.04	0.08	0.09	0.09	0.09	0.11	0.12	0.11	0.12	0.13	CS	0.97
1990*	CS	0.14	0.22	0.25	0.20	0.18	-	-	-	-	-	CS	0.99

*Based on data January to June.

Presence of cetaceans

The most common small cetaceans in the Magellan regions are Commerson's and Peale's dolphins. Commerson's dolphins are found principally in the eastern Strait of Magellan (Region IX), especially from the Segunda Angostura eastwards (Goodall, 1994). Aerial surveys in this area in January-February 1984 indicated the presence of 3,211 (± 1,680) dolphins (Leatherwood *et al.*, 1988). A more extensive aerial survey carried out in May 1987 gave a population estimate of only 313 (*sic*) individuals (Venegas and Atalah, 1988). The difference may be due to (a) a real decrease in population; (b) seasonal migrations of the dolphins from the area; or (c) differences in survey methods or observer abilities. Commerson's dolphins in the Kerguelen Islands migrate offshore in winter (Robineau, 1985; De Buffrénil *et al.*, 1989) and winter offshore movements have been suggested for those of the Magellan region (Goodall *et al.*, 1988a; Goodall, 1994). It thus seems more likely that there are fewer dolphins in the area during the most intensive fishing periods. Peale's dolphins are found throughout the year and their distribution covers all interior waters including the most intensive crabbing areas, they may be the species most affected by crab fishing. From 1984, the areas south of the Magellan Strait (Regions V, VI and VIII) where dusky dolphins are most frequently observed, have become important crabbing areas. An apparently resident group of Chilean dolphins is observed throughout the year in Seno Skyring, a non-crabbing area.

Interviews and public information

Crab industry interviews

Most of the heads of companies who were interviewed accused the fishermen of ignorance and irresponsible behaviour. They considered the fishermen to be responsible for problems related to the use of wildlife as crab bait. However, they assumed their share of responsibility for the regional overfishing of crab and admitted to participating in illegal practices. For example, one administrator admitted that several thousand pinnipeds had been killed by his company in the last few years for bait and aphrodisiacs; genitals of sea lions (*Otaria flavescens*) and fur seals (*Arctocephalus australis*) were exported illegally to Asian markets while their carcasses served as crab bait.

All of the managers interviewed agreed that their bait supplies did not cover the necessities of the fishermen, but in the case of the companies which did not own their own vessels, the managers assumed no responsibility for the actions of independent fishermen. Fishermen generally accepted their responsibility for killing wildlife but claimed that no economically viable alternatives exist. Many fishermen believe that red meat is by far the best bait.

Many fishermen claimed that the introduction of harpoons by fishermen from the region of Valdivia (Region IX – 40°S) in the 1970s triggered an increase in the use of wildlife, cetaceans in particular. The use of harpoons was well documented in the 1970s (Sielfeld *et al.*, 1977a; b; Goodall and Cameron, 1980). Fishermen argued that the men from Chiloë, the majority of the crab fishermen, did not know how to use longlines or harpoons and that this accounted for the deficit of bait supplies. However, in November 1992, a metal-working shop in Punta Arenas was manufacturing harpoons to catch dolphins.

Alternative sources of bait

Company heads and fishermen agreed that an improvement in the transport to the fishing areas of cheap, legal bait, such as demersal fishery waste could provide part of the solution.

The availability of 'legal bait' in the region is deduced from annual fisheries and meat production statistics. Since most artisanal fish products are sold whole, only waste from industrial fish processing is taken into account; this has increased since 1987 (INE, 1988–1989; SERNAP, Annual Statistics Reports). The availability and applicability of different types of bait were studied by Diaz (1988). The most common species available were frozen hake (*Macruronus magellanicus*), jurel (*Trachurus murphy*), salted sardines (*Clupea bentincki*) and anchoveta (*Engraulis ringens*). His results suggest that although sardines and anchoveta are perhaps the best crab bait, they would cost more than demersal fishery waste.

Cetacean mortality

Both fishermen and industry representatives insisted that the mortality of marine mammals was highest from 1980–1986 and that it had decreased to a minimum since the arrival of the industrial fishing fleet in the region (1988), which produces significant quantities of waste annually.

Nevertheless, according to eye-witness accounts, the take of small cetaceans for bait continued, for example, in Otway Sound (April 1991) and Beagle Channel (February 1991). Photographic evidence of the use of wildlife was published in the local newspaper (19 March 1991). According to Cardenas *et al.* (1986a; b) companies provided up to 30% of the needed bait in 1985/1986. Fishermen claimed that most dolphins were taken during 1983–1986, although the majority of the estimated 2,000 tonnes of bait (mostly illegal) consisted of sea lions. Our estimate of the total amount of bait used in 1986 (950 tonnes) would require a maximum of 6,300 sea lions (average weight 150kg) or 13,750 dolphins (average weight 70kg) in the event that these species had been the exclusive source of illegal bait. We assume that in the actual crab bait fishery (1992), the take of small cetaceans did not exceed 10% of the total demand for bait (45 tonnes), or an equivalent of 600 dolphins per year.

DISCUSSION

Our results indicate that small cetacean mortality in the artisanal sector has declined substantially since 1990, as a consequence of the three factors outlined below.

(1) *A decrease in the demand for bait due to reduced fishing effort*

The estimated 450 tonnes of bait used in 1992 is about half the annual estimate for the period between 1985 and 1989. This decrease in fishing effort may have been a result of the depletion of crab stocks, or for economic or technical (regulatory) reasons. In any event the decrease might facilitate the recovery of regional wildlife populations.

(2) *A decrease in the proportion of illegal bait*

Between 1983 and 1988, much of the bait was provided by wildlife. By 1992, the regional production of waste (in both slaughter houses and the industrial fishery) was sufficient to cover the estimated amount of bait needed. In addition, there are indications that the fishery for legal bait in the fishing grounds has increased substantially.

(3) *A decrease in the proportion of small cetaceans in the illegal bait*

In the last few years, the most affected species of wildlife in terms of bait have been sea lions and penguins, both easy targets when in breeding colonies on land. Dolphins appear to have become less abundant in the fishing areas, which may also be a factor in their decline in relative importance as bait.

The present situation

A number of questions arise concerning the ecological consequences of the historic crab fisheries. In this section we use available data for 1993–4 (i.e. after the main period reviewed in this paper) to describe new trends observed in the artisanal fishery.

(1) *Diversification*

The artisanal fishery in Region XII is slowly recovering after a period of major changes due to certain events that forced restructuring in this sector. As a consequence of the overexploitation of centolla and the establishment of a seven month closed season, artisanal fishermen turned their attention towards other resources.

Although the annual catch of crustaceans continues to be significant (2,487 tonnes in 1992; 2,200 tonnes in 1993), the actual landings have dropped by almost half compared to 1988. This can be better shown by considering the percentage of crustaceans as part of the total artisanal production. Between 1985 and 1989 crustaceans represented 30% of the total artisanal production. Since then the percentage has declined as follows: 1990, 25%; 1992, 20%; 1993, 10%. By contrast, in 1989, sea urchins accounted for only 0.5% of the total artisanal catch (80 tonnes). By 1993, they comprised 50% of the total artisanal catch, most of which was exported to Japan. Early in 1994, a daily average of 3 tonnes of sea urchins was being exported to Japan.

Other traditional resources in the region include clams, mussels, squid and octopus. The exploitation of molluscs initially seemed to offer an interesting alternative, but since 1990, persistent red-tide events lasting up to a year in a large part of the region have meant that they became too toxic for human consumption. In 1992, a red tide lasting for a year or more (Dr Luis Vergara, Director of the Servicio Nacional de Salud, *La Prensa Austral*) affected 100% of the interior waters. Nevertheless, molluscs provided 33% (6,500 tonnes) of the total artisanal catch in 1993 (c.f. 60% in 1989).

Many artisanal fishermen in the region invested in demersal fishery equipment, encouraged by the high catches of the newly arrived industrial fleet. However, for a number of reasons this proved unsuccessful, including a lack of knowledge on the biology and migration patterns of these species, insufficient technical knowledge, an inability to compete economically with the industrial fleet and the fact that artisanal vessels are restricted to interior waters. An estimated 80% of these fishermen returned to the exploitation of traditional resources as illustrated by the percentage contribution of demersal fishing to total artisanal fishery production: 1990, 20%; 1992, 2%; 1993, 5%.

In summary, although with limited diversification the relative importance of crustaceans in artisanal fishery landings has diminished significantly, in terms of absolute production, the catch continues to be important. The Magallanes artisanal fishery continues to be unpredictable and susceptible to sudden changes in the external market.

(2) *Legislation*

Modifications in fishery legislation in 1991 introduced the concept of 'Full Exploitation Regime' with a partial restriction of access through the auction of established fishing quotas. As noted earlier, a special decree was introduced extending the closed season for centolla from 5 to 7 months per year, but this was revoked in 1991 when the red tides prevented the mollusc fishery acting as an alternative source of income during the closed season. The new legislation has enhanced the reorganisation of the crab fishery by restricting the number of operating companies and increasing the requirement for infrastructure as a condition of permits. The fact that artisanal fishermen must subscribe to a regional register and reside in the region of their fishing activity should facilitate control and management in the region. Modifications also refer to the creation of Regional and Zonal Fisheries Councils with consultative and regulatory power, respectively, and the participation of the artisanal sector. Finally, a rigorous application of more severe sanctions should increase the efficiency of control.

(3) *Organisation*

The artisanal sector is beginning to move towards labour organisation through unions and cooperatives, although participation is still limited (approx. 30% of the 1,600–1,700 fishermen). This should facilitate co-operation with regard to control, technical assistance, social and medical care, education etc. The creation of a training centre in 1992 (FUNCAP, Fundación para la Capacitación del Pescador Artesanal) that provides free specialisation courses to artisanal fishermen and the requirement that they subscribe to the local register should result in some improvement in social conditions.

(4) *Education*

The knowledge of and interest in marine mammals in Chile is increasing, as indicated by the number of workshops and conferences and by the growing number of researchers in the field. There is also more concern for conservation by the community channelled through regional and national non-governmental organisations. The strong increase in (eco)tourism in the region may increase awareness of the economic value of marine mammals. Tourism has been the fastest growing sector in Magellanes' local economy for the last three years and in 1993, ecotourism accounted for about 25% of the total regional tourism revenue (total of US$70 million, 160,000 visitors; Servicio Nacional de Turismo, Sernatur, 1994).

Although marine expeditions are now offered, despite the great potential (e.g. see the WDCS report on whale watching in Latin America and the Carribean, 1994) none as yet is based on dolphin or whale watching activities.

(5) *External pressure*

On 13 May 1992, a US based NGO formally petitioned the US government to ban imports of crab and crab products from Chile, under the 1972 Marine Mammal Protection Act. This provides for the Secretary of the Treasury to ban the import of commercial fish and fish products caught with methods that kill marine mammals in excess of US standards. The petition was supported by at least nine major US based environmental and wildlife conservation NGOs and by Fisheries Associations.

In response, the Chilean government through its regional office SERNAP, produced a leaflet on aspects of the biology of some of the species of marine mammals in regional waters and called for a study of the bait problem in Region XII.

A multi-disciplinary commission was established to study the availability of legal bait and mechanisms for its distribution in the fishing areas. The commission determined that a stock of 40 tonnes of bait (mostly originating from industrial fishery waste) should be kept frozen in case no fresh legal bait is available. However, no agreed mechanisms have been established concerning the legal enforcement of the use of this bait or the cost of permanently maintaining such a stock. Ultimately, the decision to buy and be supplied with legal bait depends upon the fishermen themselves.

RECOMMENDATIONS

(1) To reduce to a minimum the use of illegal bait, an independent consultant should be engaged to: (a) assess the current availability of legal bait in the region; (b) make cost-benefit comparisons; (c) plan for the development of an infrastructure to distribute bait to the fishing areas; and (d) provide a legal framework to make the use of legal bait obligatory.

(2) Public awareness regarding cetaceans should be increased by: (a) establishing a follow-up to the 1992 programme of education for children on marine mammals and their environment, supported by the IUCN Cetacean Specialist Group; (b) evaluating the potential of dolphin and whale watching in the region and ensuring that the promotion of projects to develop this activity includes suitable regulations and guidelines; (c) the promotion of marine protected areas in Chile, including the incorporation of sites of special interest for marine mammals.

(3) Studies of the populations of small cetaceans should be supported; these should focus on obtaining data that can be used to assess fishery impacts on populations (e.g. abundance, distribution and stock identity; populations dynamics, trophic relations).

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Interactions Between Small Cetaceans and Peruvian Fisheries in 1988/89 and Analysis of Trends

Koen Van Waerebeek[1,2] and Julio C. Reyes[3]

ABSTRACT

In 1988 and 1989 we monitored the fish terminal of Pucusana, central Peru, for 259 and 233 days respectively, and observed 1,613 and 1,292 small cetaceans landed. The estimated total yearly kills (1988/1989) at this port are 2,289 (SE=130) and 2,320 (SE=117) animals, including 1,725/1,893 dusky dolphins, 383/331 Burmeister's porpoises, 155/57 common dolphins, 18/31 bottlenose dolphins and 8/8 specimens of other species. With few exceptions, the animals were captured incidentally or directly in gillnets in a multi-species artisanal fishery (only about twelve animals were seen with harpoon wounds). The total kill at Pucusana in 1989 had increased roughly by a factor of three compared to 1986 levels and tenfold compared to 1985. A shift was observed in seasonality of peak landings of dusky and common dolphins. Catch estimates for another port, Cerro Azul (13°00'S), are 68 (SE=17) dolphins and porpoises in December 1987 and 131 (SE=47) in July 1988. Analysis of statistics provided by the Ministry of Fisheries (MIPE) suggest a steady decline in small cetacean catches for the entire coast of Peru, from an estimated 9,700 animals (756 metric tonnes) in 1985 to 5,500 (426 metric tonnes) in 1988; the reason for this is unknown since the trend in artisanal fishing effort associated with cetacean mortality cannot be deduced from existing data. There is an urgent need to continue and expand research in the area.

KEYWORDS: INCIDENTAL CAPTURE FISHERIES; SOUTH PACIFIC; DUSKY DOLPHIN; BURMEISTER'S PORPOISE; COMMON DOLPHIN; BOTTLENOSE DOLPHIN; SHORT-FINNED PILOT WHALE; LESSER BEAKED WHALE; DWARF SPERM WHALE; RISSO'S DOLPHIN; SOUTHERN RIGHT WHALE DOLPHIN

INTRODUCTION

Since Clarke (1962) first reported a Burmeister's porpoise (*Phocoena spinipinnis*) for sale in the Chimbote fish market in 1960, several workers have drawn attention to a growing catch of small cetaceans off the Peruvian coast (Grimwood, 1969; Clarke *et al.*, 1978; Mitchell, 1975; Brownell and Praderi, 1982).

Our investigation of the Peruvian dolphin fishery started in 1984 in collaboration with A. Luscombe from the Lima-based Association for Ecology and Conservation (ECCO). For the ensuing two years it was expanded into an IUCN/UNEP funded project directed by D. Gaskin from Guelph University (Gaskin *et al.*, 1987; Read *et al.*, 1988). After 1987 we proceeded to set up a small field laboratory, named the 'Peruvian Centre for Cetacean Research' (CEPEC), in the fishing town of Pucusana and continued the research (Reyes and Van Waerebeek, 1988; Van Waerebeek, 1989; Van Waerebeek and Reyes, 1990a).

Although progress in the analysis of biological data of exploited species has been slow due to a lack of resources, information is available for the Burmeister's porpoise (McKinnon, 1988; Reyes and Van Waerebeek, 1994), bottlenose dolphin, *Tursiops truncatus* (Reyes, 1989; Van Waerebeek *et al.*, 1990) and *Mesoplodon peruvianus*[4] (Reyes *et al.*, 1991). An exhaustive study of the biology of Peruvian dusky dolphins (*Lagenorhynchus obscurus*) has recently been finalised (Van Waerebeek, 1992a; b; 1993; Van Waerebeek *et al.*, 1993; Van Waerebeek and Read, In press).

The purpose of the present paper is threefold: (1) to offer a detailed report of the observed take of dolphins and porpoises at Pucusana in 1988 and 1989; (2) to compare this with equivalent data from earlier years, to identify tendencies and where possible to interpret them; (3) to evaluate official statistics in an attempt to assess the current extent of small cetacean exploitation in Peru.

ARTISANAL FISHERY

Over the period 1984–89, field research was conducted primarily in Pucusana (12°30'S) and to a lesser extent in Cerro Azul (13°00'S), two artisanal fishing villages on the central Peruvian coast. They were selected because of their considerable landings of cetaceans and accessibility (Fig. 1). Other coastal ports and fishing communities were visited on a much less regular basis.

Below we summarise the principal aspects of the small cetacean fishery interaction in Peru, as revealed in earlier work by colleagues and ourselves (Read *et al.*, 1988; Van Waerebeek and Reyes, 1990a; Van Waerebeek and Reyes, 1990b; Van Waerebeek *et al.*, 1990). A few minor points have been adapted to match new insights gained.

Fishery mortality of small cetaceans in Peru results from both an incidental and a directed take. Off central Peru, four species account for more than 99% of the catch: the dusky dolphin, Burmeister's porpoise, the bottlenose dolphin and the long beaked common dolphin (*Delphinus delphis* according to current IWC practice c.f. *Delphinus capensis*; see Heyning and Perrin, 1994). Over three quarters of the total kill are dusky dolphins. Occasionally single individuals of other species are landed.

Most animals are caught in medium-sized (600–1,500m x 10m) multifilament nylon drift gillnets with stretched mesh sizes of up to 20cm. The nets are usually set at dusk and recovered in the morning by artisanal fishermen operating from small open boats (<15m). Target species include the blue shark (*Prionace glauca*), the shortfin mako shark (*Isurus oxyrhynchus*), hammerhead sharks (*Sphyrna* spp.), the thresher shark (*Alopia vulpinus*), eagle rays (*Myliobatis* spp.) and other large schooling fish such as bonito (*Sarda chiliensis*) and dorado (*Coryphaena hippurus*) as well as dusky dolphins. In recent years it has become common practice to set driftnets with the intention

[1] *Centro Peruano de Estudios Cetológicos (CEPEC), Casilla 1536, Lima 18, Peru*
[2] *Institut Royal des Sciences Naturelles de Belgique, Bruxelles, Belgium*
[3] Present address: *Casilla 392, Talcahuano, Chile*
[4] We recommend 'lesser beaked whale' be the vernacular name.

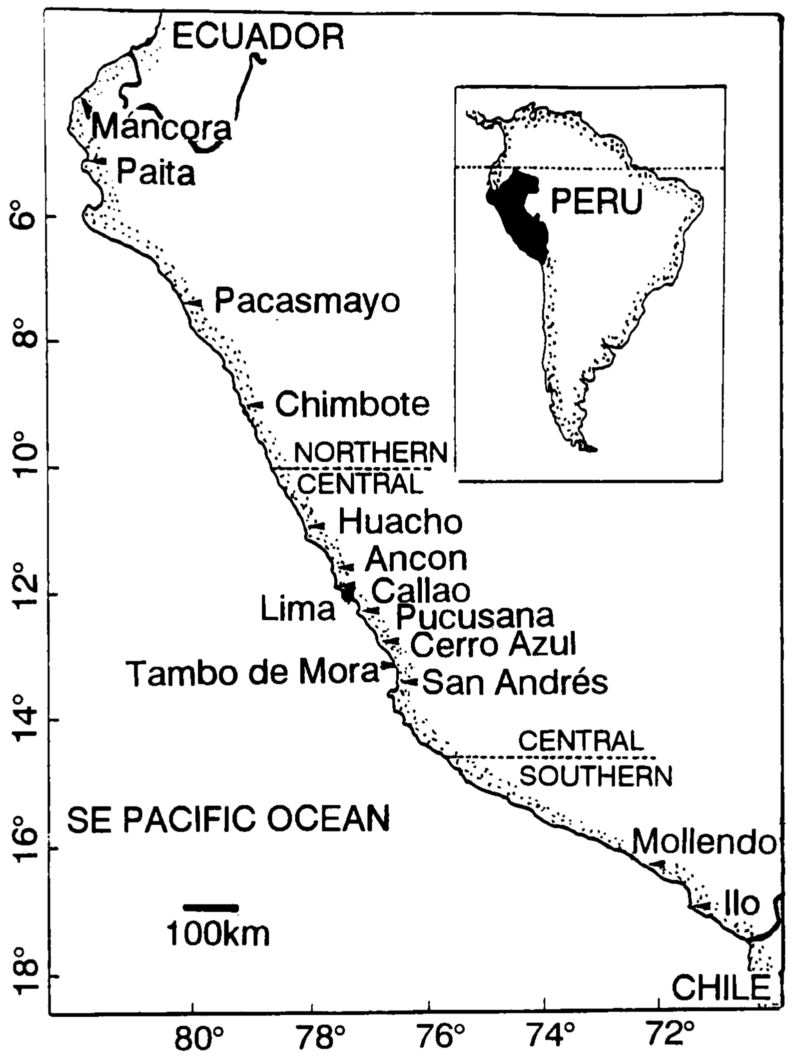

Fig. 1. Map of Peru. Fishing ports with important small cetacean catches are indicated.

of catching dusky dolphins in areas where schools have been located. This occasionally results in several tens of dolphins being unloaded at fish terminals in a single day.

Offshore bottlenose dolphins and other oceanic species are a welcome bycatch to the fishermen, especially in summer months. Burmeister's porpoises become entangled accidentally primarily in demersal gillnets, set for bottom-dwelling rays (*Myliobatis* spp.) and sharks (*Mustelus* spp.), less often for *pejegallo* (*Callorhinchus callorhinchus*) and lorna (*Sciaena deliciosa*).

Dolphins may also be caught by hand-thrown harpoons (especially common dolphins) and in purse seines in the industrial fishery for small pelagic fish. It is doubtful whether purse seines are set specifically on dolphin pods, although in March 1985 some 15 common dolphins, including live animals, were seen landed by a purse seiner at the wharf of Chimbote (09°05′S). From fishermen's reports it seems that such bycatches continue to occur with some regularity.

The meat of the dolphins is primarily used for human food, mostly fresh but also in a dried variety called *muchame*. Estimated total annual kills for Pucusana increased from 170 in 1985 to 760 the next year and 1,101 (SE=32) in 1987. The total catch in Peru for 1985 was roughly estimated at 10,000 dolphins and porpoises.

MATERIALS AND METHODS

CEPEC port monitoring

In 1988 and 1989, we monitored the fish terminal of Pucusana for landed small cetaceans over a total of 259 and 233 days respectively. As in preceding studies (Read *et al.*, 1988; Van Waerebeek and Reyes, 1990a, Van Waerebeek and Reyes, 1990b), the mean daily catch rate for each species was calculated, stratified by month, in order to estimate monthly and total annual catches. Standard errors (SEs) were determined following Read *et al.* (1988).

At least one of us was present in Pucusana for an average 21.4 days per month (range: 5–31 days), except for May 1989 when no monitoring took place. The mean daily catch rate for that month was estimated as the sum of the catch rates for April and June 1989 divided by two. The SE was estimated as the square root of the sum of the respective variances divided by two (Wonnacott and Wonnacott, 1969), assuming that covariance between April and June catch rates is negligible.

Unfortunately we were not able to follow closely the dynamics of the fishery dolphin trade as was possible for a short period in 1986 (Lehman, 1988) and nor was it possible to monitor Cerro Azul or other Peruvian ports with sufficient regularity to enable estimates to be made of yearly catches. However, catches were recorded at Cerro Azul for five days in December 1987 and for 13 days in July 1988, and monthly kill estimates for these months were computed. Random visits to a few other coastal towns allowed us to obtain some idea of the exploitation of small cetaceans in those areas.

Shifts in seasonality and catch composition at Pucusana are analysed by comparing combined data over the period 1985–7 with those of 1988–9. Estimated kill figures are evaluated on a yearly basis.

Table 1

Cetacean catch composition (in %) for the period 1985-89, used in the computation of mean weight for a hypothetical 'Small Cetacean Unit' (SCU) to interpret Ministry of Fisheries' (MIPE) statistics expressed in metric tonnes. In square brackets are total counts of small cetaceans examined on which composition is based; for northern Peru this includes some cetacean remains collected in the vicinity of fishermen's landing sites. No data are available for southern Peru. Mean weight of 'other species' category is approximated by the mean weight for bottlenose dolphins.

		Percent catch composition	
Species	Mean body weight (kg)	Central Peru [N=5,411]	Northern Peru [N=114]
L. obscurus	73.00	77.8	0.0
P. spinipinnis	48.93	12.3	71.1
D. delphis	84.67	7.1	15.8
T. truncatus	171.44	2.4	11.4
G. macrorhynchus	951.67	0.30	1.8
Mesoplodon sp.n.	253	0.17	0.0
Other species	171.44	0.18	0.0
Small cetacean unit		76.53kg	84.84kg

Official statistics

The only complete set of quantitative data available for each of the 48 principal maritime ports and fishing villages of Peru are the official statistics compiled by the Ministry of Fisheries (MIPE) in collaboration with the Instituto del Mar del Perú (IMARPE). For management reasons, MIPE divides the Peruvian coast into northern, central and southern zones, with borders set roughly at 10°S and 14°30′S (Fig. 1).

However, MIPE data on cetacean landings do not distinguish among species and catches are expressed in metric tonnes of small cetacean (*tonino*). We estimate approximate numbers of animals caught by dividing the total weight by the weight of a hypothetical 'small cetacean

Table 2

Observed numbers (line 1), estimated numbers (line 2) and standard errors (in brackets) of small cetaceans, stratified per month, landed at the Pucusana fish terminal, central Peru, in 1988. Estimates and SE have been rounded to the nearest integer.

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Dusky	2	9	6	8	250	70	269	127	68	12	277	127	1225
dolphin	3	10	9	13	287	88	491	219	93	74	308	131	1725
	(1)	(2)	(3)	(4)	(28)	(8)	(105)	(46)	(11)	(43)	(37)	(26)	(124)
Burmeister's	2	12	3	6	55	44	13	14	41	11	47	11	259
porpoise	3	13	5	10	63	55	24	24	56	68	52	11	383
	(1)	(1)	(1)	(3)	(11)	(6)	(5)	(6)	(8)	(17)	(5)	(1)	(25)
Bottlenose	3	1	2	0	1	0	0	2	0	0	1	3	13
dolphin	4	1	3	0	1	0	0	3	0	0	1	4	18
	(1)	(0)	(1)	(0)	(0)	(0)	(0)	(2)	(0)	(0)	(0)	(0)	(3)
Common	0	0	0	11	15	48	30	1	0	0	1	2	108
dolphin	0	0	0	18	17	60	55	2	0	0	1	2	155
	(0)	(0)	(0)	(5)	(2)	(14)	(13)	(1)	(0)	(0)	(0)	(0)	(19)
Other species	3	1	0	0	0	1	0	0	0	0	1	1	7
	4	1	0	0	0	1	0	0	0	0	1	1	8
	(1)	(0)	(0)	(0)	(0)	(1)	(0)	(0)	(0)	(0)	(0)	(1)	
Total	10	23	11	25	321	163	312	144	109	23	327	145	1613
	13	25	17	42	369	204	569	248	149	143	363	150	2289
	(2)	(2)	(3)	(10)	(29)	(19)	(115)	(45)	(15)	(46)	(37)	(4)	(130)

Table 3

Observed numbers (line 1), estimated numbers (line 2) and standard errors (in brackets) of small cetaceans, stratified per month, landed at the Pucusana fish terminal, central Peru, in 1989. For estimates of the month May see text. Estimates and SE have been rounded to the nearest integer.

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Dusky	95	87	53	47	-	201	163	97	53	128	73	63	1060
dolphin	140	87	68	109	205	287	253	334	106	159	81	65	1893
	(34)	(0)	(14)	(14)	(26)	(42)	(37)	(68)	(32)	(29)	(9)	(3)	(151)
Burmeister's	11	36	18	45	-	7	5	2	1	18	16	16	175
porpoise	16	36	23	104	59	10	8	7	2	22	27	17	331
	(6)	(0)	(3)	(14)	(8)	(3)	(3)	(1)	(1)	(4)	(3)	(1)	(19)
Bottlenose	5	0	0	0	-	3	2	0	0	1	12	23	
dolphin	7	0	0	0	2	4	3	0	0	0	1	12	31
	(3)	(0)	(0)	(0)	(2)	(2)	(1)	(0)	(0)	(0)	(0)	(1)	(4)
Common	0	0	0	0	-	4	3	11	3	0	0	0	21
dolphin	0	0	0	0	3	6	5	38	6	0	0	0	57
	(0)	(0)	(0)	(0)	(1)	(2)	(3)	(13)	(2)	(0)	(0)	(0)	(14)
Other species	1	0	0	0	-	2	-	-	-	-	1	1	5
	1	0	0	0	3	3	0	0	0	0	1	1	9
	(1)	(0)	(0)	(0)	(1)	(1)	(0)	(0)	(0)	(0)	(0)	(0)	(1)
Total	111	123	71	92	-	217	173	110	57	146	100	92	1292
	165	123	92	212	270	310	268	379	114	181	111	92	2320
	(35)	(0)	(15)	(32)	(28)	(43)	(38)	(68)	(33)	(32)	(9)	(4)	(117)

unit' (SCU). The SCU is based on the mean recorded weight for each species and the average observed species composition from as many ports as possible over the 1984–1989 period (Table 1). While 77.8% of small cetaceans landed in central Peru are dusky dolphins, this species does not normally occur off northern Peru (Brownell and Praderi, 1984; Van Waerebeek, 1992b). Therefore a separate SCU for central and northern Peru are needed. At present we have insufficient data to compute an SCU for southern Peru and thus assume, based on our knowledge of the distribution of small cetaceans (Van Waerebeek *et al.*, 1988) that it is not different from that of the central coast.

RESULTS

Cetacean landings: Pucusana

In 1988 and 1989 we observed, respectively, 1,613 and 1,292 small cetaceans of nine species landed at the Pucusana fish terminal. The total yearly kill at this port is estimated as 2,289 (SE=130) for 1988 and 2,320 (SE=117) for 1989. No correction has been made for small cetaceans killed and lost, since this factor is unknown. The observed and estimated numbers of dolphins and porpoises landed in each month are given in Tables 2 and 3. The months with the highest kill rates are July in 1988 (569 specimens; SE=115); June (310; SE=43) and August (379; SE=68) in 1989.

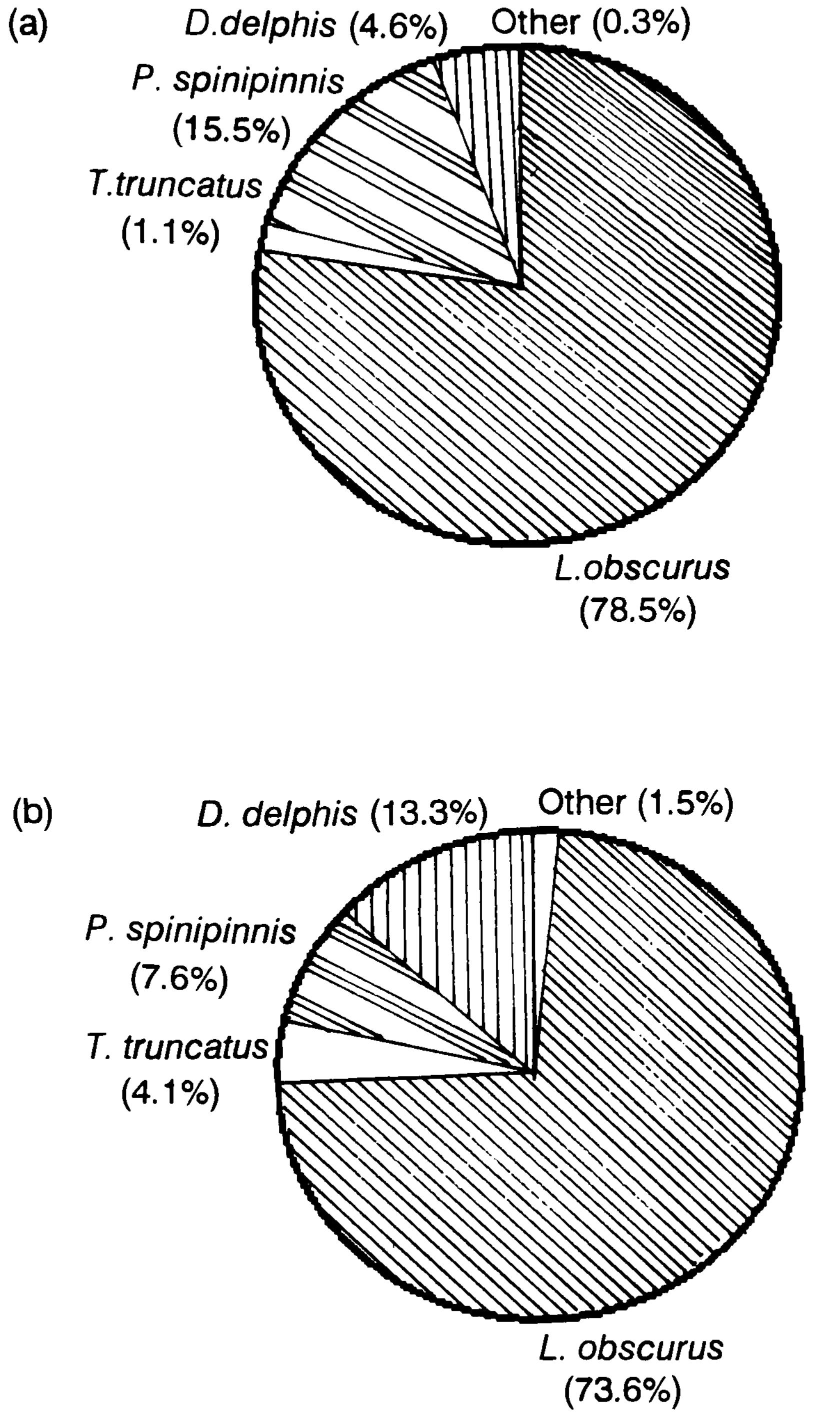

Fig. 2. Comparison of species composition of small cetaceans landed at Pucusana fish terminal, pooled over 1988–89(a) and 1985–87(b).

Dusky dolphins accounted in both years for more than three quarters of the kill, Burmeister's porpoises for an average 15% and common dolpins decreased significantly in prevalence from nearly 7 to 2.5%. Bottlenose dolphins represented on average only 1% (Fig. 2). In the two year period, the following 'other' species were seen at the fish terminal: five short-finned pilot whales (*Globicephala macrorhynchus*), three lesser beaked whales, one dwarf sperm whale (*Kogia simus*), one Risso's dolphin (*Grampus griseus*) and one southern right whale dolphin (*Lissodelphis peronii*). The latter is the second confirmed record of this species in Peruvian waters and the most northerly of its entire known range (Van Waerebeek *et al.*, 1991).

In the 1988–89 period, with few exceptions, dolphins and porpoises were captured in gillnets in a multi-species artisanal fishery as described above. In general, time constraints prevented us from collecting much data on fishery effort or catches by gear type. However, for a controlled subsample of 61 Burmeister's porpoises landed, the following observations were made: 47.5% (29) of the animals were captured in demersal nets set for bottom dwelling elasmobranchids and the holocephalid *pejegallo*, 31% (19) were landed with blue sharks and dusky dolphins taken in surface drift nets, while only some 10% (6) were caught in inshore sciaenid nets.

Harpooning developed into a systematic capture method in 1987 (Van Waerebeek and Reyes, 1990a) but a subsequent local decree prohibited this practice. After a few dolphins had been seized by port authorities, buyers refused further animals with harpoon wounds. As a result, over the two year period only four common dolphins, three bottlenose dolphins and four dusky dolphins examined at the fish terminal showed harpoon wounds. In one instance, however, some fishermen were caught landing a few butchered dusky dolphins directly on the beach at night, which they admitted had been harpooned. Later, with a change of port authority personnel, enforcement relaxed and harpooning resumed to some extent in 1990. At Pucusana we recorded only one animal, a common dolphin, landed by a purse seiner.

The price per kg of dolphin (whole animal) offered to the fishermen almost doubled from US$0.14 per kg in late 1986 (Lehman, 1988) to an average of US$0.25 in April 1989. Several buyers have specialised in the trade in dolphin meat, which has ceased to be regarded as inferior. Prices continue to fluctuate, depending on availability and demand at the Lima central market.

Cetacean landings: Cerro Azul

Part-time monitoring of the small fish terminal of Cerro Azul resulted in a kill estimate of 68 (SE=17) dolphins and porpoises in December 1987 and 131 (SE=47) animals in July 1988. The species composition is given in Table 4.

Table 4

Observed and estimated numbers (±1SE) of small cetaceans landed at Cerro Azul during December 1987 (n=5) and July 1988 (n=13). Estimates and standard errors are rounded to the nearest integer. DD= dusky dolphin; BP = Burmeister's porpoise; BD = bottlenose dolphin and CD = common dolphin.

	Species:	DD	BP	BD	CD	Total
Dec 1987	Observed	6	3	1	1	11
	Estimated	37	19	6	6	68
	SE	±16	±7	±6	±6	±17
July 1988	Observed	51	1	0	3	55
	Estimated	122	2	0	7	131
	SE	±47	±2	±0	±3	47

Official statistics

MIPE data suggest that the total Peruvian kill of small cetaceans has declined since the 1979 peak catch (1,409 tonnes). National landings decreased from 756 tonnes in 1985 to 426 tonnes in 1988 (Fig. 3), equivalent to a decrease from an estimated 9,700 to 5,500 small cetaceans in those years. However, the accuracy of these data is questionable. Only at the best equipped fish terminals, such as Pucusana, are specimens actually weighed. In most smaller ports body weight is still estimated from the size of the animal. We have good estimates of total kills per species for the period 1985–89 in Pucusana and by combining this with data on mean weights we can calculate total weight estimates for the yearly catch. Table 5 shows that the MIPE totals for Pucusana fall well within ±1 SE of our estimates and as such are sufficiently accurate.

Unfortunately we have but a single example to check the accuracy of MIPE statistics for other ports. In 1986, the fish terminal of Cerro Azul was monitored for 142 days and 237 cetaceans were landed. Subsequently the 1986 total catch

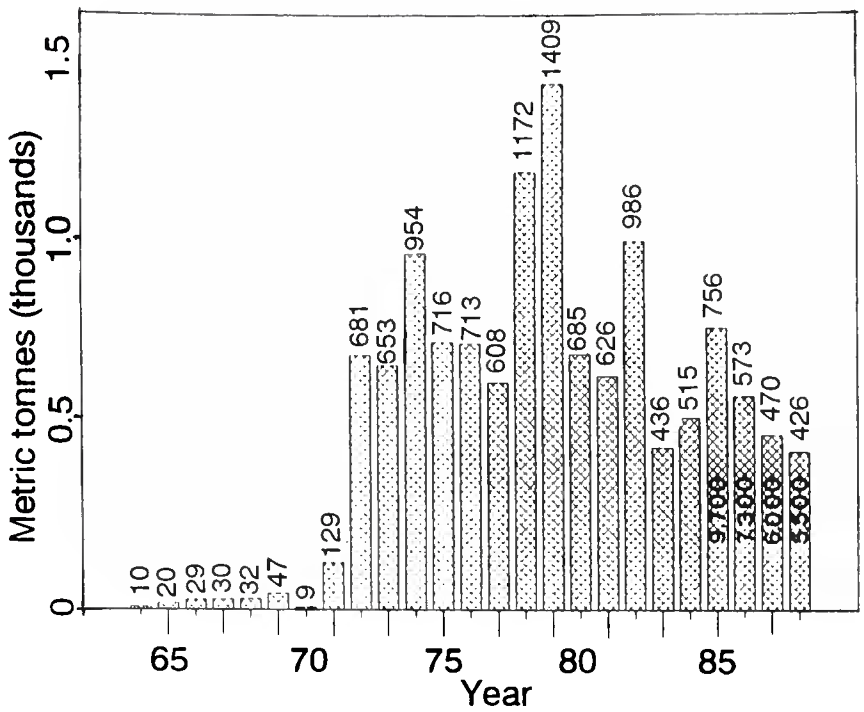

Fig. 3. Total mass (in tonnes) of small cetaceans landed at Peruvian coastal ports between 1964 and 1988. Confidence interval data do not exist. Source: Department of Statistics, Ministry of Fisheries (MIPE), Lima. Figures positioned vertically inside bars are estimated numbers of small cetaceans caught, calculated from total weight, mean specimen weights and recorded species composition (see text).

was estimated at 587 animals with SE 80 (Read *et al.*, 1988). The total weight is estimated at 40.65 tonnes (SE 11.84 tonnes), which is significantly different (99% confidence intervals) from the 99 tonnes cited by MIPE statistics. The difference may have been caused by systematic overestimation of weights or by human error in the manipulation of figures.

Other errors in MIPE data are likely to arise from unreported bycatches. The latter may be particularly true for incidentally caught small cetaceans in the extreme north of Peru, where cetacean meat is of very low esteem. Specimens are often discarded and thus fail to be registered in the port logbooks (S. Zambrano, Asociación de Ecología y Conservación, pers. comm.).

In summary, we suggest that the MIPE data require careful interpretation, since their reliability may vary over time and from one port to another. However, positive and negative deviations might offset each other, resulting in a lower error margin in the total catch figure.

DISCUSSION

Pucusana

The increase in gross cetacean landings at Pucusana in recent years has been dramatic. Catches in 1989 were roughly three times those in 1986 and tenfold compared to 1985 levels (Fig. 4).

The proportion of dusky dolphins in the total kill has remained almost steady at roughly three out of four animals (77%) since 1985 (Fig. 2). The rapid development of the directed gillnet fishery for dusky dolphins (Fig. 5) has been the principal reason for the strong growth in overall numbers of cetacean catches.

The estimated kill of Burmeister's porpoises more than quadrupled from 83 in 1987 to 383 animals in 1988 (Fig. 5) while its relative share in the catch rose abruptly from 7.5% to 16.7%.

Landings of bottlenose dolphins have oscillated around a mean of 26 animals a year, with no apparent changes between years (Fig. 5), with most catches being taken from the offshore stock. Due mainly to the large numbers of

Table 5

Total annual weight (in metric tonnes) of small cetaceans landed at Pucusana and Cerro Azul according to figures of the Peruvian Ministry of Fisheries (MIPE) and estimates by the authors (CEPEC). The latter were calculated based on the observed catch composition and recorded mean weights for each species. The 1985 estimate was taken from Read *et al.,* 1988. MIPE data do not have confidence intervals.

	Source	1985	1986	1987	1988	1989
Pucusana	MIPE	17	77	87	173	?
	CEPEC	18.1	62.8	87.3	163.4	169.1
	SE	±3.6	±16.7	±16.4	±38.9	±42.9
Cerro Azul	MIPE	44	99	47	53	-
	CEPEC	-	40.6	-	-	-
	SE	-	±11.8	-	-	-

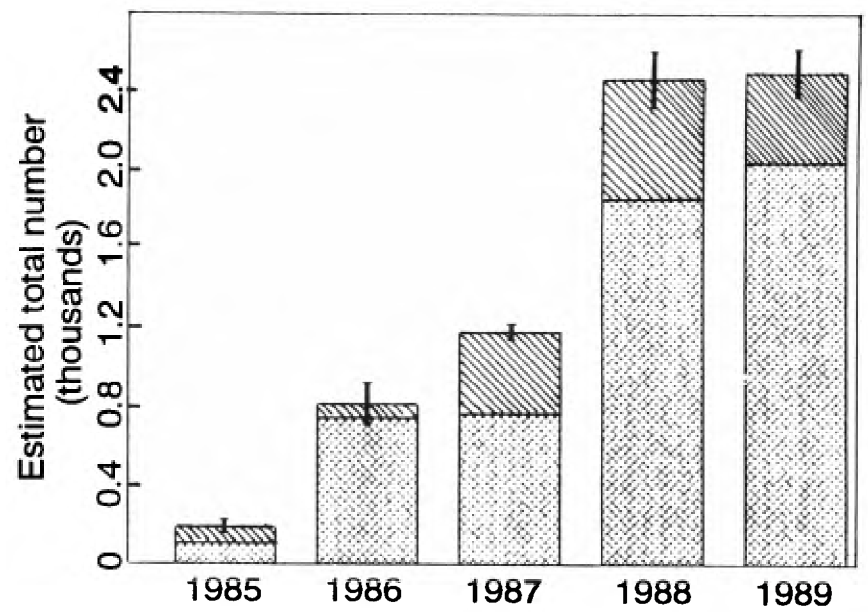

Fig. 4. Estimated yearly numbers, with confidence intervals (±1SE), of small cetaceans landed at Pucusana. Double-hatched area indicates dusky dolphins. Data for 1985–6 are taken from Read *et al.* 1988.

dusky dolphins landed in recent years, bottlenose dolphins represented a steadily decreasing component of total cetacean landings: from a peak of 11% in 1985 to 1% in 1988–89.

In 1985–1986 the common dolphin was so rarely encountered that we included it in the category 'other species'. In 1987, a harpoon fishery suddenly emerged resulting in 264 common dolphins being landed, accounting for 24% of total cetacean landings in that year. Since then catches have been steadily decreasing again (Fig. 5), at least partly due to a successful anti-harpoon campaign.

No pattern seems to exist in the frequency with which *G. macrorhynchus*, *M. peruvianus* or other species are landed.

Months with peak catches of dusky and common dolphins have shifted over the study period (Fig. 6). In the period 1985–87, large numbers of dusky dolphins were landed from August to November, i.e. during late winter and spring, but in 1988–89 catches increased as early as May (late autumn) and were down again by September, the former height of the 'dusky season'. An entirely analogous situation was seen in the long beaked common dolphin (Fig. 6). At this point it is not possible to tell whether this is due to fluctuations in environmental factors, which may affect the timing of movements of the dolphins or a reflection of shifts in fishing effort.

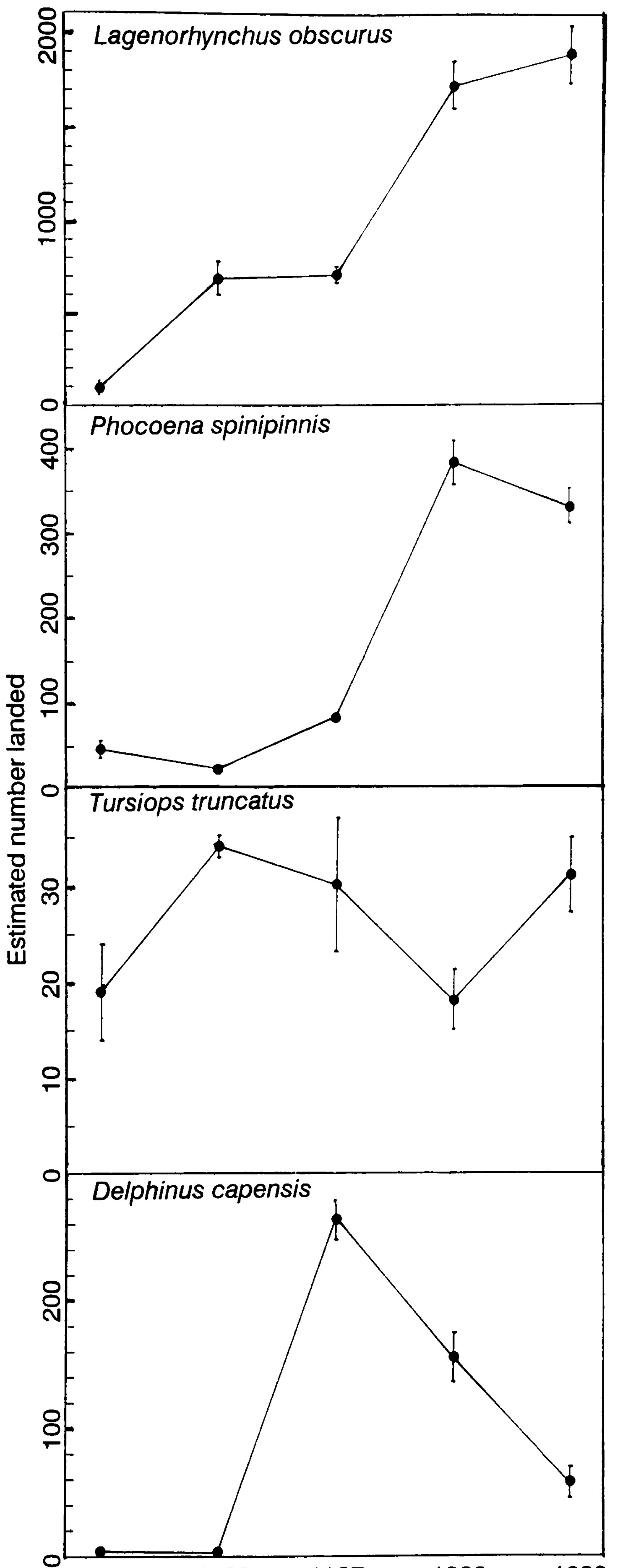

Fig. 5. Estimated annual landings of dusky dolphins, Burmeister's porpoises, bottlenose dolphins and long-beaked common dolphins at Pucusana port, Peru. Confidence intervals are ±1SE, several of which are too small to be visibly indicated.

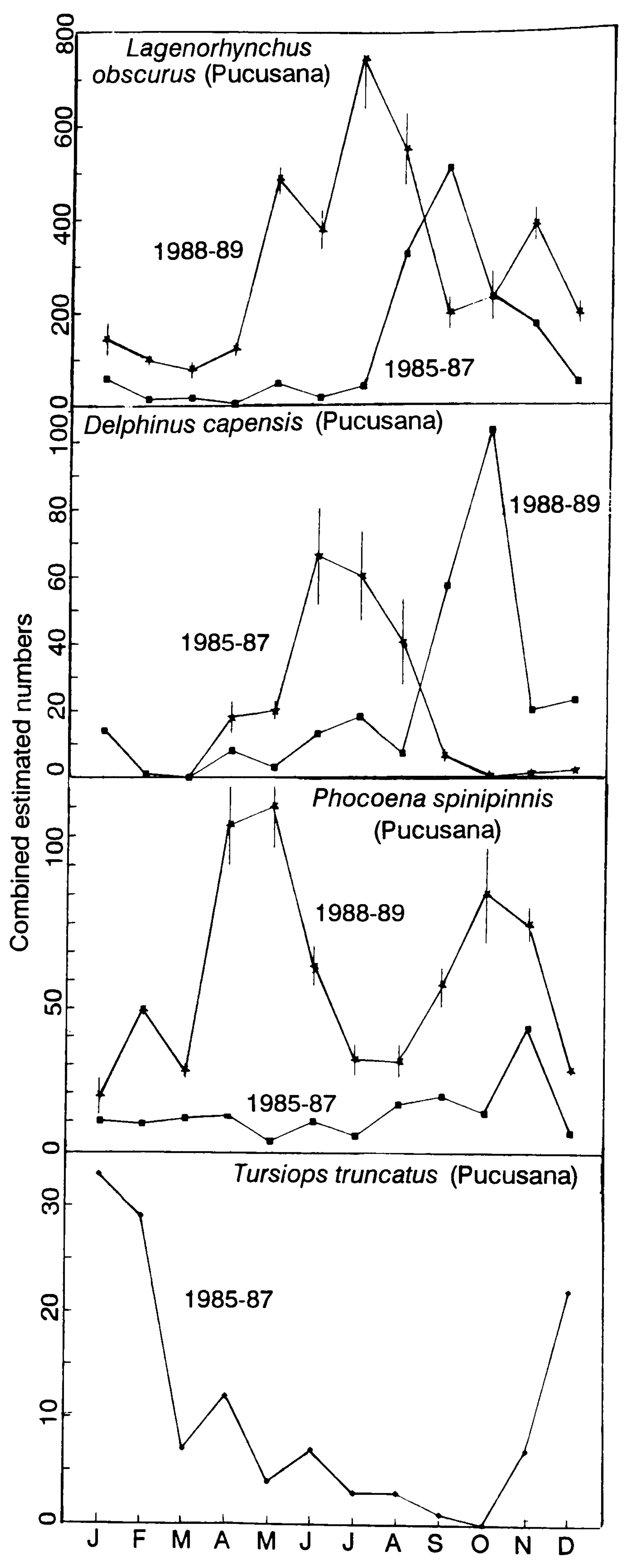

Fig. 6. Monthly distribution in landings of small cetaceans at Pucusana, Peru combined for monitoring periods 1985–87 and 1988–89. Confidence intervals (±1SE) are indicated where available.

A serious problem concerning the winter 'high season' of the dusky dolphin fishery is that it falls in the midst of the reproductive peak, resulting in a high mortality of pregnant or lactating females and neonates. In winter, many of the pelagic (mostly warmwater) fish are too far offshore to be economically and safely fished. This encourages fishermen to set nets closer inshore, on average 40.9±13.7km (Gaskin *et al.*, 1987), resulting in high kill rates of dusky dolphins. In summer the main fishing effort is concentrated farther from shore at 75.3±61.4km (Gaskin *et al.*, 1987), perhaps beyond the highest density zone of dusky dolphins, which might explain the lower numbers of this species landed during the summer.

In the Burmeister's porpoise, two peaks in fishery mortality can be seen (Fig. 6), one during autumn (April-May) and one in spring (October-November) but the reason for this remains unclear.

Bottlenose dolphins are caught predominantly in summer from November to March (Fig. 6), confirming previous observations (Read *et al.*, 1988; Van Waerebeek *et al.*, 1990). Due to the summer narrowing of the coastal upwelling zone (Schweigger, 1964) and the fact that fishermen in the summer venture farther from the coast, offshore bottlenose dolphins from subtropical waters fall within range of the artisanal fishery.

Trends in the fishery

A cardinal point when discussing the trends in exploitation is whether MIPE cetacean landing data should be regarded as accurate or not. We will assume that they are roughly reliable at least to the point of demonstrating a relative tendency.

Cetacean landings are unevenly distributed along the Peruvian coast (Read *et al.*, 1988). According to MIPE statistics, in the period 1981–84, the central coast accounted for 62% of the kill, the north for 24% and the south for 15%. The dominance of the central area became stronger between 1985 and 1988 (74% central Peru, 22% in the north and 4% in the south; Fig. 7). If true, this could be explained by the observed development of a directed catch of dusky dolphins in a few ports close to Lima and not, or to a lesser degree, in other ports. For example (based on MIPE data), Pucusana and Cerro Azul combined were responsible for 15% of the total Peruvian kill in 1983–85 while this figure had risen to 29% in 1987 and to 53% in 1988.

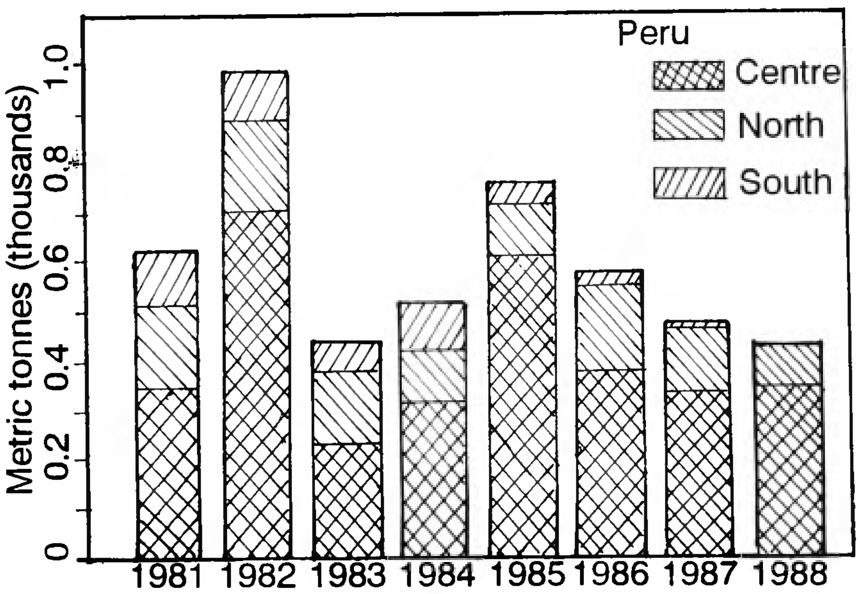

Fig. 7. Regional distribution of small cetacean kill (in tonnes) in Peru between 1981 and 1988. Confidence interval data do not exist. Source: Department of Statistics, Ministry of Fisheries (MIPE), Lima. For definition of regions see text.

Our own data confirm a major increase in catches at Pucusana (Fig. 4) and suggest a fair increase at Cerro Azul, largely as a result of increased landings of dusky dolphins and parallel improvements in land-based facilities for processing and transport and the general efficiency of personnel. Examples range from better availability of butcher's knives to the use of modern thermoregulated transport trucks. As a result, the Pucusana fish terminal has smoothly handled ever larger numbers of dolphins and porpoises. In 1989, one dolphin buyer even systematically transported an important part of the Cerro Azul catch to Pucusana for cleaning and eviscerating prior to final shipment to Lima.

Improved facilities seem to play their own role in enhancing catches. With little doubt partly due to a newly built wharf at Tambo de Mora (13°30'S) this port has nearly tripled its cetacean landings in the past two years (MIPE statistics).

Fig. 8 shows that gross annual landings of fresh fish products (excluding molluscs but including cetaceans) have been rising in the wake of the severe 1982–83 El Niño event (Barber and Chavez, 1983). The higher catches probably should at least partly be ascribed to the rebuilding of fish stocks after the El Niño. Whether this was accompanied by an increase in artisanal fishing effort or not, remains unclear since we were unable to obtain specific effort data.

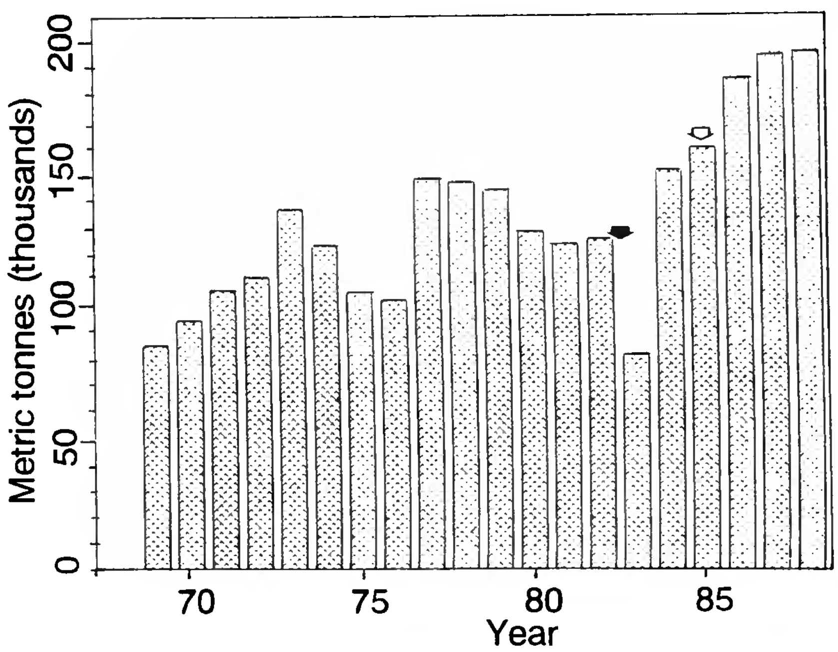

Fig. 8. Total fresh fish landings for human consumption (including cetaceans, excluding molluscs), in tonnes, from coastal Peru in 1969–88. Confidence limits are not available. Source: Department of Statistics, Ministry of Fisheries, Lima. Black arrow: severe 1982–3 El Niño. Open arrow: first port monitoring by authors.

If we would choose to regard MIPE cetacean data as too inaccurate to be useful, we are left with our evidence of very high catches at Pucusana and, probably, Cerro Azul. What happens at other Peruvian ports, especially in the north, is in any case a matter of grave concern and should be investigated as soon as possible.

Research needs

Whereas it is recognised that MIPE is the most appropriate institution to collect data on cetacean catches over the entire Peruvian coast, it is strongly recommended that MIPE modifies monitoring of dolphin and porpoise landings to a number-of-animals-by-species base. Parallel to such a measure, practical instruction of port authority personnel in identification of the most commonly encountered small cetaceans should be arranged.

Dedicated monitoring should continue and be expanded to include at least a few important ports in northern and southern Peru. In particular, more information on catch compositions and actual fishing effort are needed for a more accurate interpretation of available MIPE data. Also it seems essential that systematic boat surveys be initiated to gather elementary data on relative abundance of species in relation to season, locality and successive years. Finally, biological sampling ought to continue and existing facilities in Peru should be upgraded to allow for specific sample and data analysis.

POSTSCRIPTUM

Ministerial decree #569-90-PE, issued by MIPE (*El Peruano 29 November 1990*), introduced a ban on the taking, processing and trade of small cetaceans in Peruvian waters. However, post-ban monitoring (1991–94) indicated that both incidental and directed takes remained high and may even have increased. It is highly unlikely that current levels of removal are sustainable. Stringent measures should be taken to reduce incidental mortality. The existing law should be implemented to halt directed killing. This is discussed further in Van Waerebeek and Reyes (1994).

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SC/46/SM16

Post-Ban Small Cetacean Takes off Peru: A Review

Koen Van Waerebeek [1,2] and Julio C. Reyes [1,3]

ABSTRACT

Information on small cetacean mortality in Peruvian fisheries is reviewed for the 1990–1993 period, i.e. after the national ban on cetacean exploitation. Most ports along the Peruvian coast were sampled during short visits while Cerro Azul, Pucusana, Chimbote, Ancón and San Andrés were more intensively monitored. The ban was found not to be enforced or at best only partially so. Fishermen often avoided overtly landing entire carcasses, which impeded quantification of kills. Large numbers of small cetaceans were caught directly and indirectly in drift and set gillnets, were harpooned or were netted in purse seines (and often landed alive) by vessels operated by the fishmeal industry. Principal species affected included *Lagenorhynchus obscurus*, *Delphinus capensis*, *Phocoena spinipinnis* and *Tursiops truncatus*, although occasional takes of at least six other small cetacean species occurred. Estimated annual kills (±SE) were: 1,651±53 (1990) at Pucusana; 2,118±389 (1992) and 1,927±237 (1992/93) at Cerro Azul; 2,100 (1991) and 1,383±274 (1992) at Ancón; 1,825±220 at Chimbote (1993) and about 470 at San Andrés (1992). Santa Rosa, San José, Culebras, Huarmey and Chancay also accounted for high landings. Although no scientific estimate of the total annual take of cetaceans in the period 1990–1993 can be calculated, the best available evidence suggests it ranged between 15,000 and 20,000 specimens. Albeit illegal, fresh and processed *muchame* type cetacean meat is widely available and openly sold. A new ministerial decree of August 1994 caused a welcome wave of law enforcement action, but its impact and long-term effects still have to be assessed. Recommendations on how to mitigate kills are discussed.

KEYWORDS: KEYWORDS: SOUTH PACIFIC; DIRECT CAPTURE; INCIDENTAL CAPTURE; FISHERIES; MANAGEMENT; DUSKY DOLPHIN; LONG-BEAKED COMMON DOLPHIN; SHORT-BEAKED COMMON DOLPHIN; BOTTLENOSE DOLPHIN; BURMEISTER'S PORPOISE; SHORT-FINNED PILOT WHALE; LESSER BEAKED WHALE; MINKE WHALE; RIGHT WHALE DOLPHIN.

INTRODUCTION

Peruvian artisanal and commercial fisheries operate from some 181 coastal localities, ranging from international seaports with vast fishing fleets such as Chimbote and Paita, to simple beach-heads. Only about 50 of these have some port infrastructure (Wosnitza-Mendo *et al.*, 1988). Small cetaceans have been taken both incidentally and directly in gillnet and harpoon fisheries at least since the early 1970s but until the mid-1980s almost nothing was known of kill levels and even less on the distribution and biology of affected species.

The 'IUCN/UNEP Burmeister's Porpoise Project' implemented in 1985–86 first tackled these issues in a systematic way. Much of the Peruvian and northern Chilean coast was surveyed to identify the sites with highest cetacean landings. Scientific monitoring and a sampling programme was then started at two selected ports, Pucusana and Cerro Azul, south of Lima (Van Waerebeek and Guerra, 1986; Gaskin *et al.*, 1987; Guerra *et al.*, 1987; Read *et al.*, 1988). Volunteers of the Peruvian Centre for Cetacean Studies (CEPEC) in cooperation with the Association for Ecology and Conservation (ECCO) continued this work and despite limited resources, obtained a wealth of information on fisheries interactions (Van Waerebeek and Reyes, 1990a; b; 1994a; García-Godos, 1993; Van Waerebeek *et al.*, 1993; Van Waerebeek, 1993c; Van Waerebeek *et al.*, 1994) and on the biology of the most frequently captured Peruvian small cetaceans, the dusky dolphin *Lagenorhynchus obscurus* (see Manzanilla, 1989; Van Waerebeek, 1992a; b; 1993a; b; Van Waerebeek *et al.*, 1993; Van Waerebeek and Read, In press), Burmeister's porpoise *Phocoena spinipinnis* (see Reyes and Van Waerebeek, 1995), bottlenose dolphin *Tursiops truncatus* (see Reyes, 1993; Van Waerebeek *et al.*, 1990) and the long-beaked common dolphin *Delphinus capensis* (see Van Waerebeek, 1993c; Van Waerebeek *et al.*, 1994).

The Peruvian Ministry of Fisheries (MIPE) estimated the 1985 cetacean kill in Peru at 756 tonnes (MIPE, unpublished data), equivalent to around 10,000 dolphins and porpoises (Read *et al.*, 1988; Van Waerebeek and Reyes, 1994a). The combined takes of the dusky dolphin, Burmeister's porpoise, long-beaked common dolphin and bottlenose dolphin (inshore and offshore populations) accounted for more than 98% of the catch. The majority of animals were taken by artisanal fishermen in drift and set gillnets, together with several species of sharks (blue, mako, hammerhead and mustelid sharks), rays and other large fishes such as bonito (*Sarda chilensis*), dorado (*Coryphaena hippurus*) and cojinova (*Seriolella violacea*). Large numbers were also killed by hand-held harpoons and in nets set by 300–350 GRT purse seiners fishing for anchovy and sardines for the fishmeal industry. Most of the cetacean meat is consumed fresh by people of modest income groups or salt-dried and commercialised as an expensive delicacy (*muchame*).

After 1985, MIPE statistics suggested a decline in total annual take to 426 tonnes (equivalent to about 5,500 specimens) in 1988 and a subsequent peak kill in 1989 of 1,093 tonnes (Ramírez and Zuzunaga, 1991), i.e. about 14,100 specimens. However, sampling of the Pucusana port by CEPEC volunteers showed that the cetacean kill in 1989 had increased roughly by a factor of three compared to 1986 levels and tenfold compared to 1985 (Van Waerebeek and Reyes, 1994a). In 1989 alone, a total of 2,317±117 SE dolphins and porpoises were landed at the Pucusana wharf. Details of the fishery are given in Read *et al.* (1988), Van Waerebeek and Reyes (1990a; b; 1994a), Reyes and Van Waerebeek (1991), Van Waerebeek (1993c), Van Waerebeek *et al.* (1993; 1994) and García-Godos (1993).

[1] *Centro Peruano de Estudios Cetológicos (CEPEC), casilla 1536, Lima 18, Perú*
[2] *Institut Royal de Sciences Naturelles de Belgique, 29 Rue Vautier, B-1040, Brussels, Belgium*
[3] Present address: *casilla 392, Talcahuano, Chile*

Legal status of cetaceans in Peru

In 1990, the Peruvian government protected small cetaceans by law following increasing concern expressed in Peru and abroad about the long-term survival of these animals. Ministerial resolution No. 569–90-PE of 23 November 1990 (Anon., 1990) outlawed the capture and trade in small cetaceans or products thereof (meat). Responsibility of enforcement lay with the regional governments, regional offices of the Ministry of Fisheries and the National Office of Port Authorities and Coast Guards of the Ministry of Defence. Resolution No. 321–94-PE of 8 August 1994 (Anon., 1994) replaced the 1990 law. The contents are the same but now district and provincial municipalities are also made responsbile for implementing the prohibition. In addition, river dolphins, including the boto (*Inia geoffrensis*) and the tucuxi (*Sotalia fluviatilis*) have been legally protected in Peru since 1973 by decree No. 943–73-AG, which prohibits hunting, capture and trade in all species of the Peruvian Amazon basin.

Subsequently, legislative decree No. 635 (Codigo Penal) of 3 April 1991 in article 308 (paragraph XIII) considers crimes against the Natural Resources and the Environment and stipulates imprisonment for the hunting or commercial exploitation of species of fauna and flora that are legally protected (Cresci, 1993). International trade in cetaceans and cetacean products is subject to regulations set by the Convention on the International Trade of Endangered Species of Fauna and Flora (CITES), signed by Peru. The three most frequently captured delphinids and the Burmeister's porpoise all feature on Appendix II of CITES. Peru joined the IWC in 1979 and adopted its provisions through Ministerial Resolution No. 345–79-PE. In December 1991, the Peruvian Government approved the UNEP proposed 'Action Plan for the Conservation of Marine Mammals in the Southeast Pacific'. The principal objective is to support participating governments (Colombia, Chile, Ecuador, Panama and Peru) to improve the conservation policy of marine mammals in the region (UNEP, 1992). The UN Convention on the Law of the Sea (UNCLOS) will officially come into force in November 1994 after Guyana became the 60th nation to submit its formal ratification to the UN. Article 65 of UNCLOS provides for the international conservation of marine mammals and cetaceans in particular (Cetacean Society International, 1994).

Despite legal protection, limited post-ban sampling by CEPEC suggested that directed takes of small cetaceans, after an initial decline in some ports, had returned to former levels. In 1992, UNEP and the Whale and Dolphin Conservation Society (WDCS) agreed to support a 1993 survey to assess cetacean mortality levels with authorisation from the Peruvian Ministry of Fisheries.

MATERIAL AND METHODS

As noted above, before the 1990 ban on cetacean exploitation, the Ministry of Fisheries recorded cetacean landings in metric tonnes per port (e.g. Ramírez and Zuzunaga, 1991). Albeit crude, for many ports it represented the only available measure of fishery-related kill levels. After the ban, MIPE stopped gathering information on cetacean mortality, presumably because removals should have ceased. This paper reviews information on cetacean mortality collected during the post-ban period (November 1990 – December 1993) by the authors and volunteers of CEPEC (see acknowledgements) as well as unpublished results of the 1990 monitoring at Pucusana. It thus complements the papers by Van Waerebeek (1994) and Van Waerebeek and Reyes (1994a). Complete daily sampling data and a preliminary analysis are given in Van Waerebeek *et al.* (1994).

Data collection was essentially the same as in previous years (see Gaskin *et al.*, 1987; Read *et al.*, 1988; Van Waerebeek and Reyes, 1990a; 1994a). In summary, the authors and collaborators visited ports along the 2,500km Peruvian coast in 1993. A day spent at a particular port was counted as a sampling day only when the entire landing process of takes was observed. Three ports known to have high landings of cetaceans (Chimbote, Cerro Azul and Ancón) were selected for more intensive sampling. San Andrés was monitored by V. Tenicela (Museo Nacional de Historia Natural, Lima) in 1992. The long-term sampling programme at Pucusana had to be discontinued since the activities of the port authorities prevented fishermen landing whole carcasses at the fish terminal (although meat was routinely brought ashore). Fishermen also avoided landing cetaceans overtly in many other ports which greatly complicated our efforts to quantify takes; recorded numbers of animals may thus be lower than those actually captured. At some locations, e.g. Cerro Azul, Chancay and (initially) Ancón, dolphins and porpoises were brought ashore as if no prohibition existed.

Cetacean remains such as heads, flippers, strips of blubber, vertebra etc. found near coastal communities (±5km strip of beach either side) were presumed to originate from fishery interactions unless there was a good reason to believe otherwise. That the density of such material was usually high immediately north of ports and significantly lower or absent south of it, can be explained by the dominant northbound inshore currents. Specimens encountered on the many beach surveys were quantified by means of cranial evidence only, except where only scant remains were found. Informal interviews with hundreds of fishermen and other locals provided useful information on the best places to look for specimens. Several coastal sites could be visited only once or a few times due to their remoteness and our limited resources. The composition of the cetacean take was determined per port and per coastal region for the post-ban years and compared with pre-ban data (where available). The three coastal regions as defined by MIPE are northern Peru (Puerto Pizarro to Culebras), central Peru (Huarmey to Laguna Grande) and southern Peru (San Juan de Marcona to Vila Vila) (see Fig. 1).

Two types of estimates are employed, a 'scientific estimate' based on a random or near-random sample of acceptable size and linked to some measure of error, and a 'tentative estimate' which is an approximation based on the best available evidence but which was not necessarily derived mathematically. Standard errors (SE, further indicated by '±') of mean daily catch rates were estimated as $SE = (SD/\sqrt{n}).\sqrt{(1-\phi)}$ with SD the standard deviation, n the number of days monitored and $\phi = n/N$ the sampling fraction (Snedecor and Cochran, 1980). Standard errors and 95% confidence intervals (CI) of proportions were calculated according the normal approximation rule (Wonnacott and Wonnacott, 1990). To permit a tentative annual (post-ban) catch for Peru to be estimated, we classified ports for which no scientific estimate was available into the most plausible of four categories (Categories B-E) based on survey data and interviews and assigned an average take for each (shown in brackets); to avoid problems of possible overestimation, Category A status was not assigned to any port unless it was scientifically monitored. The five categories are described below.

Category A
Very high annual catches, exceeding 1,500 cetaceans; largely the result of directed takes.

Category B
High annual catches, 500–1,500 (1,000) animals; many caught directly. Large numbers of fresh animals and abundant remains were recorded during limited surveying. Local sources confirm high takes as the norm.

Category C
Moderate annual take, 50–500 (275) animals; predominantly incidental. Some fresh specimens and abundant skeletal material found in the neighbourhood of the port. Local sources admit cetacean takes.

Category D
Low annual take, 0–50 (25) animals. No fresh animals were seen but some skeletal material was retrieved on nearby beaches.

Category E
Virtually no take (0). No fishery that can cause cetacean mortality operates in the area. No specimen evidence (fresh or other) encountered.

'Directed take' means all live-landed and harpooned cetaceans, dolphins caught alive in purse seine nets but not released (probably most) and animals captured in large-mesh driftnets (*animalero* nets). Unusually high numbers of Burmeister's porpoise caught in nearshore small-mesh gillnets in localities where the meat is fully utilised commercially (e.g. San José) are also included. Other takes are considered 'incidental'.

Since 1990, CEPEC members have observed more than 2,000 dolphins and porpoises landed. Due to the haste with which animals are butchered, for most only the locality,

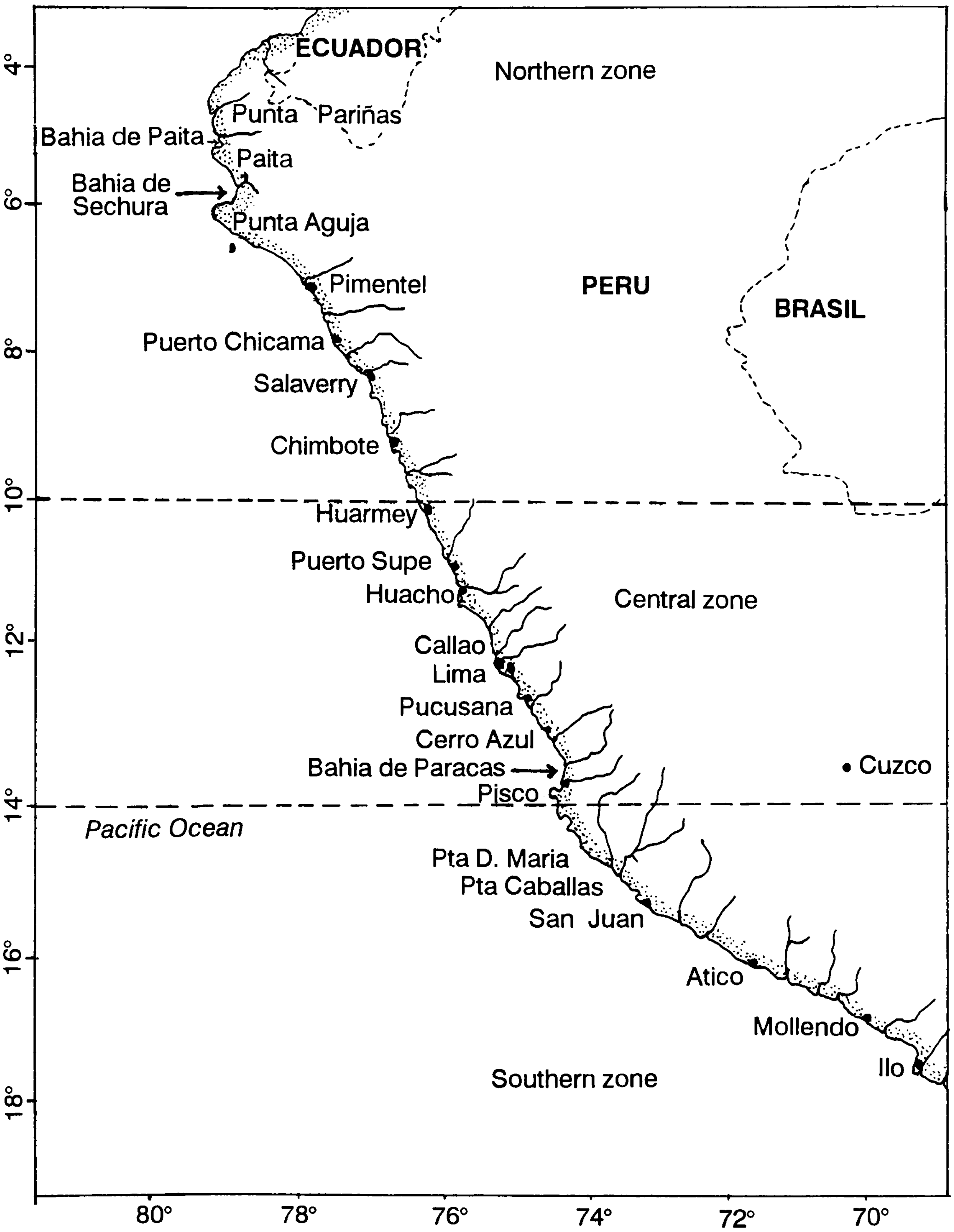

Fig. 1. Map of the region showing place names mentioned in the text.

date, species, sex and total length could be recorded. For a few hundred we documented more or less complete life history data. This and previously collected information will be analysed on a species by species basis and presented at a later date.

RESULTS

Chimbote

Chimbote (420km north of Lima) is one of Peru's few natural harbours and its largest fishing port, hosting several fishmeal factories. A 1985 attempt to set up a sampling programme in Chimbote identified high kills but was discontinued due to adverse conditions (Gaskin *et al.*, 1987).

In 1993, we sampled the artisanal terminal for 53 days, 37 days in summer (January-April) and 16 days in winter (June-August). A total of 265 dolphins and porpoises were observed: 132 *D. capensis* (49.8%, CI 43.8–55.8%); 119 *P. spinipinnis* (44.9%, CI 38.9–50.9%); 13 *T. truncatus* (4.9%, CI 2.3–7.5%); and one unidentified dolphin. Several independent sources reported occasional takes of 'much larger' cetaceans, most likely short-finned pilot whales (*Globicephala macrorhynchus*) or lesser beaked whales (*Mesoplodon peruvianus*). Results are summarised in Table 1. Although the mean daily kill was somewhat higher in summer than in winter, the difference was not significant (Z=-1.48, Mann-Whitney, P=0.14) due to large daily variations. The annual kill estimate for 1993 based on the pooled sample (mean daily take = 5.00±0.60) is 1,825±220 (CI: 1,394–2,256). These numbers refer to recorded animals only, which almost certainly underestimates true kill rates. Indeed, market workers are known to pay bribes and/or hide animals to avoid confiscation. In addition, not all captured cetaceans necessarily pass through the artisanal terminal, some are landed elsewhere and taken straight to markets.

Table 1

Catches at Chimbote in 1993

	Days			
Period	Observed	Total	Estimated catch	Mean daily kill
Summer	37	120	672 (513-831)	5.60 ± 0.67
Winter	16	92	334 (179-489)	3.63 ± 0.85

Burmeister's porpoises were typically taken by gillnet boats and small-scale purse seiners (<100 GRT). Most common dolphins were taken by industrial purse seiners (>100 GRT), fishing principally for anchovy and sardine, or small purse seiners which set on a variety of pelagic schooling fishes. A great variety of fish species was marketed at Chimbote. In January 1993, for instance, bonito, mackerel, jack mackerel, cachema, sierra, lorna, cabinza, coco, pintadilla were most often seen; more occasionally flounder, guitar fish, machete, cherlo and castañeta. Due to the often dense crowds at the port, the restricted access to the pier and the huge volumes of catches, it was rarely possible to determine from which boats individual cetaceans were unloaded. No evidence of harpooning was found in Chimbote but many common dolphins had plastic bags or wet paper stuffed into the blowhole and nasal passage, a method often used to suffocate dolphins. We witnessed two battered but live animals being killed this way, while one had its throat slit and was left to bleed to death. Unlike net-killed dolphins, the skin of most dolphins at Chimbote showed extensive bruising suggesting a violent death while out of the water, presumably onboard purse seiners.

Overall there was a solid demand for cetacean meat; carcasses were usually sold within 10–15 minutes after being eviscerated. Cetacean meat in bulk (with bone) was sold for US$0.6–0.7/kg at the terminal although when large numbers were landed, apparently temporarily saturating the market, whole dolphins were reportedly sold by wholesalers for US$6. Much of the meat was bought by fishmongers who resold it on the central market at Chimbote for US$0.9–1.2/kg. Almost as a rule, after 0800hrs little evidence of the illegal trade was visible. Fishmongers commented that by doing so they effectively avoided interference by MIPE personnel 'who rarely show up in the early morning'. We witnessed a few cases of apparent bribery involving marines on patrol (Van Waerebeek *et al.*, 1994).

The large catches of cetaceans have been a persistent problem at Chimbote. In 1986, KVW photographed 11 long-beaked common dolphins, several alive, inhumanely unloaded from a purse seiner. In three days we counted 26 common dolphins, 4 bottlenose dolphins and 1 Burmeister's porpoise at the former artisanal terminal (Read *et al.*, 1988). However, there are also apparently exaggerated claims of high catch levels. Stuart Wilson (Environmental Investigation Agency, unpublished data) claimed that during July/August 1990 catches at Chimbote averaged 200 dolphins per day. Although locals have hinted at occasional huge single-day landings, it is highly unlikely this number reflects daily mean catches over extended periods. Inappropriate extrapolations have led to overestimates of total kills (see Currey *et al.*, 1990).

Pucusana

The general characteristics of the Pucusana small-scale fishery have been described in detail by Gaskin *et al.* (1987), Read *et al.* (1988) and Van Waerebeek and Reyes (1990a; 1994a). During a total of 230 days sampled at the Pucusana artisanal terminal in 1990 we registered 958 small cetaceans: 750 *L. obscurus* (78.3%, CI 75.7–80.9%), 139 *P. spinipinnis* (14.5%, CI 12.3–16.7%), 44 *D. capensis* (4.6%, CI 3.3–5.9%), 21 *T. truncatus* (2.2%, CI 1.3–3.1%), 2 *Globicephala macrorhynchus*, 1 *Lissodelphis peronii* and 1 *Mesoplodon peruvianus*. Landings stratified by month are given in Table 2 and based on this information the 1990 annual take at Pucusana is estimated at 1,651±53 (CI: 1,547–1,755). The majority of dolphins were killed in large-mesh animalero driftnets together with large fishes, but as in earlier years, some were taken in smaller-meshed drift and set gillnets (especially porpoises). In addition, two common dolphins and one dusky dolphin were harpooned on 12 March 1990 by a single boat and there were a few animals for which cause of death could not be ascertained. A shift in the species composition of catches from dusky to common dolphins (Fig. 2) is discussed by Van Waerebeek (1994).

In response to the 1990 legislation, the Pucusana port authorities prohibited the landing of cetaceans at the terminal (and enforced it) which made it impossible to monitor kills. However, fishermen continued taking dolphins but covertly landed and sold their catches. Dolphins are unloaded into anchored boats before docking at the terminal, or are butchered on the way back from the fishing grounds. Meat hidden in boxes topped with fish is brought to shore and swiftly transferred to cool-storage trucks for transport to Lima markets; although usually this is done at night, we have also observed it during the day. Offal including intestines, blubber, backbones and heads is tossed overboard, often in the bay of Pucusana. Questioned fishermen made little attempt to deny that this occurs. Additional evidence comes from the discovery of tens of skulls and backbones scattered over the bay's seafloor (snorkeling by KVW and others). In 1992, fishermen attempted twice to revert to landing carcasses at the terminal, only to abandon it when they noticed that we resumed taking notes and photographs. In ten days 59 animals were landed (Table 4). There is little reason to believe that actual kills have diminished compared to earlier levels and port officials do not interfere with these illegal operations.

Van Waerebeek and Reyes (1994b) report on two juvenile southern minke whales, the first confirmed records for Peru, that were butchered at Pucusana after being accidentally caught in gillnets in September and October 1993; the meat was partly consumed locally and partly taken to Lima.

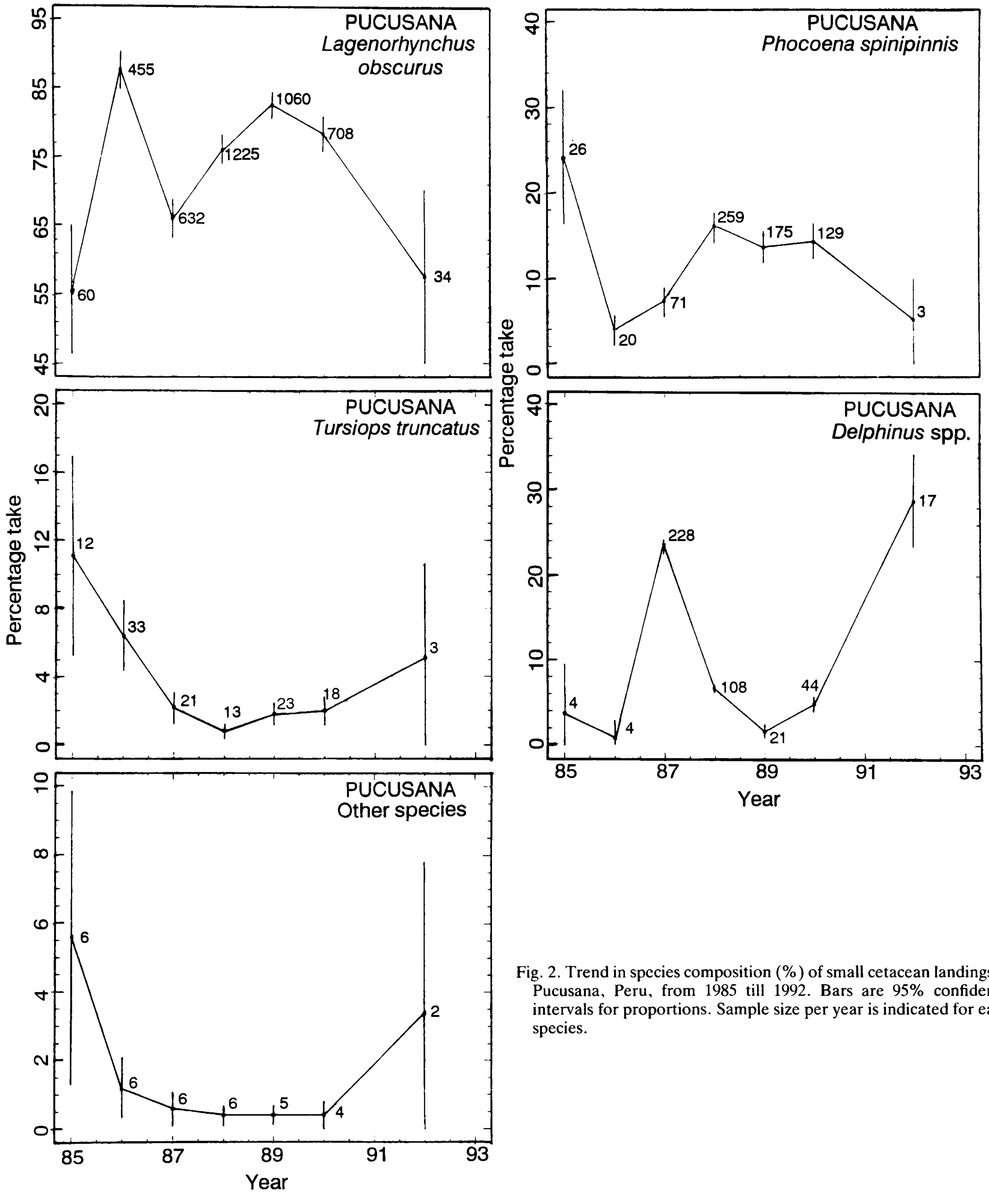

Fig. 2. Trend in species composition (%) of small cetacean landings at Pucusana, Peru, from 1985 till 1992. Bars are 95% confidence intervals for proportions. Sample size per year is indicated for each species.

Table 2

Observed numbers, estimated numbers and standard errors (stratified per month) of small cetaceans landed at the port of Pucusana, central Peru, in 1990. 'Other species' include *Lissodelphis peronii* (Sept.) and *Globicephala macrorhynchus* (Dec.). All numbers are rounded to their nearest integer; some totals may appear erroneous due to this rounding.

Month		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
No. days monitored		25	21	28	30	17	16	9	25	23	9	4	26	230
L. obscurus	OBS	28	34	76	133	49	61	44	47	165	79	8	26	750
	EST	35	45	84	133	89	114	152	58	215	272	60	31	1,289
	SE	3	1	6	0	9	11	27	6	25	17	14	4	44
P. spinipinnis	OBS	13	10	18	17	12	8	5	9	10	7	4	26	139
	EST	16	13	20	17	22	15	17	12	13	24	30	31	230
	SE	3	3	2	0	5	6	11	2	3	10	10	3	21
T. truncatus	OBS	2	2	4	3	4	0	0	0	0	0	1	5	21
	EST	2	3	4	3	7	0	0	0	0	0	8	6	33
	SE	1	1	1	0	3	0	0	0	0	0	6	2	7
Delphinus spp.	OBS	0	2	2	1	11	16	9	1	1	1	0	0	44
	EST	0	3	2	1	20	30	31	0	0	3	0	0	93
	SE	0	1	1	0	4	9	9	1	1	3	0	0	14
Other species	OBS	0	0	0	0	0	1	0	0	1	0	0	2	4
	EST	0	0	0	0	0	2	0	0	1	0	0	2	6
	SE	0	0	0	0	0	1	0	0	1	0	0	1	2
Total	OBS	43	48	100	154	76	86	58	57	177	87	13	59	958
	EST	53	64	110	154	139	161	200	71	231	300	98	70	1,651
	SE	4	3	6	0	11	15	31	6	25	20	18	5	53

Cerro Azul

During January-March 1992 (summer), we sampled the Cerro Azul fish terminal for 41 days and examined 199 small cetaceans; during winter (June-September) 25 animals were recorded in four days. The composition of the take is presented in Table 3. The mean daily catch rate for 1992 is estimated at 5.07 ±1.22 (N=45). While only about half (51.3%) of the catch consisted of *L. obscurus*, a significant decrease from the more than 80% in 1985–90, about 40% were *D. capensis*, an all-year peak (Fig. 3). Of 25 cetaceans seen landed in winter 1992, 21 were *D. capensis*.

In 1993, the fishmarket of Cerro Azul was monitored for 125 days in March-December, during which we observed a total of 684 (1,652 ±128) dolphins and porpoises (Table 3). The mean daily catch rate in 1993 was 5.16 ±0.59 (N=128), practically identical to the rate recorded in 1992 (Mann-Whitney pairs test, Z=0.24, P=0.81). Considering that different seasons were sampled, we feel confident in concluding that catch rates remained stable throughout the entire period. Using a weighted mean daily catch rate (5.28 ±0.65, N=174), the annual take for the 1992–93 period is thus estimated at 1,927 (CI 1,457–2,397) specimens.

Most cetaceans were landed together with rays, blue sharks, mako sharks, hammerheads and, to a lesser degree, with bonito. The gillnets with stretched mesh size of 20–30cm (*animalero* nets) cause by far the highest mortality. About 20 gillnet boats operate from Cerro Azul although the actual number may fluctuate; not infrequently boats from Pucusana are temporarily based at Cerro Azul and vice versa. Fishermen easily switch between nets of different mesh size which impedes estimation of effort data. Each year specimens (at least 3 in 1992) of a presumably resident group of coastal bottlenose dolphins which feed on inshore fishes (especially mullet) close to the pier, are harpooned. In 1993, we documented several harpooned animals (H) or animals killed by an unidentified piercing object (P): 6 *D. capensis* (3H, 3P), 2 *L. obscurus* (1H, 1P), 2 P. spinipinnis (P) and 1 offshore T. truncatus (H). Because we sampled Cerro Azul only part-time, the true numbers of harpooned animals must be higher.

Ancón

A. Garcia-Godos of CEPEC monitored cetacean mortality at the port of Ancón in the course of 1991–92 and carried out a preliminary analysis (García-Godos, 1993).

In 1991, Ancón was sampled for 57 days spread over all months (except April, May and July) during which 608 small cetaceans were recorded. The daily kill rate was significantly higher (Mann-Whitney pairs test, Z=-4.23, P<0.0001) in August-September (winter, mean=15.53, SD=12.55, n=32) than during other months (mean=4.44, SD=3.67, n=25). In summer, mortality is lower as most fishermen set gillnets with small mesh (5–9cm) for juvenile bonito and mackerel, which rarely entangle dolphins. The observed species composition was: 358 (58.9%, CI 55.0–62.8%) L. obscurus, 168 (27.6%, CI 24.1–31.2%) D. capensis and 82 (13.5%, CI 10.8–16.2%) P. spinipinnis. Sampling was insufficient and kills too seasonally variable to allow a scientific estimate of the total 1991 take. A tentative estimate ranges from a minimum of 1,600 animals, prorated from low-season mean daily take, and a high of 2,600, accounting for the two-tier kill rate and assuming a three-month high winter rate. The mean (2,100) is taken as best estimate. From August until September, 172 boat trips were recorded with an average kill per boat of 2.8 (SD=2.11, range=1–16), if trips with no catches are excluded. One bottlenose dolphin was harpooned, but most dolphins were caught in a directed fishery with large-mesh (22–30cm stretched) drift gillnets. Apart from the dolphins, these nets target blue, mako and hammerhead sharks, *Carcharhynus* sp., and rays. Smaller meshed (10–16cm stretched) nets were set for bonito, cojinova and elasmobranchs. Twenty-five boats were involved in the dolphin fishery on a continuous basis and another eight boats captured dolphins occasionally. Over

Table 3

Observed numbers, estimated numbers and standard errors (stratified per month) of small cetaceans landed at the Cerro Azul fish terminal, central Peru, during months sampled in 1992-1993. 'Other species' include *Globicephala macrorhynchus* (Nov.) and *Mesoplodon peruvianus* (Dec.). All numbers are rounded to their nearest integer; some totals may appear erroneous due to this rounding. Line totals are stratified estimates of corresponding period totals (three months for 1992 and ten months for 1993).

		1992				1993										
Month		Jan.	Feb.	Mar.	Total	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
No. days monitored		5	16	20	41	10	9	12	14	13	12	13	11	15	16	125
L. obscurus	OBS	52	54	5	113	29	26	53	20	35	29	6	43	135	19	395
	EST	322	101	8	431	90	87	137	43	83	75	14	121	270	37	957
	SE	185	23	4	186	26	24	27	9	28	21	8	37	75	17	103
P. spinipinnis	OBS	2	4	7	15	0	6	3	7	5	9	0	7	34	79	
	EST	12	7	11	30	0	20	8	15	12	23	0	20	68	16	182
	SE	7	3	4	9	0	7	4	8	16	7	0	11	21	5	32
T. truncatus	OBS	0	3	4	7	0	0	9	8	0	0	0	3	3	8	31
	EST	0	6	6	12	0	0	23	17	0	0	0	8	6	16	70
	SE	0	4	2	4	0	0	12	9	0	0	0	3	4	8	18
D. capensis	OBS	29	35	4	68	8	16	59	29	10	18	0	3	34	0	177
	EST	180	65	6	251	25	53	152	62	24	47	0	8	68	0	439
	SE	64	12	2	65	11	18	35	16	11	16	0	3	21	0	52
Other species	OBS	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
	EST	0	0	0	0	0	0	0	0	0	0	0	0	2	2	4
	SE	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
Total	OBS	83	96	20	228	37	48	129	64	50	56	6	56	207	36	684
	EST	514	179	31	724	115	160	320	137	119	145	14	157	414	70	1,652
	SE	196	29	6	197	10	41	46	20	35	31	8	51	81	26	128

the first three days of August 1991, some additional animals may not have been accounted for as we suspect that the fishermen hid some specimens in order to avoid control by MIPE personnel (García-Godos, 1993). During 61 observation days between February and December 1992, 231 cetaceans were caught: 113 *D. capensis* (48.9%, CI 42.5–55.4%), 102 *L. obscurus* (44.2%, CI 37.8–50.6%), 11 *P. spinipinnis* (4.8%, 2.0–7.5%) and five *T. truncatus* (2.2%, CI 0.3–4.0%). The mean daily kill was 3.79±0.75, with no obvious variation over the year. An approximate total kill estimate for Ancón in 1992 is thus 1,383 animals ±274 (CI 846–1,920). The location of the bottlenose dolphin captures suggests that they belonged to the offshore population. The dolphins were either killed by harpoon or captured in large-mesh gillnets.

In November 1992, as many as 90% of dolphins (n=199) were killed with hand-held harpoons by boat crews which originated principally from Callao and Chorrillos. In an attempt to avoid monitoring, fishermen shifted the landing and eviscerating of cetaceans towards the night. During a short visit on 3–4 August 1993, pejerrey and juvenile bonito were sold at the market, but no cetaceans; allegedly boats from Chancay had been unloading harpooned dolphins in the early morning. Support for continued kills comes from the fact that processed *muchame* type dolphin meat was available at US$7.50 per kg (wholesale price).

San Andrés

Artisanal fishermen operate mostly from San Andrés, a few kilometres south of Pisco while the industrial fishery is based further south at Paracas. Tenicela (1993) visited the port of San Andrés seven days per month for six months in 1992 (January, May, June, August, October-November). In 42 days 23 *Delphinus* sp., probably mostly *D. capensis*, (42.6%, CI29.4–55.8%), 17 *P. spinipinnis* (31.5%, CI 19.1–43.9%), 7 *L. obscurus* (13%, CI 4.0–21.9%) and one Risso's dolphin *Grampus griseus* (1.9%, CI 0–5.4%) were seen at the fishmarket.

The mean daily kill rate at San Andrés in 1992 was 1.29 specimens, suggesting a minimum annual take of 470 specimens. No SE can be estimated since Tenicela (1993) did not provide a *per diem* landing record. As in other places, the numbers cited are probably underestimates considering that the hiding of animals may be widespread. In addition, fishermen have been known to land cetaceans on surrounding beaches or at the El Chaco jetty. In January 1992, for instance, locals claimed daily takes were as high as 3–4 specimens (Van Waerebeek *et al.*, 1994) while sampling showed a daily catch estimate of only 2.5.

Most cetaceans were gillnet victims but some harpooning almost certainly occurs. Carcasses are either landed clandestinely or butchered offshore. Offal is tossed into the sea and often strands on nearby beaches. There was a significant and progressive decrease in total landings from January until November 1992 (chi-square=16.9, df 5, P=0.005) although the reason for this is unknown. No dusky dolphins were landed during winter while the single Risso's dolphin (female, 320cm) was caught in summer. Locals reportedly consume both fresh cetacean meat and prepare *muchame*. Some of the meat is transported to Lima.

Industrial purse seiners fishing for anchovy, sardines and bonito (the latter for canning) dock at private wharves and could not be inspected. However, it seems likely that non-negligible numbers of common and dusky dolphins are caught, as is generally true for Peruvian purse seine operations. Tenicela (1993) found remains of *Delphinus* sp. and *L. obscurus* near the Paracas fishmeal factories. Within the Paracas reserve, the fishing communities of Lagunillas and Laguna Grande (see below) also account for an unknown take. In 1993, cranial and fresh specimens were encountered during short visits (Table 4) but were not sufficient to enable estimation of total mortality.

Table 4

Summary results of scientific monitoring of cetacean fishery mortality at Peruvian ports in post-ban period. Type information: landings of fresh animals (L) and non-fresh remains (R). *L. obs.* = dusky dolphin; *D. cap.* = long-snouted common dolphin; *P. spi.* = Burmeister's porpoise; *T. tru.* = bottlenose dolphin.

Port	Date	Type	*L. obs.*	*D. cap.*	*P. spi.*	*T.tru.*	Other	Comments
Northern coast								
Puerto Pizarro	1 April 93	L,R	0	0	0	0	0	Small cetaceans said to be caught infrequently
La Cruz	1-2 April 93	L,R	0	0	0	0	0	Few interactions occur; shrimp fishery with trawlers and scoop nets (larvae)
Zorritos	21 February 93	L,R	0	0	0	0	0	Dolphins caught in gillnets; reportedly spotted dolphins present
Cancas	21 February 93	L,R	0	0	0	0	0	Fishermen use harpoons to take swordfish, sailfish and possibly dolphins
Mancora	19-22 Feb. 93	L,R	0	0	0	0	0	Common dolphins and porpoises are taken; also see Orozco (1988)
Los Organos	20 Feb 93	L,R	0	0	0	0	0	Fisherman described how he harpooned dolphins from bowsprit
Talara	16-17 Jan 93	L,R	0	0	0	0	0	Porpoises are said to be caught but landed furtively for fear of confiscation
Negritos	17 Jan 93	L,R	0	0	0	0	0	Landed takes transported to Talara
Paita	21-22 Feb, 28 Sept 93	L,R	0	0	0	0	1	Strip of blubber of unident. small cetacean found at terminal
Parachique	18-20 Feb 93	R	0	2	4	1	0	Tail and flipper of bottlenose dolphin; 0 fresh landings
	27,29,31 Sept 93	L	0	0	0	0	0	Pilar Tello (pers. comm. to KVW, 25 Oct 1993)
San José	14-16 Jan 93	R	0	3	6	0	1 *Ziphiid*	Also 2 backbones of *D. cap.* and 1 of *P. spi.* dump & south beach
	17 Jan 93	R	0	4	35	1	0	Tursiops vertebra only, on *ca.* 6kmof northern beach
	15,16,18 Feb 93	L	0	0	2	0	0	Fresh heads, blubber and intestines
	15,16,18 Feb 93	R	0	4	13	1	1 *G. macro.*	Also non-fresh blubber and a mummified porpoise
Santa Rosa	13-18 Jan 93	L	0	1	0	0	0	Dolphin landed on 15 January
	17 Jan 93	R	0	16	5	0	0	Beach between Santa Rosa and Pimentel
Pimentel	12 Jan 93	L,R	0	1	0	0	0	Freshly cut blubber on beach
	15-16 Jan 93	L,R	0	0	0	0	0	Large amounts of bonito landed; no full monitoring days
Eten	18 Jan 93	L,R	0	2	4	0	1 *Grampus*	One fairly fresh blubber piece of a porpoise; on beach north of the port
Pacasmayo	15 Jan 93	L	0	0	2	0	0	Juveniles (KVW-2379, -2380) caught in gillnet with rays, dogfish and robalo
	15-16 Jan 93	R	0	5	0	1	0	Northern and southern beach
Salaverry	10-11 Jan 93	R	0	2	5	0	1 *Ziphius*	Skulls
	20 Jan 93	L	0	0	1	0	0	Fresh head and testicles
	19 Dec 93	L	0	0	3	0	0	Fresh head and viscera found (D. Montes, pers. comm. to KVW, 16 Jan 93)
Chimbote	Jan-Aug 93	L	0	132	119	13	0	53 sampling days (see Van Waerebeek *et al.* 1994)
Coishco	20-21 Jan 93	R	0	1	0	1	0	Only about 100m of beach was accessible
Besique	22 Jan, 18 Mar 93	R	1	5	2	1	0	Found stranded on beach
Samanco	9 Jan 93	R	0	2	0	0	0	Decomposed carcasses, dorsal musculature removed
Los Chimus	10 Jan 93	R	0	1	9	0	1 *Grampus*	Skulls found on beach near fish terminal
Casma	25-26 Oct 92	R	0	1	1	1	0	Vertebrae of *Tursiops*
Culebras	21-25 Oct 92	R	0	0	0	0	Unident.	No cetaceans seen landed; abundant vertebrae
	11 Feb 93	R	0	1	0	0	0	Head and backbone, landed: dorado, dogfish, rays and squid
	12 Feb 93	L	0	0	0	0	0	Abundant dogfish and hammerhead; 23 gillnet boats, 10 small purse seiners
	26 Feb 93	L	0	2	0	0	0	Harpooned dolphins;
	27 Feb 93	L	0	2	4	0	0	Harpooned; fishery of bonito and mackerel declining
Regional total:			1	187	215	20	5	

/cont.

Table 4 (cont.)

Port	Date	Type	*L. obs.*	*D. cap.*	*P. spi.*	*T.tru.*	Other	Comments
Central coast								
Huarmey	21,22,24 Oct 92	R	1	12	0	0	0	
Supe	19-21 Oct 92	L,R	0	0	0	1	0	Mandibula; no fresh cetaceans seen landed
Huacho	18 Oct 92	L	2	0	0	0	0	AGG-G11, -612; taken in bonito nets by different boats
	19 Oct 92	L	0	0	0	0	0	No cetaceans landed; unident. remains of *Delphinus* or *L. obs.*
	10 Feb 93	L,R	1	0	0	0	0	Skull on beach; no animals seen landed
	11 Feb 93	L	?	?	?	?	?	Meat of 2-3 unident. animals disembarked clandestinely
Chancay	16 Oct 92	L	0	0	0	0	0	No cetaceans landed
	17 Oct 92	L,R	3	1	1	0	0	Skulls found on beach; no fresh animals seen
	9 Feb 93	L	0	0	4	0	0	Taken with dogfish and cojinova
	10 Feb 93	L	0	0	0	0	0	Small fishes were landed; one live *Dermochelys coriacea*
	9-10 Feb 93	R	3	1	0	3	0	In addition 12 backbones of either *Delphinus* or *L. obs*
	25 Oct 93	L	6	0	0	0	0	Landed with rays, blue and hammer shark (gillnet; 1 boat)
	26 Oct 93	L,R	8	24	2	0	4	Skulls state 2-4; around fish terminal; no fresh animals
	6 Nov 93	L	26	5	0	0	0	6 *L. obs* butchered in terminal; others kept in cool storage room
	7 Nov 93	L	0	0	0	0	0	No boats returned to port
Ancón	1991	L	358	168	82	0	0	57 sampling days (see García-Godos, 1993; Van Waerebeek *et al.* 1994)
	1992	L	102	113	11	5	0	61 sampling days (see García-Godos, 1993; Van Waerebeek *et al.* 1994)
Pucusana	28 Apr 92	L	6	0	1	0	0	Gillnetted
	29 Apr 92	L	6	6	0	0	0	Gillnetted
	1 May 92	l	7	5	0	0	0	Gillnetted
	3 May 92	L	0	4	0	1	0	
	4 May 92	L	0	1	0	0	0	
	5 May 92	L	0	1	0	1	1	*Globicephala macrorhynchus*
	6 May 92	L	8	0	0	1	1	*Grampus griseus*
	10 Oct 92	L	0	0	2	0	0	KVW-2352, -2353
	14 Oct 92	L	2	0	0	0	0	KVW-2354, -2355
	15 Oct 92	L	5	0	0	0	0	Dusky dolphins seized by port authority
Cerro Azul	20 Mar 91	L	1	0	5	0	0	JCR-1928 till -1933
	1992	L	117	89	15	7	0	45 sampling days (see Van Waerebeek *et al.* 1994)
	1993	L	395	177	79	31	2	128 sampling days (see Van Waerebeek *et al.* 1994)
San Andrés	Jan-Nov 92	L	7	23	17	6	1	42 sampling days (see Tenicela 1993)
	8 Jan 92	R	0	0	1	2	0	Fresh heads; coastal *Tursiops*, one collected
	16 Jul 92	R	0	5	1	0	0	Skulls on the beach near the port
	5 Nov 92	R	0	0	3	0	0	Skulls on the beach near the port
	10 Apr 92	R	3	1	0	0	0	Freshly butchered dusky dolphins; state 3 *Delphinus* head
Tambo de Mora	8 Oct 93	L	0	0	2	0	0	Landed together with rays
	9 Oct 93	L,R	0	0	0	1	0	Skull on beach close to wharf; no fresh animals
Laguna Grande	5 Nov 92	R	2	6	18	3	0	Skulls near jetty (Antigua rancheria)
Regional total:			1,069	642	246	62	2	
Southern coast								
S.J. de Marcona	17-18 Aug 93	R	4	0	1	0	0	Osteological material
Lomas	18-20 Aug 93	R	8	0	1	2	0	Skulls
Matarani	12,13,21 Aug 93	L,R	0	0	1	0	0	Blubber floating in harbour
Llo	405 Aug 93	L,R	0	0	1	0	0	Skull on beach, possible stranded; no fresh animals
Meca-Ite	6 Aug 93	L,R	0	0	1	0	0	Weathered skull on beach; no fresh animals seen
Regional total:			12	0	5	2	0	

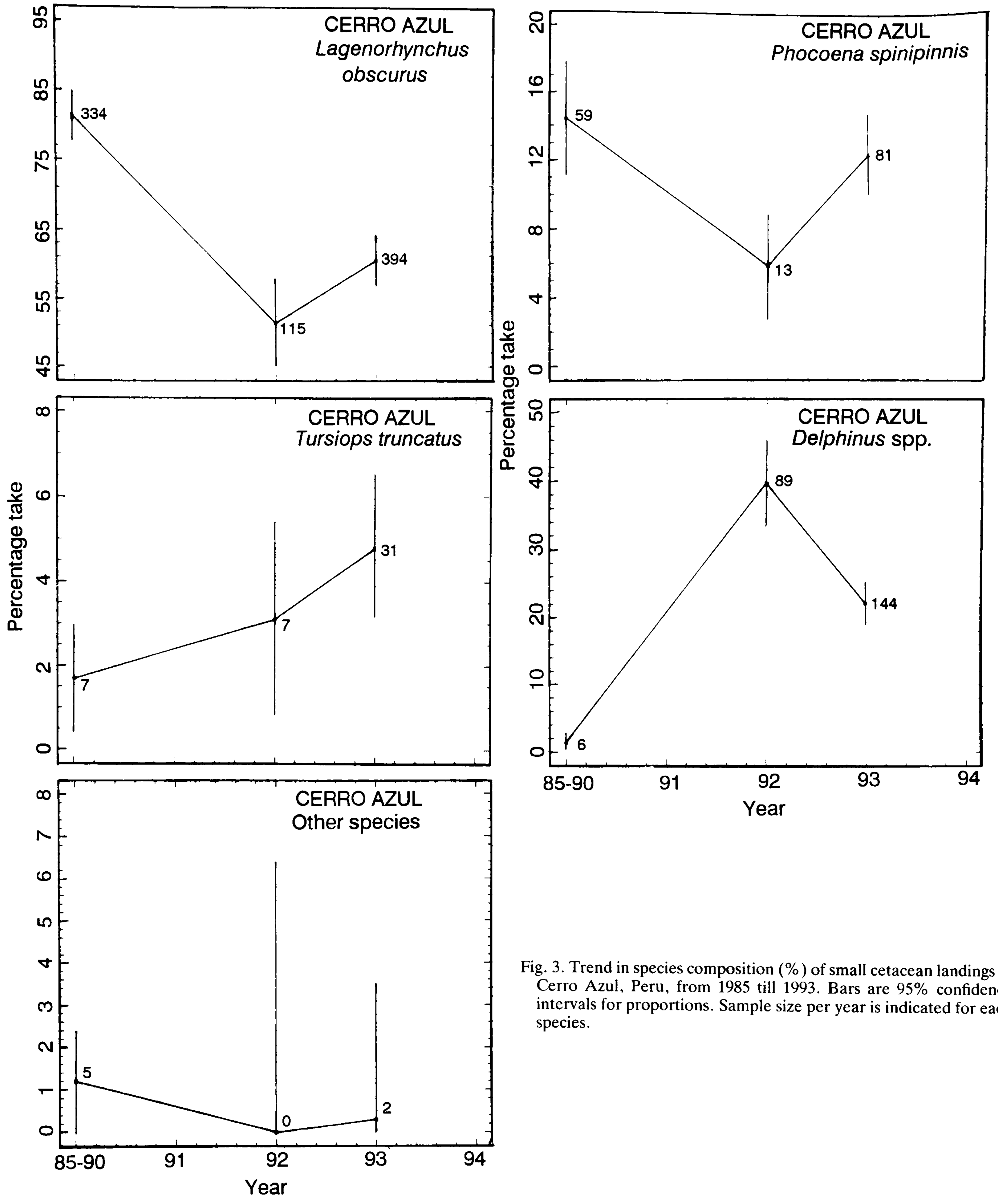

Fig. 3. Trend in species composition (%) of small cetacean landings at Cerro Azul, Peru, from 1985 till 1993. Bars are 95% confidence intervals for proportions. Sample size per year is indicated for each species.

OTHER PORTS

Below we discuss evidence of post-ban cetacean catches at less intensively surveyed Peruvian ports. Additional information can be found in Van Waerebeek *et al.* (1994). Information and sampling dates are summarised in Table 4.

Puerto Pizarro (03°29'S, 80°28'W)

This port is home to some 120 mostly gillnetting boats, apart from a few small purse seiners. Several fishermen use monofilament gillnets. Reportedly small cetaceans are caught incidentally and brought to port infrequently. If landed, they are often given away for free because they have little value compared to the still abundant commercial fish species. No cetacean remains were found in the environs of the disembarking site.

La Cruz (03°37'S, 80°37'W)

Industrial vessels trawl for shrimp (*Penaeus panameniae*) and local fishermen gather shrimp larvae with individual scoop nets. Some line-fishing also occurs. Beaches north and south of the pier were examined over a distance of about 3km but no cetacean material was found. This suggests that few, if any, interactions occur.

Zorritos (03°41′S, 80°35′W)
Some 50 boats operate out of Zorritos using both gillnets and longlines. Dolphins are caught 'at times' (two independent sources). One fisherman was familiar with 'dolphins with white dots', identifiable as the pantropical spotted dolphin, *Stenella attenuata*, frequently seen close inshore in southern Ecuador (Ben Haase, Centro Informativo Natural Peninsular, unpub. data). No direct evidence of cetacean captures was found.

Cancas (03°53′S, 80°55′W)
Moreno (1988) discussed the artisanal fishery at Cancas. The prevalent fishing methods are long-lines (47% of unit effort) and gillnets (20% UE), the latter set primarily for flounder and dogfish. Many boats carry a bowsprit which permits harpooning of swordfish and sailfish and at least occasional kills of dolphins must be expected (see Los Organos). About 50 boats, including small purse seiners, operate from Cancas.

Máncora (04°05′S, 81°04′W)
Some 50 fishing boats are based at Máncora, and deploy both gillnets (typically 10cm mesh) and longlines depending on target species. Hand-held harpoons are carried by most boats and are said to be used for harpooning swordfish and large tuna. Orozco (1988) named dogfish (*Mustelus whitneyi*), conger, sierra, dorado, bonito and thresher shark as the main commercial species and reported takes of unspecified small cetaceans in late 1986. Interviews with fishermen by one of us (KVW) using photographs of Peruvian cetaceans suggested that common dolphins, Burmeister's porpoises and, rarely, pilot whales are taken. Fishermen also recognised the bottlenose dolphin but not the dusky dolphin, as expected from their known distributions. Various sources claimed that 'dolphins' (probably bottlenose) occasionally swim in large groups close to shore. No cetacean remains were found on nearby beaches.

Los Organos (04°11′S, 81°07′W)
Catches of a large variety of fish species by more than 80 boats are unloaded daily at a tiny wharf. Both gillnets and longlines are used. One fisherman described how he regularly harpooned 'long-beaked dolphins', presumably common dolphins, from the bowsprit of his boat. Cetacean meat is consumed locally by fishermen and their families. Inshore swimming (bottlenose?) dolphins were mentioned.

Talara (04°35′S, 81°25′W)
We counted 40 small purse seines and some 45 wooden boats equipped with mast and sail used in a nearshore hook-and-line fishery at this major fishing centre of northern Peru, but from interviews it was clear that many more boats were out at sea. Porpoises are caught and consumed at Talara but are not openly sold to avoid confiscation. Our general impression was that control was fairly strict, more so than in any other port visited. This probably helps to explain why no evidence of cetaceans was encountered during our stay.

Negritos (04°36′S, 81°15′W)
This is an anchorage site just south of Talara for small sailing boats that fish mostly nearshore. Fish is transported to and sold at the Talara market. There was no evidence of any dolphin take.

Paita (05°05′S, 81°10′W)
Moreno and Mendieta (1988) studied the artisanal fishery at Paita during 1986–88. Of the total fishing effort, 13% was accounted for by gillnetting (for dogfish and suco), 52% by small purse seines (sardines, suco, cachema) and 35% by longlining (dorado, blue and mako sharks). Landings of cetaceans were confirmed but not quantified (Moreno and Mendieta, 1988). During our two visits, only a strip of blubber from an unidentified small cetacean was found, although the importance of this fishing port suggests that considerable bycatches probably occur. Paita should be monitored more closely in the future.

Yasila (05°07′S, 81°10′W)
A small group of fishermen reside at Yasila, a tiny resort south of Paita. They mostly gather shellfish although a few gillnet boats and purse seiners were seen. We found no cetacean remains on nearby beaches.

Caleta Constante
A small beach-head without infrastructure. No cetaceans were landed in the period 25–30 September 1993 (Pilar Tello, pers. comm., 25 October 1993). On the first day, three bottlenose dolphins were sighted swimming close inshore in a southerly direction.

Parachique (05°44′S, 80°52′W)
Meléndez (1988) reported in some detail on fishing effort in Parachique: 80% consists of small-scale purse seining (for sardine, mullet, suco, cachema), 7% gillnetting (for dogfish, bonito, suco), 8% longlining, 2% bottom trawling (for *Penaeus* spp.) and 3% diving. Gillnets are either polyfilament (No. 12, 18, 24) or monofilament (No. 50) with mesh-size 7.6–12.7cm. Fishermen admitted an incidental take of Burmeister's porpoises but no fresh specimens were seen landed during two visits in 1993. However, in two hours of beach-combing north of Parachique, skeletal remains of *P. spinipinnis, Delphinus* sp. and (probably) *T. truncatus* were found. A group of 6–7 bottlenose dolphins were sighted very close to shore on 19 February 1993. The community of Matacaballo has a small jetty a few kilometres north of Parachique where divers land mostly shellfish.

San José (06°46′S, 79°58′W)
The San José fishing community specialises in an inshore set-gillnet fishery for several species of rays, guitarfish, dogfish and flounder (rays and guitarfish are salted and dried for the production of a popular local dish (*chinguirito*)). This fishery results in relatively high levels of mortality of *P. spinipinnis* and other small cetaceans (Table 4).

Pimentel (06°45′S, 79°55′W)
The fishermen's community at Pimentel is fairly small compared to that at neighbouring Santa Rosa: some 263 fishermen (7% of the Lambayeque total) are registered. Annual harvest of fishery products in 1992 was 4.56% of the regional total, equivalent to 1,740 tonnes (Anon., 1993). Gillnetting is the prevalent fishing art at Pimentel. There is evidence of at least occasional catches of *Delphinus* sp. (Table 4) but no estimate of total kills is available.

Santa Rosa (06°56′S, 79°57′W)
With 2,200 registered fishermen this is by far the largest artisanal fishermen's community of the Lambayeque region (55% of total). In 1992, IMARPE officials recorded

a total volume of 33,949 tonnes of marine products (Anon., 1993). During our visit, about 80 large boats were operative. Fishing trips may last up to three days. Large numbers of bonito have been taken for two years using typical gillnets extending 36.6–54.9 deep and stretching 512m in length. The net maze used is 3.8–4.4cm wide. Several fishermen admitted capturing dolphins with some regularity. However, since the ban, dolphins have been butchered in the boats and the meat taken to shore hidden in baskets. A beach survey from Santa Rosa north to Pimentel yielded abundant cranial material of *D. capensis* and *P. spinipinnis* (Table 4). No cetacean material was found south of Santa Rosa which suggests that remains are dumped at the port and are swept to the north by inshore currents.

Puerto de Eten (06°57′S, 79°52′W)
This tiny community of 50 fishermen contributes only 1% of the total regional catch (Anon., 1993). Beach seines are set from the pier to trap inshore fish, mostly mullet. Line-and-hook fishermen claimed no dolphins are seen. Although locals did not report cetacean bycatches, on a beach search north of Eten we encountered skeletal material of six specimens (Table 4). A check of the southern 'Media Luna' beach yielded only one Burmeister's porpoise vertebra and one vertebra of an unidentified small delphinid, besides a weathered vertebral fragment of an unidentified large whale.

Pacasmayo (07°20′S, 79°35′W)
Two juvenile Burmeister's porpoises were photographed when hauled onto the wharf together with rays, dogfish and robalo. The porpoises, sold together for about $15, were eviscerated at the end of the pier. Remains were pitched into the sea except for the head, kept with the meat to prove the species identity to port authority personnel. For some unknown reason, porpoises are permitted to be used commercially but not *Delphinus* spp. This situation existed long before the 1990 ban came into effect (Van Waerebeek and Reyes, unpub. data). Abundant skeletal material, especially of *Delphinus*, was found on nearby beaches (Table 4).

Pto. Chicama, Malabrigo (07°40′S, 79°15′W)
This is a small port with factories for fishmeal and canned fish. During our visit, 13 small-scale purse seiners, 8 gillnet boats and one industrial purse seiner were anchored. Sharks, guitarfish, mullet and suco were landed. A MIPE employee admitted that porpoises are caught. Fishermen prefer to keep cetacean meat for their own consumption rather than risk having it seized by port authorities who, apparently, enforce the dolphin protection law. No skeletal material was found along the shores.

Salaverry (08°14′S, 78°59′W)
According to a watchman at the industrial seaport of Trujillo, industrial seiners often land cetaceans. Fishermen claimed to catch more porpoises than dolphins and 'almost daily'. The takes were confirmed by the finding of skulls of eight cetaceans, including an adult Cuvier's beaked whale (*Ziphius cavirostris*). Monitoring showed *P. spinipinnis* is regularly captured.

Puerto de Santa (08°58′S, 78°38′W)
This is an impoverished fishing community at the mouth of the Santa river, some 20km north of Chimbote. Thirteen small boats, two with gillnets, were anchored in the bay during our visit. Beach seines were observed. No cetacean remains were found along the beach, but neither was any fish offal. Sources confirmed that landings from Santa are usually taken to Chimbote by road. On one occasion a Burmeister's porpoise was seen being unloaded in Chimbote from a small truck which came from Santa.

Coishco (09°04′S, 78°37′W)
Fishmongers at Chimbote reported that large numbers of dolphins were landed at Coishco, a small town close to an industrial fishery complex with private wharf and several fishmeal processing units. About 50 purse seiners (100–350 tonnes) were reportedly fishing for anchovy. Mr. Felipe Velásquez of COPES claimed no dolphins were captured by his company's purse seiners and granted us access to the wharf. One worker stated that, although company regulations did not allow dolphins to be unloaded on the dock, they were simply landed on the beach nearby and sold in Chimbote. This was supported by the fact that a fresh piece of blubber with a dorsal fin, a partial backbone and several loose vertebra, most likely from *Delphinus* sp., were retrieved on a 100m strip of the beach.

Besique (09°11′S, 78°30′W)
This resort in the Bay of Samanco is frequented in summer by tourists from Chimbote. Beach seining for a variety of inshore fishes is widely practised. Beaches were searched during several visits in 1993 and abundant small cetacean material was retrieved (Table 4), probably originating from dolphins caught by purse seiners and gillnet boats docking at Samanco. Groups of six and three coastal bottlenose dolphins were sighted from the beach on 18 and 24 March 1993 respectively.

Samanco (09°16′S, 78°30′W)
This is an industrial complex with a modern, private pier, serving three companies principally dedicated to fishmeal production. CEPEC members visited the complex several times in 1993, each visit lasting a few hours. About 20 purse seiners were landing anchovy round the clock. According to workers, a single purse seiner occasionally may land 10–15 'long-beaked dolphins', presumably common dolphins. The latter are butchered at the wharf and the meat is either distributed locally or sold in Chimbote. The few artisanal gillnet boats present mostly set nets for small inshore fishes. On 8 January we observed four purse seiners disembarking anchovy and (as we were told the next day) two dolphins. Later, two somewhat decomposed *Delphinus* sp. carcasses, with dorsal musculature removed, were seen stranded close to the pier. For monitoring to be effective, a 24hr/day presence is required.

Los Chimus (09°20′S, 78°28′W)
This small resort and fishing town south of Samanco has a newly-built fish terminal that was not in use when we sampled the port. Thirty-four small fishing boats (29 with gillnets, five with diver air compressors for mollusc gathering) were anchored beyond the surfzone. On *ca.* 1km of beach we found 11 small cetacean skulls (Table 4), more than 25 carapaces of green turtles (*Chelonia mydas*) and unusually large numbers of *Otaria byronia* skulls. All specimen remains are thought to originate from fishing interactions.

Tortugas (09°22′S, 78°25′W)
This is a small fishermen's settlement at the southern end of the Los Chimus Bay. Fishery activity is limited to shellfish and octopus extraction. Locals stated that no dolphins were killed; no cetacean bones were found in the vicinity.

Casma (09°28′S, 78°19′W)
This is home to both an artisanal and industrial fishery fleet. Local fishermen stated that they 'occasionally' capture cetaceans in gillnets and this was confirmed by small cetacean bones found along nearby shores (Table 4). Long-term monitoring is needed because Casma has the potential to account for high cetacean mortality.

Culebras (09°56′S, 78°13′W)
Although no fresh dolphin remains were found, we discovered large numbers of vertebrae from small delphinids near this port in 1992. Local sources referred to high dolphin kills both by gillnets and harpoon (up to 5–10 animals per boat) especially in winter. Four harpooned *D. capensis* were registered in four days of monitoring in February 1993 (Table 4) and it seems possible that high *D. capensis* mortality occurs; this port should be monitored more thoroughly.

Huarmey, Puerto Grande (10°04′S, 78°10′W)
Artisanal fishermen land catches directly onto the beach close to the industrial wharf. No fresh cetacean remains were found but large amounts of skeletal material, especially from *D. capensis*, was collected on the beach in 1992–93 (Table 4). This substantiates reports by fishermen that dolphins are regularly taken, including by harpoon. Purse seiners reportedly have landed 30–40 animals at once on occasion. Much of the meat is sold locally and sells for $1.7/kg – comparable to the cheaper cuts of beef.

Puerto Chico (10°44′S, 77°47′W)
This beach, close to Barranca, has no infrastructure but is used as a disembarking site. On our visit only lorna was brought ashore by gillnet fishermen but cetaceans are reported to be landed occasionally; no remains were found.

Puerto Supe (10°48′S, 77°46′W)
During our visit we counted 21 wooden boats, 10 small purse seiners and 10 industrial purse seiners. We found one bottlenose dolphin mandibula during a short beach search. Fishermen admitted to landing and selling dolphins in the knowledge that it was illegal but, curiously, notified port authorities before doing so. Dolphins killed in purse seines were said to be tossed on the beach where they were quickly used by locals.

Caleta Vidal (10°50′S, 77°44′W)
This is a tiny fishing community 5km south of Supe from where approximately ten boats operate. Catches are landed directly on the beach and taken to Puerto Supe or Barranca for sale, which may explain why no cetacean remains were found.

Huacho (11°07′S, 77°37′W)
Both an artisanal and industrial purse seine fleet are based at Huacho. Large catches of *L. obscurus* were recorded in winter 1985 (Gaskin *et al.*, 1987). We found both freshly landed animals and skeletal remains during short visits in 1992 and 1993 suggesting that gillnet mortality persists (Table 4), but no kill estimates can be made. Meat was sold at $1.3/kg. Industrial purse seiners 'occasionally' land *L. obscurus* and *Delphinus* sp. (Engineer Ayala, Instituto del Mar del Perú, pers. comm. to A. García-Godos, CEPEC).

Chancay (11°37′S, 77°16′W)
Chancay is home to an important purse seiner fleet and some 60–70, mainly gillnet-equipped, wooden boats. Gaskin *et al.* (1987) reported large catches of *L. obscurus* in winter 1985. During several visits in 1993 large numbers of fresh cetaceans and skulls were encountered (Table 4). The species composition (n=82) was: 52.4% (CI 41.6–63.2%) *L. obscurus*, 36.6% (CI 26.2–47.0%) *D. capensis*, 7.3% (CI 1.7–13.0%) *P. spinipinnis* and 3.7% (CI 0–7.7%) *T. truncatus*. Interviews suggested that 'moderate to large' catches, interspersed with periods of low or zero kills, occur year-round. Several port workers blamed the industrial fishery for high takes of common dolphins. Most dusky dolphins seen were caught in gillnets. Although port authorities are known to seize dolphins they do not do so systematically.

Tambo de Mora (13°30′S, 76°11′W)
During our short visits only a few *P. spinipinnis* were seen landed here and only a bottlenose dolphin skull was found (Table 4), however, the relative inaccessibility of the wharves impeded adequate sampling. Reportedly cetaceans are 'often' landed but so far there is no indication that a true dolphin fishery has developed as had been feared (Van Waerebeek and Reyes, 1994a). Much of the meat is said to be processed into *muchame* and is probably sold in nearby Chincha where it has been readily available for a long time (Dr. Robert Clarke, Pisco-Peru, pers. comm., 2 April 1994). CEPEC observers sighted bottlenose dolphins swimming close to the piers on two consecutive days.

Laguna Grande (14°10′S, 76°13′W)
This is a squatters' fishing community situated in the Paracas Marine Reserve which has its roots in the scallop exploitation boom of the early 80s. A single visit in 1992 yielded large numbers of cetacean bones on the beach in the proximity of a jetty (Table 4).

San Juan de Marcona (15°20′S, 75°09′W)
About 60, mainly outboard-powered, gillnet boats operate from this port. Before the ban 'very few dolphins and porpoises have been landed' (P. Majluf, cited in Gaskin *et al.*, 1987). Carlos Castañeda (pers. comm. to A. García-Godes, CEPEC, 17 August 1993) resident at San Juan during the summer of 1992–93 reported an averaged daily take of three small cetaceans during that period and had witnessed landings of live animals. The presence of skeletal material on the shore around the port supports claims of persisting catches (Table 4).

Lomas (15°32′S, 74°50′W)
Gillnet boats and small purse seiners were said to net dolphins 'at times'. Fairly abundant skeletal remains of *L. obscurus, P. spinipinnis* and *T. truncatus* was found in the immediate vicinity of the port (Table 4). From partly burned cranial and vertebral remains of a balaenopterid whale only the atlas was collected.

Chala (15°32′S, 74°50′W)
Chala harbours about a dozen boats which mainly extract molluscs and crustaceans. Inshore fishes are captured with handlines. No longlines are deployed. Two partial backbones of small dolphins (either *Delphinus* sp. or *L. obscurus*) and a few loose vertebra were found around the wharf and the beach to the north of it. Fishermen admitted they sometimes take dolphins accidentally.

Ocoña/La Planchada (16°26′S, 73°08′W)
Ocoña features a fishmeal factory and a large wharf where the purse seiners dock. Artisanal fishermen extract mostly shellfish, especially abalone (*Concholepas concholepas*). However, some gillnetting activity occurs and locals commented that at times dolphins are caught and eaten. Due to rough weather little fishing occurs during winter months.

Matarani (16°58′S, 72°07′W)
This medium-sized port has three fishmeal and canning factories which rely on the purse seine fishery for anchovy and sardines. Some 35 longline and gillnet boats and 25 diving-equipped shellfish boats operate from Matarani. Fishermen, fully aware that the capture of small cetaceans is prohibited, maintain that port authorities exert control. However, the blubber of a freshly skinned Burmeister's porpoise was seen floating in the harbour. A few locals admitted they occasionally ate dolphin meat. Several stated also that bottlenose dolphins and large whales, probably southern right whales (see Van Waerebeek *et al.*, 1992), are sighted from the pier with some regularity. The port of Mollendo (17°02′S, 72°01′W) has been closed for years.

Ilo (17°38′S, 71°20′W)
Ilo hosts three fishmeal factories. Small scale fishermen extensively use longlines since shellfish production has dropped. In summer, gillnets are set for bonito and cojinova, resulting in most of the annual mortality of small cetaceans. On a three hour beach survey south of the port a single skull of *P. spinipinnis* was found. Locals said the animal had stranded about a month ago and its meat had been used for bait. Remains of an as yet unidentified balaenopterid whale were found south of Ilo. Allegedly the whale was hauled onto the beach when it entered very shallow water and locals started butchering it before it died.

Meca-Ite (17°54′S, 70°58′W)
This beach-head has about ten inshore fishing boats. In summer, boats from Ilo are said to operate in the area. Local fishermen reported occasional entanglements of porpoises and bottlenose dolphins in their nets. A weathered skull of *P. spinipinnis* was found along the shore and bones of an unidentified whale were found along the rocky beach of Punta San Pablo.

Vila-Vila (18°08′S, 70°36′W)
Longlines are set principally between October and January. Some 27 boats were counted on our visit, including 15 equipped with compressors for gathering shellfish by divers. In three days, two *P. spinipinnis* were reportedly entangled in inshore gillnets, but the animals were not seen by the CEPEC observers. The broken skull of a large whale was found at Boca del Rio but no other cetacean material was discovered.

CHARACTERISTICS OF POST-BAN CETACEAN EXPLOITATION

Species composition
The species composition of cetacean catches for northern, central and southern Peru in the post-ban period is summarised in Table 5. Off northern Peru, most of the mortality comprises Burmeister's porpoises (about 50%) and long-beaked common dolphins (44%). The virtual absence of dusky dolphins off northern Peru is consistent with known distribution limits (Van Waerebeek, 1992a; b) and the two dusky dolphin skulls found by A. García-Godos and J. Alfaro (CEPEC) in Salaverry (08°14′S), currently represent the most northerly record of the species. In central Peru, dusky dolphins (53%) and long-beaked common dolphins (32%) are the most important species. The sample from southern Peru is too small to allow comparison with other areas and the absence of *D. capensis* in the present sample is probably an artifact. Combined landings of the lesser beaked whale, short-finned pilot whale, short-beaked common dolphin (*D. delphis*), Risso's dolphin, southern right whale dolphin, Cuvier's beaked whale and southern minke whale account for only a few percent of the total Peruvian take and can be considered as a true incidental catch.

Table 5

Species composition of post-ban cetacean kill in Peru per coastal region. Standard error (SE) and lower and upper 95% confidence intervals (CI) are indicated.

Coastal region		*L. obs.*	*D. cap.*	*P. spi.*	*T. tru.*	Other	Total
North	No. specimen	1	187	215	20	5	427
	%	0.2	43.8	50.4	4.7	1.2	100
	SE(%)	0.2	2.4	2.4	1.0	0.6	-
	Lower CI	0	39.1	45.6	2.7	0.2	-
	Upper CI	0.7	48.5	55.1	6.7	2.2	-
Central	No. specimen	1,069	642	246	62	2	2,021
	%	52.9	31.8	12.2	3.1	0.1	100
	SE(%)	1.1	1.0	0.7	0.4	0.1	-
	Lower CI	50.7	29.7	10.7	2.3	0	-
	Upper CI	55.1	33.8	13.6	3.8	0.2	-
South	No. specimen	12	0	5	2	0	19
	%	63.2	0	26.3	10.5	0	100
	SE(%)	11.1	0	10.1	7.0	0	-
	Lower CI	41.5	0	6.5	0	0	-
	Upper CI	84.8	0	46.1	24.3	0	-

The worrying decline in the percentage of dusky dolphins in landings over time (Figs 2 and 3) is discussed by Van Waerebeek (1994) who suggested that this may reflect an increase in the relative abundance of *D. capensis* of central Peru.

Total annual take
Ironically, since small cetaceans acquired legal protection, it has become even more difficult to accurately estimate total annual takes. Based on the best available evidence for each Peruvian port, we have tried to categorise them in terms of their post-ban landings below.

Category A: Chimbote (1,825 for 1993); Pucusana (1,651 for 1990); Cerro Azul (1,927: mean catch of 1992/1993); Ancón (1,740: mean catch of 1991/1992). Estimated combined annual take: 7,140.

Category B: (mean = 1,000 p.a.): Santa Rosa, San José, Culebras, Huarmey, Chancay. Extrapolated take p.a.: 5,000.

Category C: (mean = 275 p.a.): Máncora, Paita/Yacila, Los Organos, Talara, Supe, Pacasmayo, Salaverry, Coishco, Los Chimus, Casma, Chicama, Huacho, Callao (?), San Andrés (470 for 1992), Tambo de Mora, San Juan de Marcona, Lomas. Extrapolated take p.a.: 4,870.

Category D: (mean = 25 p.a.): Puerto Pizarro, Zorritos, Cáncas, Parachique, Pimentel, Eten, Santa, Puerto Chico, Vidal, Chorrillos, Laguna Grande, Chala, Ocoña/La Planchada, Matarani, Ilo, Meca/Ite. Extrapolated take p.a.: 400.

Category E: (0 take): La Cruz, Punta Mero, Acapulco, Negritos, Matacaballo, Caleta Constante, Besique, Tortugas.

By combining the category totals (17,400), we estimate the total yearly take for Peru in the period 1990–93 to range between 15,000–20,000 small cetaceans, i.e. higher than the estimated peak catch for 1989 (14,100 animals) based on MIPE data (1,093 tonnes, Ramírez and Zuzunaga, 1991). Landings at Pucusana in 1990 were lower than in preceding years but landings at Cerro Azul have greatly increased (see Read *et al.*, 1988; Van Waerebeek and Reyes, 1990a; b; 1994a). No comparisons can be made for other ports due to lack of information for earlier years.

In the absence of abundance data and reliable stock delineation, assessing the impact of catches is impossible: sighting surveys are urgently needed. However, the high levels of mortality are already a cause of concern in many cases. IWC (1994) states that removals of the southeastern Pacific dusky dolphins are probably not sustainable. Similar concerns seem warranted for *D. capensis* and *P. spinipinnis*.

Fisheries and attitudes

Artisanal fishermen are surprisingly mobile and frequently travel along the coast in search of the best fishing grounds. Due to the proximity of Chancay and Ancón, for instance, fishermen of both towns often operate from each other's home port. A similar pattern is observed at Pucusana and Cerro Azul.

With a few obvious exceptions, interview feedback from fishermen agreed well with our view obtained from monitoring and beach surveys. In general, fishermen from northern Peru were more communicative than those from central and southern coasts and showed no reticence to talk about dolphin catches. We found that virtually all fishermen were aware that small cetaceans are protected but very few were receptive (and those almost certainly out of politeness) when we explained why the ban must exist. Although they routinely cited 'economic difficulties' to justify killing cetaceans, rarely are those difficulties as acute as claimed. Their view rather reflects a general sense of uncertainty about their short-term future due to the genuine unpredictability of harvest and dangerous working conditions and, it seems to us, a refusal to plan ahead. The opportunistic approach of small-scale fishermen reflects the short-term view that prevents many artisanal fishermen from investment or taking decisions which would be to their clear benefit in the medium or longer-term. Unless this attitude can be changed by improving their real (and, more importantly, perceived) security, ecological arguments will remain irrelevant and cooperation unlikely. This will require a dedicated and thoughtful policy towards artisanal fishermen and much patience.

The apparent unwillingness/inability of MIPE to enforce the ban, in part reflects the truly complex nature of the problem and in part the unfortunate but widespread perception of environmental issues as low-priority. It also must be said that the poor level of education of policing personnel and the armed forces, combined with economic factors such as insufficient pay which render them susceptible to bribery, certainly compound the problem.

However, short of a fully enforced, outright ban of all gillnet and harpoon fisheries and strict control of purse-seine operations, neither of which can be achieved overnight (if ever), there is no practical panacea to this problem (see also Jefferson and Curry, 1994). Unfortunately, time may be short for several stocks of Peruvian small cetaceans and some measures that can be expected to significantly mitigate mortality rates are discussed in the recommendations section.

One possible longer term solution concerns the changing of fishing techniques. A 1992–1993 IUCN/WDCS study has shown the high potential of fish-baited longlines to partly replace gillnets in the shark and ray fishery, and thus reduce cetacean mortality (Reyes, 1993). Additional data collected at Pucusana further confirms the feasibility of longline fishing. During six fishing trips (four in November and two in December 1993) one boat equipped with a small longline (150 hooks) reportedly caught, on average, about 300kg (200–400 kg) blue sharks and 118kg (80–200 kg) mako shark, using a variety of low-value fish species as bait. In the December trips, an additional 175kg of dorado (*Coryphaena hippurus*) was also caught. The mean net income after subtraction of all costs (fuel/subsistence) was about $153 per two-day trip. This amount is customarily divided between the two fishermen (each 25%), and the owners of the boat and longline (each 25%), often the fishermen themselves. These earnings compare favourably with the minimum guaranteed monthly wage in Peru of US$61 and typical labourer/employee monthly wages of US$90–140.

However, should the use of longlines be promoted, the process should be supervised to ensure no unforeseen and counterproductive results arise. For example, uncontrolled South American longline fisheries in Venezuela, French Guiana and southern Ecuador have used dolphin meat as bait (Agudo and Romero, 1990; Van Waerebeek, 1990; Felix and Samaniego, pers. comm., February 1994). Although the present price of dolphin meat in Peru is too high for its use as bait, increased demand might encourage fishermen to harpoon additional animals when out fishing. Dolphin offal such as blubber and intestines from the dolphin fishery is not used as it is alleged to be ineffective. Long-line interactions with non-target species do occur but apparently are rarely lethal. During test sets, South American fur seals *Arctocephalus australis* and an unidentified albatross became hooked when trying to steal bait, but escaped without much harm (Reyes, 1993). No cetacean mortality has been reported in longlines off Peru, although the stealing of the catch from the hooks by marine mammals can lead to directed kills by fishermen.

Problems of humane killing

The principal cause for concern with respect to humane killing is the live-landing of animals, especially by industrial purse seine vessels, and the use of hand-held harpoons to catch bottlenose, dusky and common dolphins; harpooning is particularly prevalent off central and northcentral Peru. One of the worst recorded infractions occurred in November-December 1992 when over a 23-day period, 178 harpooned common and dusky dolphins were landed (besides netted ones) at the wharf of Ancón. Visiting fishermen from Callao (5 boats) and Chorrillos (1 boat) were mostly responsible for the harpooning, although one boat from Ancón had also participated (see García-Godos, 1993). When this was drawn to the attention of the Ministry of Fisheries, the only measure taken was an 'interrogation of locals and fishermen' who claimed not to have caught any cetaceans. This illustrates the urgent need for more rigorous control and the application of penalties.

There is sufficient evidence to state that the commercial purse seine fishery for anchovy and sardines off Peru for the fishmeal industry is responsible for large, albeit unknown, kills of dolphins. The most heavily affected species in the Chimbote area is *D. capensis*, but data in Tenicela (1993), as well as its distribution, suggests that *L. obscurus* is also involved off central Peru.

Muchame

Muchame (also known as *Buchami* or *musciame*) is the salt-dried dorsal muscle of small cetaceans prepared according to a recipe of Italian origin. A black market may still exist in northern Italy (G. Notarbartolo di Sciara, Tethys Res. Institute, pers. comm., 13 Nov. 1993) and this raises the question as to whether some Peruvian muchame is illegally exported. Although it has been around for decades in Peru, indications are that in recent years its illegal trade and consumption of *muchame* have increased considerably. A market study in June-July 1993 revealed its wide availability in the shops and supermarkets of Lima and Callao (Van Waerebeek *et al.*, 1994). Ancón, Pucusana, Chincha and Arequipa are other towns where it can be purchased without difficulty. Its availability may well be explained by the huge profit margins: prices range from $7.5 to $35.9 /kg whilst fresh cetacean meat sells for $0.7–2.0 /kg).

RECOMMENDATIONS

It is clear that the 1990 law protecting Peruvian small cetaceans from exploitation was, depending on the locality, only at best partially enforced. Recent field work by CEPEC members suggests that the law of August 1994 is having more effect so far (November 1994). Authorities regularly seize landed cetaceans, at least at some ports, while pressure from impending penalties and public opinion is higher. Despite this, unknown quantities of cetacean meat are still used commercially and there is no direct evidence that the mortality rate is really down. We recommend that a number of measures be taken to further alleviate the situation.

(1) Dolphins accidentally captured in purse seines should be released. Independent observers, backed by new *ad hoc* regulations, should investigate the issue in detail, determine precise circumstances of captures and suggest practical solutions. The Inter-American Tropical Tuna Commission (IATTC), which has long-term expertise with monitoring of large-scale seining operations, should be consulted as an advisory body.

(2) Fishermen should be required to declare bycatches immediately after docking. Port officials should proceed to confiscate and register the animals by species. The consumption of fresh cetacean meat should be permitted if it is derived from such registered animals and the meat is distributed for free among locals and institutions of public utility. Any form of commerce in cetacean products should remain banned.

(3) Inspecting personnel should be trained in the recognition of species and signs of fishery mortality.

(4) Scientists should have priority access to specimens for study and biological sampling.

(5) The use of large-mesh gillnets (*animalero* nets) that cause the highest rates of directed mortality among dolphins, should be phased out as soon as possible.

(6) Small scale long-lines, which are not known to cause cetacean mortality in Peru, should be promoted as a cost-effective and superior alternative to large-meshed gillnets in the Peruvian shark and ray fishery, provided adequate monitoring takes place.

(7) A feasibility study should be carried out to assess the potential of dolphin-watching (ecotourism) as an alternative source of income for some groups of artisanal fishermen in areas of high cetacean density (and high takes).

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A Note on Incidental Fishery Mortality of Southern Minke Whales off Western South America

Koen Van Waerebeek[1,2] and Julio C. Reyes[1,3]

ABSTRACT

The accidental entanglement of two juvenile southern minke whales in artisanal gillnets in 1991 is discussed. They represent the first positive records of this species for Peru. Some biological data are provided and the incidental fishery mortality of these and other large whales off the west coast of South America is reviewed. It is likely that severe underreporting occurs due to vastly inadequate monitoring effort.

KEYWORDS: INCIDENTAL CAPTURE; FISHERIES; MINKE WHALE; SPERM WHALE; SOUTH PACIFIC; HUMPBACK WHALE; RIGHT WHALE

INTRODUCTION

The multifilament gillnets used in the Peruvian artisanal fishery are typically set for several species of sharks, rays and schooling fish (e.g. bonito *Sarda chilensis*) and several dolphin species. This fishery has been described in detail by Read *et al.* (1988) and Van Waerebeek and Reyes (1990; 1994b).

This paper reports on two southern minke whales (*Balaenoptera acutorostrata*[4]) incidentally caught off the coast of Peru in 1991. Despite an official ban on small cetacean catches, the minke whales were landed at the local wharf, being too large to be hauled and processed on board the fishing boats. Only the limited data presented below could be collected, because market workers processed the whales quickly for fear of seizure by port authorities.

DETAILS OF THE MINKE WHALES

A juvenile male minke whale (KVW-2298) was landed on 27 September 1991 by artisanal fishermen at Pucusana port (12°30′S) on the central Peruvian coast. The crewmaster stated that the animal had been caught in a drift gillnet set five hours steaming distance from port (estimated no further than 20 n.miles offshore). Several fishermen reported having seen several unidentified 'whales' on the fishing grounds during that period. A second minke whale, a juvenile female (KVW-2299), was landed at the same port on 30 October 1991. It was not possible to ascertain whether it had become entangled in a drift or set gillnet, but sand found in its stomach seemed to confirm one fisherman's assertion that it had been caught nearshore in shallow water.

Specimen KVW-2298

The animal was a juvenile male of 421cm standard length. It had normal body colouration with grey lips and a white throat and tongue. No white patch was present on the dorsal side of the flippers. Some measurements and meristics were taken: length of dorsal fin, 23cm; height of dorsal fin, 14.5cm; fluke span, 95.5cm; length of fluke (insertion to tip), 64cm; width of fluke, 27cm; depth of fluke notch, 4.5cm; anterior length of left flipper (severed, including caput ulni), 70cm; maximum width of left flipper, 15cm; number of ventral grooves, 59; maximum width and height of largest baleen plate, 4.7cm and 11.2mm, respectively; bristles, creamy white; number of baleen plates, left, 301 (the 216 posterior plates had a lead coloured exterior border, each over one fourth to one fifth of baleen width); number of baleen plates, right, 296 (167 posterior plates with lead-coloured exterior border, extending gradually until posterior baleen were entirely lead-grey); one testis weighed 19g, with epididymis 33g; combined weight of kidneys about 5kg. The stomachs contained a reddish liquid with a few unidentified euphausids and two fish eye lenses. No milk was recognised, nor were parasites found. The skull was collected. Photographs were taken.

Specimen KVW-2299

This animal was a neonate female of 325cm. It had normal colouration and the flippers were grey without a white band. Some measurements were taken: anterior length of flipper (left/right) 47/45.5cm; posterior length of flipper (left/right), 34/33cm; width of flipper (left/right), 12/12cm; length of dorsal fin, 25.5cm; height of dorsal fin, 15cm; number of ventral grooves: 49, running some 5cm short of the umbilicus; number of baleen plates (left/right), 261/260; stomach contents included mucus and sand, no parasites and a greenish liquid (presumably digested milk) was seen in the duodenum. Photographs are available.

DISCUSSION

We were unable to locate any references to minke whales from Peruvian waters and therefore conclude that these are the first confirmed records of this species for Peru (see Clarke, 1962; Grimwood, 1969; Ramirez, 1985; 1990; Ramirez and Urquizo, 1985; Stewart and Leatherwood, 1985). It must be stressed, however, that this is not necessarily evidence that minke whales are only exceptional visitors to these waters. At least in part, it reflects the fact that dedicated research on smaller cetaceans (i.e. other than the species of large whales once exploited off the coast of Peru) is a recent exercise. Ten

[1] *Centro Peruano de Estudios Cetológicos (CEPEC), casilla 1536, Lima 18, Peru.*

[2] *Institut Royal des Sciences Naturelles de Belgique, Bruxelles, Belgium.*

[3] Present address: *Casilla 392, Talcahuano, Chile.*

[4] Although under review, the IWC currently only recognises one species of minke whale, *Balaenoptera acutorostrata*. However, some authors consider (and we concur) that the Southern Hemisphere minke whale is a separate species, *Balaenoptera bonaerensis*.

species of odontocetes, including the newly described *Mesoplodon peruvianus*, and one mysticete, the southern right whale (*Eubalaena australis*), have been reported for the first time in Peruvian waters between 1985 and 1991 (Van Waerebeek and Reyes, 1988; Van Waerebeek *et al.*, 1988; 1992; Reyes, 1990; Reyes *et al.*, 1991).

Previous cases of incidental kills of large whales off the west coast of South America

Baleen whales

Only a few well-documented cases of incidental kills of minke whales or other large cetaceans exist for the west coast of South America. Guerra *et al.* (1987) reported that a minke whale drowned in 1979 in a purse seine net set on anchoveta (*Engraulis ringens*) by an industrial vessel in the Bay of Mejillones (at 23°S), Antofagasta (northern Chile); a photograph was taken by the captain of the ship.

In October 1988, a humpback whale (*Megaptera novaeangliae*) was netted alive and, after the fishermen were assured of repair cost compensation if they cut their nets, was subsequently released at Punta San Juan (15°22′S) in southern Peru (Majluf and Reyes, 1989).

A southern right whale calf was killed and subsequently stranded after receiving severe propeller cuts from a personnel boat shuttling back and forth between shore and *Gracilaria* algae culture floats in the Gulf of Arauco, southern Chile, in August 1989 (Canto *et al.*, 1991).

Sperm whales

Two sperm whales (*Physeter macrocephalus*) died in drift gillnets for dorado (*Coryphaena hippurus*) and bonito (*Sarda chilensis*) in Ecuador: an 11.4m animal about one mile off Engabao, Guayas, on 7 May 1991 after five days of being entangled (Félix, 1991) and a 10.8m animal, west of Isla de la Plata, Manabí, in June 1991 (Haase, 1991b). In addition a 12.6m female sperm whale that stranded in Punta Carnero on 15 August 1991 may have been a victim of the local gillnet fishery although it might have died after being hit by a large ship because the maxillary part of the skull was fractured (Haase, 1991a); a post-mortem collision obviously cannot be excluded.

From 18 sperm whale strandings on the Ecuadorean continental coast between 1987 and 1993, evidence of interaction with some type of fishing gear (mostly gillnets) was available in eight cases (Félix *et al.*, 1994). One 13.6m male was killed after entanglement in a purse seine net (Prieto and Bravo, 1991).

Sufficient evidence is available to confirm that sperm whales occasionally become entangled off central Chile in the fairly recently developed gillnet fishery for swordfish (Reyes and Oporto, 1994).

General

The increasing frequency of reported cases of incidental kills of large whales (including minke whales) in the Southeast Pacific coastal region raises concern about the true magnitude of the problem and the possible impact on populations. The area supports a vast number of often unregulated artisanal and industrial fisheries as well as rapidly expanding inshore mariculture activities (e.g. Cushing, 1982; Wosnitza-Mendo *et al.*, 1988; Reyes and Oporto, 1994; Van Waerebeek, pers. obs.) all of which negatively interfere with marine mammals.

Severe underreporting of incidental cetacean mortality is likely, given the small number of cetologists covering this vast area and the fact that they are limited by inadequate funding and infrastructure.

Stock identity

Very little is known of the stock identity of minke whales in Peruvian and Chilean waters. A recent review of published literature could identify only 15 positive records of minke whales off western South America (Van Waerebeek and Reyes, 1994a). There is no minke whale material in Chilean and Peruvian collections (e.g. see Sielfeld, 1983) but given the opportunistic nature of such collections, this is perhaps not surprising.

In the most recent reviews of the stock identity of Southern Hemisphere minke whales (Donovan, 1991; IWC, 1991a; b) it was clear that information from breeding areas is very limited and that information from feeding grounds suggests no clear stock boundaries. The hypothesis put forward for management purposes (IWC, 1991b) assumed five breeding grounds (including one in the southeastern Pacific, between 10–20°S and 110°-120°W, based on limited sightings data from Japanese scouting vessels; Kasamatsu and Nishiwaki, 1990) and overlapping feeding areas (IWC, 1991a, fig. 1). However, the probable existence of two species of minke whales in the Southern Hemisphere (see Mitchell, 1993), further complicates rational conservation efforts. We concur with the view that considerable effort should be put into examining stock structure in lower latitudinal waters, with the emphasis on molecular genetic techniques (e.g. IWC, 1993).

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SC/46/SM26

A Note on the Status of the Dusky Dolphins (*Lagenorhynchus obscurus*) off Peru

Koen Van Waerebeek

Centro Peruano de Estudios Cetológicos (CEPEC), Casilla 1536, Lima-18, Peru and Institut Royal de Sciences Naturelles de Belgique, Brussels, Belgium

ABSTRACT

This paper briefly examines the cetacean catch composition by species in Peruvian fisheries between 1984 and 1993. Despite a number of difficulties in interpreting the data, there is a significant decline in the proportion of dusky dolphins recorded between 1985–90 (77.5%) and 1991–93 (52.8%). During the same period the proportion of long-beaked common dolphins increased from 6.7% to 31.8%. Possible reasons for this are discussed. One possibility is that this reflects a true decrease in the abundance of dusky dolphins in response to exploitation. It is argued that the precautionary principle requires that effective conservation measures are implemented as a matter of urgency. In addition, studies should be carried out to determine the true reason for the change in proportions.

KEYWORDS: SOUTH PACIFIC; INCIDENTAL CATCHES; FISHERIES; MANAGEMENT; DUSKY DOLPHINS; LONG-BEAKED COMMON DOLPHINS; BURMEISTER'S PORPOISE; BOTTLENOSE DOLPHINS

The Peruvian Centre for Cetacean Research (CEPEC) initiated the scientific monitoring of cetacean landings in central Peru in 1984 and since that time the dusky dolphin, *Lagenorhynchus obscurus*, has been the most heavily exploited small cetacean in Peruvian waters; in some ports it comprised 80–99% of total takes (Read *et al.*, 1988; Van Waerebeek and Reyes, 1990; 1994a). Other commonly landed species included Burmeister's porpoise, *Phocoena spinipinnis*, the long-beaked common dolphin, *Delphinus capensis* (nomenclature see Van Waerebeek *et al.*, 1994; Heyning and Perrin, 1994; IWC, 1995), and the bottlenose dolphin, *Tursiops truncatus*.

A craniometric study and analysis of body size demonstrated the existence of a discrete eastern South Pacific dusky dolphin stock (Van Waerebeek, 1992). Some cranial differences also suggested separation of dusky dolphins from central Peru and northern Chile but a greater sample size from Chile is required to confirm or refute this (Van Waerebeek, 1992; 1993). Repeated concern has been expressed that removal rates of dusky dolphins off western South America may not be sustainable (Read *et al.*, 1988; IWC, 1994; Van Waerebeek and Reyes, 1994b; Van Waerebeek *et al.*, 1994). However, in the absence of abundance estimates and reliable estimates of either direct (large-mesh, gillnet and harpoon fisheries) or incidental kills, the impact of such mortality has not been assessed for any Peruvian small cetacean species. As a response to the concern expressed, a ban on small cetacean takes was decreed by the Ministry of Fisheries in 1990 but this has been largely ignored and the annual total kill in Peru was estimated at between 15,000 and 20,000 animals for the period 1991–93 (Van Waerebeek *et al.*, 1994; Van Waerebeek and Reyes, 1994b).

In this note I examine the species composition of the cetacean catch off central Peru (from Huarmey (10°04′S) to Laguna Grande (13°55′S) in the Paracas National Reserve) over a long-term period in order to try and identify any possible shifts in relative abundance. The catch data are obtained from freshly landed animals and cranial remains collected in refuse dumps and beaches around ports. Most animals were killed in gillnets or by hand-held harpoons and were landed at Pucusana, Cerro Azul or Ancón, the ports most intensively monitored throughout the study period. The recorded catches by species are given in Table 1. Unfortunately, the datasets for southern and northern Peru are too small to allow similar comparisons.

During the 1991 sampling effort of the Ancón wharf, García-Godos (1993) noted more common dolphins and fewer dusky dolphins being landed than usual, a trend that seemed to consolidate itself in other ports and in subsequent years (see Table 1). To minimise possible effects caused by short-term fluctuations in ecological conditions, which may influence species composition, I have defined two broad sampling periods with 1991 as the dividing line: 1985–1990 ($N_1 = 6{,}308$) and 1991–1993 ($N_2 = 2{,}022$). Significance was verified by contingency tests ($\alpha = 0.05$) and 95% confidence intervals (CI) of sample proportions were calculated according to the normal approximation method.

The percentage of dusky dolphins decreased significantly (chi^2 = 457, df 1, $P < 0.0001$) from 77.5% (CI 76.5–78.5%) in 1985–90 to 52.8% (CI 50.6–55.0%) in 1991–93, while that of common dolphins increased (chi^2 = 858, df 1, $P < 0.0001$) from 6.7% (CI 5.5–7.9%) to 31.8% (CI 29.8–33.8%). The proportions of the other main species, the Burmeister's porpoise and bottlenose dolphin did not differ significantly between the two periods (respectively chi^2 = 0.54, df 1, $P = 0.46$ and chi^2 = 3.76, df 1, $P > 0.05$).

In the absence of information suggesting that either fishing practices or fishing grounds have changed significantly over the period, I believe it is most likely that the observed changes in the relative rates of dusky and long-beaked common dolphins reflect true shifts in their relative abundance off central Peru. Both species primarily feed on Peruvian anchovy, *Engraulis ringens* (McKinnon, 1988; Van Waerebeek and J.C. Reyes, unpublished data) and have a neritic distribution. They are often entangled side by side in gillnets, suggesting that they intermingle, as is claimed by local fishermen. Sightings of two mixed schools during a boat survey in April 1994 (Van Waerebeek, unpublished data) support this view.

Table 1

Species composition of small cetaceans captured in coastal fisheries off central Peru from 1985-1993. Numbers are actually recorded individuals and are based on fresh (F) or cranial (C) specimens. They are not measures of total annual catches because sampling coverage was partial and unequal between both periods. Although more than 99% of *Delphinus* in Peru belong to *D. capensis*, a few *D. delphis* are also included in the statistics.

			L. obscurus		*Delphinus* spp.		*P. spinipinnis*		*T. truncatus*		Other species		Total	
Year	Locality	Type	N	%	N	%	N	%	N	%	N	%	N	Source
1984-85	Pucusana	C	35	41.7	5	6.0	18	21.4	21	25.0	5	6.0	84	Read *et al.* 1988; CEPEC files
1985	Pucusana	F	60	55.0	4	3.7	26	23.9	12	11.0	7	6.4	109	Read *et al.* 1988; CEPEC files
1985	Ancon	F	379	99.2	2	0.5	1	0.3	0	0.0	0	0.0	382	Read *et al.* 1988; CEPEC files
1985	Huacho	F,C	50	98.0	0	0.0	1	2.0	0	0.0	0	0.0	51	Read *et al.* 1988; CEPEC files
1985-86	San Andres	F,C	3	10.3	1	3.4	18	62.1	7	24.1	0	0.0	29	Read *et al.* 1988; CEPEC files
1986	Pucusana	F	455	87.8	4	0.8	20	3.9	33	6.4	6	1.2	518	Read *et al.* 1988; CEPEC files
1986	Cerro Azul	F	192	81.4	0	0.0	40	16.9	1	0.4	3	1.3	236	Read *et al.* 1988; CEPEC files
1987	Pucusana	F	623	64.5	230	23.8	77	8.0	29	3.0	7	0.7	966	Van Waerebeek and Reyes, 1990
1987	Cerro Azul	F	6	54.5	1	9.1	3	27.3	1	9.1	0	0.0	11	CEPEC files, unpublished
1988	Pucusana	F	1,224	75.3	110	6.8	272	16.7	13	0.8	6	0.4	1,625	Van Waerebeek and Reyes, 1994a
1988	Cerro Azul	F	51	92.7	3	5.5	1	1.8	0	0.0	0	0.0	55	Van Waerebeek and Reyes, 1994a
1989	Pucusana	F	1,060	82.6	21	1.6	175	13.6	23	1.8	5	0.4	1,284	Van Waerebeek and Reyes, 1994a
1990	Pucusana	F	750	78.3	44	4.6	139	14.5	21	2.2	4	0.4	958	Van Waerebeek *et al.* 1994
1984-90	Central Peru	F,C	4,888	77.5	425	6.7	791	12.5	161	2.6	43	0.7	6,308	
1991	Ancon	F	358	58.9	168	27.6	82	13.5	0	0.0	0	0.0	608	Garcia-Godos, 1993; Van Waerebeek *et al.* 1994
1992	Ancon	F	102	44.2	113	48.9	11	4.8	5	2.2	0	0.0	231	Van Waerebeek *et al.* 1994
1992	Cerro Azul	F	117	51.3	89	39.0	15	6.6	7	3.1	0	0.0	228	Van Waerebeek *et al.* 1994
1992	S. Andres, Laguna Grande	F,C	12	11.4	35	33.3	40	38.1	17	6.2	1	1.0	105	Tenicela, 1993; Van Waerebeek *et al.* 1994
1992	Pucusana	F	34	57.6	17	28.8	5	8.5	3	5.1	0	0.0	59	Van Waerebeek *et al.* 1994
1992-93	Chancay	F,C	46	52.3	31	35.2	8	9.1	3	3.4	0	0.0	88	Van Waerebeek *et al.* 1994
1992-93	Huarmey, Supe, Huacho	F,C	4	23.5	12	70.6	0	0.0	1	5.9	0	0.0	17	Van Waerebeek *et al.* 1994
1993	Cerro Azul	F	395	57.6	177	25.8	80	11.7	32	4.7	2	0.3	686	Van Waerebeek *et al.* 1994
1991-93	Central Peru	F,C	1,068	52.8	642	31.8	241	11.9	68	3.4	3	0.1	2,022	

One possible explanation for the change is that a partial niche vacuum created by high removal rates of dusky dolphins by coastal fisheries is being filled by an ecologically close species such as the long-beaked common dolphin; the roughly 25% relative reduction in landings of the former species is compensated by a 25% relative increase of the latter. Of course, in the absence of detailed knowledge of the natural history, distribution and abundance of these species, any number of ecological factors might be invoked to explain the observed changes. For example it may be a natural cyclic phenomenon whereby common dolphins move inshore, probably from the north or offshore. In this case a restoration of the 'normal' *Lagenorhynchus/Delphinus* proportion should ultimately be expected. Alternatively, it could be due to a combination of both a natural and a fisheries-caused ecological disturbance. Continued monitoring and an extension of the research programme to include a greater area will be needed to find out.

Despite the uncertainty, I believe that in accordance with the precautionary principle, it is important that effective conservation measures are implemented and that existing legislation is enforced as a matter of urgency (Van Waerebeek and Reyes, 1994b; Van Waerebeek *et al.*, 1994). In that sense I applaud the ministerial resolution of 5 August 1994 (No. 321–94-PE) which reiterates the prohibition of small cetacean exploitation in Peruvian waters, if this means that enforcement will be given new impetus.

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An Investigation of Incidental Catches of Large-Mesh Driftnet Fisheries from the South Pacific and North Atlantic

Michael Earle

Greenpeace International, Rue Cochetay 54, 4140 Gomze-Andoumont, Belgium

Thomas H. Woodley

Department of Zoology, University of Guelph, Guelph, Ontario, Canada N1G 2W1[1]

and

Michael Hagler

Greenpeace New Zealand, Private Bag, Wellesley St, Auckland, New Zealand

ABSTRACT

Driftnet fishing on the high seas for tuna and swordfish has expanded rapidly in recent years, yet little information is available on mortality levels for either target or non-target species. This paper documents catch rates of target and non-target species from a few observed operations and briefly describes the fishing operations of vessels from three areas: the American swordfish fishery in the Northwest Atlantic; the Japanese and Taiwanese fishery for albacore tuna in the Tasman Sea; and the French fishery for albacore tuna in the Northeast Atlantic. Observed incidental catches of cetaceans included common dolphins in all three fisheries, a southern bottlenose whale in the Tasman Sea fishery and striped dolphins in the Northeast Atlantic. The catch rate in the Tasman Sea fishery in 1990 was 0.080 cetaceans per km of netting, whereas 0.18 cetaceans per km of netting were recorded for the French albacore fishery in 1991. Although it is not known whether incidental catches of cetaceans by these fisheries are reducing the populations, these estimates indicate that large numbers could be killed annually.

KEYWORDS: INCIDENTAL CAPTURE; NORTH ATLANTIC; SOUTH PACIFIC; FISHERIES; COMMON DOLPHINS; BOTTLENOSE WHALE; STRIPED DOLPHINS

INTRODUCTION

Driftnet fisheries for tuna (*Thunnus* sp.) and swordfish (*Xiphias gladius*) have recently developed on the high seas in many regions of the world. High seas driftnets characteristically catch a wide range of species incidental to the fishing operation (FAO, 1990a; b; Northridge, In press). In most cases, estimating the impact of these fleets on non-target marine species is virtually impossible due to the lack of data on catch rates and on population sizes and dynamics of those species. We examined three driftnet fisheries: a fishery for swordfish in the northwest Atlantic and two others for albacore (*Thunnus alalunga*) in the northeast Atlantic and South Pacific.

The swordfish fishery in the northwest Atlantic occurs along the edge of the American continental shelf in the region of Georges Bank. By 1989, about 13 vessels were using driftnets in this fishery (Read, 1994; Matthew Gianni, pers. comm.).

Japan began a driftnet fishery for albacore in the South Pacific during the austral summer of 1983/84; by the 1988/89 season, up to 196 vessels from Japan, South Korea and Taiwan were operating. Following strong regional protest and diplomatic pressure, South Korea and Japan withdrew their driftnet vessels following the 1988/89 and 1989/90 seasons, respectively. Eleven Taiwanese driftnet vessels operated during the 1990/91 season (Anon., 1991).

In the northeast Atlantic, French fishermen began experimenting with driftnets and pelagic pair trawls for albacore in 1986. By 1991, over 40 vessels from France, 2 from Ireland and 3 from the UK were operating.

[1] Present address: *International Marine Mammal Association, 3 Paisley Street, PO Box 515, Guelph, Ontario, Canada, N1H 6K9*

In order to obtain some of the information necessary to estimate the impacts of these driftnet fisheries on non-target species, we observed their fishing operations for four periods between 1989–1991. Our objectives were to provide estimates of species composition and catch rates for non-target species and to briefly describe their fishing operations.

METHODS

Observations were made of the following fleets: the northwest Atlantic swordfish fishery (13–15 August 1989), the Tasman Sea albacore fishery (11–21 January 1990) and the northeast Atlantic albacore fishery (18–19 June 1990 and 20–28 June 1991). Information was collected on fishing locations, gear deployment practices, net design and catches of target and non-target species.

Net lengths were estimated in one of two ways. In the Tasman Sea, the length of a tan (individual section of netting) was measured and then multiplied by the total number of tans deployed. In other cases, lengths were estimated directly from the latitude and longitude coordinates of both ends of the net following deployment, as determined by a *Magellan* GPS NAV 1000 satellite navigation system. The distance between these coordinates was calculated as the length of the net. Where possible, these lengths were verified with a *Furuno* FR1505DA radar system.

Catch composition and numbers were recorded by observers in a small inflatable boat stationed near the point where the net was hauled on board the driftnet vessel. The inflatable was deployed from the Greenpeace mother ship. Animals were identified to the lowest taxonomic level possible. Occasionally, when weather conditions precluded launching the inflatable, observations were made using 7x50 binoculars from the bridge of the mother ship at distances of 50–100m.

For nets surveyed during retrieval that were of known length, catch rates were calculated for target and non-target species as the number of individuals per km of net. Since net length varied from vessel to vessel, mean catch rates (M) for each species were obtained by weighting the catch of each net by the length of net examined:

$$M = \frac{\sum_i n_i}{\sum_i L_i}$$

where n_i is number of individuals of a species caught in net i and L_i is the length of net i in km. The standard error of this mean was calculated as

$$SE = \sqrt{\frac{1}{(N-1)}\left[\frac{\sum_i n_i^2/L_i}{\sum_i L_i} - M^2\right]}$$

where N is the number of nets observed.

Nets were observed underwater for details of construction. In some cases, divers also observed the nets to provide information on species composition of the catch, although these data were not appropriate for catch rate calculations.

RESULTS

USA East coast swordfish fishery

Three American vessels were observed driftnetting in 460–920m of water along the outer edge of Georges Bank, 16km southwest of the Canadian/USA boundary for three days in August 1989. Sets ranged from 1.8–2.7km in length, with a 56cm stretch mesh size. They were deployed at dusk and floated 6m below the surface. Ships remained attached to their nets throughout the night, and nets were retrieved at dawn. Netting was made of braided nylon twine.

Catches of three sets were observed during retrieval operations, two in their entirety and about one half of the third for a total of 6.5km. The combined catch was 26 swordfish, 2 bigeye tuna (*T. obesus*) and 4 common dolphins (*Delphinus delphis*). These few data provide a catch rate estimate of 0.62 (SE = 1.64) cetaceans per km of netting.

Tasman Sea albacore fishery

Nine driftnetting vessels of the Japanese and Taiwanese albacore fleets were monitored in the Tasman Sea (37°-42°S, 156°-161°E) in waters of about 4,500m depth for 11 days in January 1990. Nets were usually deployed along a near north/south axis, across the expected easterly migration path of the tuna. Up to eight vessels deployed nets in a parallel formation about 3km apart.

The Japanese and Taiwanese driftnets differed somewhat in design, although total length per set was about 40km for both fleets. Japanese sets consisted of eight individual nets, 5km in length, deployed end to end. Nets consisted of 124 tans that were 39m long and 10m deep. They had a stretch mesh size of 180mm. The Taiwanese vessels, however, deployed sets of five nets that were 8km long. Each net consisted of 200 tans that were 39m long and 15m deep. They were constructed of multi-monofilament twine with a stretch mesh size of 200mm. Both fleets deployed the driftnets at the surface and attached radio beacons to both ends of each net. A gap of about 60m separated individual nets. Deployment began at about 1600 hrs (local time) and retrieval began between 0135 and 0900 hrs the following morning.

A total of 87.5km of netting from 18 nets, deployed during five sets, was observed during retrieval operations. The present analysis differs slightly from the preliminary report of Coffey and Grace (1990), because they used data collected during underwater observations for estimating catch rates and did not use weighted means. The total catch included 898 tuna (albacore and skipjack, *Katsuwonus pelamis*), 4 sunfish (*Mola mola*), 5 sharks, 3 billfish (Istiophoridae) and swordfish, 7 common dolphins and 24 bream (*Brama* ,.) (Table 1). No birds or turtles were observed in the nets.

Table 1

Catch records of albacore driftnet vessels in the Tasman Sea, 15-21 January 1990. Weighted means are per km.

Date	Net length (km)	Tunas	Ocean sunfish	Sharks	Billfish and Swordfish	Common dolphins	Bream
15	5.0	105	0	1	0	1	0
16	5.0	98	1	0	0	0	0
16	5.0	140	0	0	0	0	0
16	5.0	70	0	0	1	0	0
16	5.0	96	0	0	0	0	0
16	5.0	31	0	1	0	0	0
16	5.0	94	1	0	0	1	0
16	5.0	77	0	1	0	0	1
16	5.0	86	1	1	0	1	3
18	5.0	6	0	1	0	2	0
18	5.0	13	0	0	0	0	0
18	5.0	18	1	0	0	1	0
18	5.0	8	0	0	0	0	0
18	5.0	6	0	0	0	0	0
18	5.0	22	0	0	1	0	2
20	5.0	9	0	0	0	0	2
21	2.5	10	0	0	1	1	1
21	5.0	9	0	0	0	0	12
Totals	87.5	898	4	5	3	7	21
Weighted means		10.263	0.046	0.057	0.034	0.080	0.240
SEs		2.102	0.020	0.022	0.022	0.031	0.137

The catch rate for common dolphins was 0.080 (SE = 0.031) per km of netting. Estimated catch rates for other species are given in Table 1. Additionally, divers observed a southern bottlenose whale (*Hyperoodon planifrons*) in a net and released it alive.

Northeast Atlantic albacore fishery

A preliminary investigation of the French driftnet fleet in 1990 recorded a total catch of 84 albacore, 10 blue sharks (*Prionace glauca*), 2 bream and 1 common dolphin during underwater observations of four sets over three days in June. Nets ranged from 5–20km in length (as measured by radar).

In 1991, the operations of six French vessels were observed in the region of 43°-45°N, 17°-19°W in depths of 4,000m over a period of nine days. The vessels were estimated to be 20–23m in length with crews of seven to eight. Nets were suspended from the surface, ranged from 15–20m in height and had a stretch mesh size of about 160–170mm. They were constructed of multifilament nylon. Sets consisted of one or two nets, depending on the vessel, and had a total length of 5.7–8.5km (mean=6.8km, n=5). Deployment began between 2100–2200 hrs (local time) and retrieval began about 0530 hrs the following morning. Since it was not possible to observe all deployments, length estimates could not be obtained for all nets.

The total catch of 12 nets from eight sets included 2,144 albacore (including 55 that fell from nets and were lost), 130 sharks (mostly blue sharks), 82 bream, 4 swordfish, 3 common dolphins, 2 striped dolphins (*Stenella coeruleoalba*) and several other species (Table 2). The cetacean bycatch comprised a dolphin calf of about 1m, three dolphins that appeared to be immature and an adult of just over 2m.

Length estimates were obtained for seven of the twelve nets surveyed in 1991, totalling 28.1km (Table 2). The catch rates derived for these nets for common and striped dolphins were 0.11 (SE = 0.09) and 0.07 (SE = 0.05) per km of netting, respectively, or 0.18 (SE = 0.12) cetaceans per km of netting. A complete list of catches, net lengths and catch rates for the 1991 observations is provided in Table 2.

DISCUSSION

The present study provides some of the first estimates of catch rates of target and non-target species in large-mesh driftnet fisheries, although the surveys were of small sample sizes. The estimated catch rates of cetaceans (0.080 cetaceans per km in the Tasman Sea albacore fishery; 0.18 per km in the northeast Atlantic albacore fishery and 0.62 per km in the northwest Atlantic swordfish fishery), suggest that total cetacean mortality during the fishing season may be substantial given the number of sets made each year; the non-cetacean bycatch may also be substantial.

Data are also available from fisheries observers in these three fisheries. For the swordfish fishery, data were available on catches from 54 sets by nine vessels between 16 August and 14 November 1989 and 69 sets in 1990 (Anon., 1990; Read, 1994). In addition to swordfish, 33 species were observed caught during the two years. This included eight species of marine mammals with 43 common dolphins, 18 long-finned pilot whales (*Globicephala melaena*), 17 Risso's dolphins (*Grampus griseus*), 16 bottlenose dolphins (*Tursiops truncatus*), 13 unidentified beaked whales (Ziphiidae), 7 spotted dolphins (*S. frontalis*), 5 striped dolphins, 1 sperm whale (*Physeter macrocephalus*) and 1 unidentified dolphin (Delphinidae) (Anon., 1990; Read, 1994). Leatherback (*Dermochelys coriacea*) and loggerhead (*Caretta caretta*) turtles were also caught in the nets. The fewer species observed in our study presumably reflects the much smaller sample size.

Although the data released on the American swordfish driftnet fishery did not include lengths of the nets observed (Anon., 1990; Read, 1994), if a length of 2.7km is assumed (the maximum length allowed under US domestic law; see also Read, 1994) catch rates can be estimated. The total catch of 54 cetaceans reported from 54 sets in 1989 results

Table 2

Catch records of French albacore driftnet vessels in the northeast Atlantic, 21-28 June 1991. Weighted means are per km.

Day of June for the set	Surveyed portions of nets (km)	Albacore tuna	Shark	Bream	Jellyfish	Squid	Swordfish	Sea Bass	Common Dolphin	Striped Dolphin	Leather-jacket	Unidentified fish
20	NA	168	5	5	0	1	0	0	0	0	0	6
21	3.0	203	7	1	0	1	2	1	0	0	0	5
21	NA	41	2	2	0	0	0	0	0	0	0	3
22	NA	124	3	5	0	0	0	0	0	0	0	1
22	NA	148	19	7	0	2	0	0	0	0	0	5
23	3.7	221	15	2	0	0	1	0	0	0	1	0
23	3.2	233	8	4	0	1	0	0	0	1	0	1
24	3.9	300	25	12	0	2	0	0	0	0	1	0
24	NA	118	2	1	0	0	1	0	0	0	0	0
25	3.9	254	23	2	0	0	0	0	0	0	0	0
26	4.7	221	8	1	0	2	0	1	0	0	0	2
27	5.7	113	13	40	34	2	0	1	3	1	0	0
* Total A	NA	2,144	130	82	34	11	4	3	3	2	2	23
** Total B	28.1	1,545	99	62	34	8	3	3	3	2	2	8
** Weighted means		54.98	3.52	2.21	1.21	0.28	0.11	0.11	0.11	0.07	0.07	0.28
** SEs		8.08	0.72	1.06	0.98	0.07	0.09	0.05	0.09	0.05	0.05	0.21

* Calculated from all nets surveyed.

** Calculated only from nets where a known portion was surveyed.

in an estimate of 0.37 cetaceans per km while the total catch of 67 cetaceans caught in 69 sets provides an estimate of 0.36 cetaceans per km in 1990. These values are lower than the estimate of 0.62 cetaceans per km derived from our small sample.

A New Zealand government observer surveyed the operations of the Japanese experimental albacore driftnet vessel RV *Shin-Hoyo Maru* in the Tasman Sea during the same fishing season as the present study (Sharples *et al.*, 1990). A total of 41 species was observed in 22 sets, including three leatherback turtles and two Westland black petrels (*Procellaria westlandica*). The marine mammal catch consisted of 45 common dolphins, 10 striped dolphins, 1 short-finned pilot whale (*Globicephala macrorhynchus*) and 1 southern bottlenose whale. The number of species reported is again greater than in our study, probably reflecting the larger sample size. All except the bottlenose whale were dead upon retrieval, and that animal was released but carried a section of netting with it. The 57 cetaceans were caught in 22 sets totalling 698.4km, providing a weighted mean catch rate of 0.082 (SE = 0.022) cetaceans per km. This figure is similar to the estimate of 0.080 cetaceans per km derived in the present study.

In the northeast Atlantic, the IWC (1992) reported catch rates of 0.03–0.08 cetaceans per km of netting for the French albacore driftnet fishery for 1989 and 1990, based on data in Antoine (1990). These bycatch estimates are somewhat lower than the 0.18 per km reported here.

Few other estimates of cetacean catch rates in tuna and swordfish driftnet fisheries are available. An observer aboard the *Shin-Hoyo Maru* in the Sub-Tropical Convergence, to the south of French Polynesia, recorded catches from 14 sets in 1990. Eight common dolphins and 1 Risso's dolphin were caught in 408km, which results in a weighted mean of 0.022 cetaceans per km. FAO (1990a) provided a figure of 0.058 cetaceans per km for the 'North Pacific tuna driftnet fishery', although no source is credited for the estimate. Data reported from an observer programme for the swordfish driftnet fishery off the coast of California result in a catch rate of 0.046 cetaceans per km (Lennert *et al.*, 1994).

Bycatch rate estimates provided here can be used with data on fishing effort to provide annual catch estimates for the relevent driftnet fisheries. Such estimates would have to be treated with caution, because they are based on relatively small sample sizes. Clearly, the collection of more extensive data on catch rates of incidentally caught species, and the other information (estimates of population size and fishing effort) required for proper assessments of the impact of driftnet fishing on non-target species is required to refine these figures.

Overall, our observations of driftnet fisheries in the South Pacific and North Atlantic indicate substantial cetacean bycatches. Indeed, it seems that wherever cetacean distributions overlap with driftnet fisheries, cetaceans will inevitably be caught, sometimes in large numbers (IWC, 1992).

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Causes and Solutions

SC/O90/G50

How Many Did You Catch? The Effect of Methodology on Bycatch Reports Obtained from Fishermen

Jon Lien

Ocean Sciences Centre and Department of Psychology, Memorial University of Newfoundland, St. John's, Newfoundland, A1C 5S7, Canada

G.B. Stenson

Science Branch, Fisheries and Oceans, St. John's, Newfoundland, Canada

Sue Carver

Whale Research Group, Memorial University of Newfoundland, St. John's, Newfoundland, A1C 5S7, Canada

and

John Chardine

Canadian Wildlife Service, St. John's, Newfoundland, Canada

ABSTRACT

Reports of fisheries bycatches are obtained from fishermen by various methods and often presented without evaluating the reliability of the reports. We examined the effects of method of obtaining estimates of small cetacean and seal bycatch on reports by inshore fishermen in Newfoundland and Labrador during 1990. Fishermen were phoned and questioned about incidental catches. Responses were examined for effect of the interviewer's agency and sex. About 15% of fishermen interviewed were re-phoned and re-questioned. Fishermens' ability to recall well documented numbers of animals caught a decade earlier was evaluated. *In situ* interviews were conducted and logbooks examined in a manner that permitted comparisons among data obtained by different methods. Differences in reports caused by different motivations were examined by paying a sub-sample of fishermen.

Results indicate that bycatch estimates are influenced by methodology used to obtain reports from fishermen. Fishermen are influenced by interviewers. Bycatch estimates were markedly skewed. In most studies variance of estimates of bycatch within and between fishermen were positively correlated with size of reported catches; fishermen tend to count '1 – 2 – 3 – 4 – 5 – dozens – hundreds – thousands'. We conclude that investigations without assessments of their methodology for obtaining their bycatch reports cannot be evaluated or interpreted. Scaling corrections and improvements of survey methodology are discussed.

KEYWORDS: INCIDENTAL CAPTURE; FISHERIES; METHODOLOGY; NORTH ATLANTIC

INTRODUCTION

Incidental entrapment of non-target species in fishing gear (bycatch) is a worldwide phenomenon of major concern to resource managers. For example, in Newfoundland and Labrador, some 30,000 inshore fishermen employ substantial amounts of fishing gear, several kinds of which catch individuals of a wide variety of target and non-target species. The levels of bycatch are very difficult to determine, especially in areas such as Newfoundland, which is geographically large and intensively fished. Historically, data on incidental catches have been based upon reports obtained from fishermen through phone interviews, mailed questionnaires, or *in situ* interviews. In reports of such data it has been assumed that there was no systematic bias in reporting and that catches were counted more-or-less accurately. Few, if any, studies have incorporated procedures to test these assumptions (Lien *et al.*, 1989).

Studies based on reports from fishermen can suffer from numerous problems. The first is inconsistency in reliability of reports from fishermen (Lien, 1987). Numbers may be inaccurate and change depending upon the interviewer and when and how questions are asked. Problems such as these make it virtually impossible to correct estimates to quantify catches accurately.

The second is determining bias in estimated catches reported by fishermen. For example, examination of data obtained in most studies indicates that variance of estimates of bycatch, both within and between fishermen, are correlated with size of catches. Fishermen tend to count '1 – 2 – 3 – 4 – 5 – dozens – hundreds – thousands' (Lien *et al.*, 1989).

Finally, although there are strong indications that bycatch estimates are influenced by the methods used to obtain data (Lien, 1980), there has been no effort to quantify effects of differences in methodology, motivation or interviewer.

Like other investigators, we have attempted to obtain reliable, useful estimates of numbers of animals incidentally taken and their geographic and seasonal variation. This paper presents findings on how method affects bycatch estimates.

METHODS

Five techniques for obtaining bycatch reports from fishermen were examined: (1) phone interviews; (2) *in situ* interviews; (3) log books; (4) recall of past catches; and (5) payment for samples.

(1) Phone interviews

A total of 350 fishermen from Newfoundland and Labrador were phoned in May 1990 and asked about incidental catches during the immediately previous (1989) fishing season. Fishermen were selected randomly from a list of chairmen of local 'fishermens' committees'; such individuals are typically among the most successful fishermen and are active in organising local fishery-related activities.

Fishermen were assigned randomly to one of four experienced interviewers (two male; two female). Two interviewers were fishermen; two were fisheries technicians. Each interviewer identified himself/herself as calling on behalf of either a government fishery agency or a university (Science Branch, Fisheries and Oceans or the Whale Research Group of Memorial University). A maximum of six attempts was made to reach an individual before he/she was dropped.

Each fisherman was asked to describe the types of gear used in 1989 and for each gear type to summarise information on fishing effort (amount used and duration of fishing). Questions were asked on fish catches and on incidental catches of non-teleost species (cetaceans, pinnipeds, birds, sharks and turtles) in each type of gear. The various local names fishermen used for non-target species were collapsed into unified categories: 'seals', 'small cetaceans', 'whales' and 'seabirds'. Interviewers asked fishermen if they would be willing to continue reporting bycatch and rated their 'cooperativeness' as uncooperative, helpful or very helpful.

Approximately two to three weeks after the initial phone survey was completed, 15% of the fishermen contacted were phoned by a different interviewer and asked again about their 1989 bycatch. During this second interview questions were restricted to bycatches in groundfish gillnets.

(2) In situ interviews concerning immediately previous season

Interviewers travelled to convenient fishing communities on the southern shore of the Avalon Peninsula and on the northeast coast of Newfoundland and conducted *in situ* interviews with 37 crew skippers regarding bycatch. They were interviewed in the presence of their crews. Questions were identical to those asked in the phone interviews.

(3) Examination of logbooks

Forty five fishermen were phoned in 1989 and asked to participate in a monitoring program by reporting fishing effort, fish catches and marine mammal bycatches. Log books were returned at the end of each month from April through August. Participants were paid $50 at the end of the fishing season when they had returned all completed log books.

(4) Phone interviews concerning catches from a previous decade

A phone survey of 100 chairmen of fishermens' committees regarding small cetacean bycatch by inshore fishermen was conducted in 1980 (Lien, 1980; 1987). We phoned these fishermen again in June 1990 and asked about their 1980 catches, their 1989 bycatch and asked them to estimate changes in the magnitude of bycatch.

(5) Phone interviews with payment for samples

To examine effects of motivation on tendency to report, 56 fishermen who had been contacted in the 1990 phone survey and indicated a willingness to participate further in bycatch studies were formed into four groups: (1) fishermen who volunteered to collect and save specimens for scientists (n=5); (2) those who had stated they would participate in further monitoring of bycatch and were later called and asked specifically to collect and save specimens; they received no payment for reports (n=20); (3) those as in (2) but given $10 for each reported bycatch animal collected; and (4) those as in (2) but given $25 for each by-caught animal reported and collected.

At the end of the season fishermen in all groups were called, thanked for their participation in the program, and questioned again about their total bycatch of small cetaceans, both reported and unreported.

RESULTS

Results are presented below by method; comparisons among methods are made in the discussion.

Phone interviews concerning the immediately previous season

Only 235 (67%) of the fishermen selected were successfully reached by phone. Nearly all interviewed were rated as 'very helpful' (81.6%) or 'helpful' (17.0%) by interviewers.

Mean reported bycatches of small cetaceans (Table 1) and seals (Table 2) were highest in groundfish gillnets. Although the percentage of fishermen who reported catching at least one small cetacean (12.6%) in groundfish gillnets was similar to those reporting at least one bycatch in salmon gillnets (10.7%), mean catches were much higher for groundfish (0.91 animals/fisherman) than for salmon (0.27 animals/fisherman) gillnets. Mean numbers of animals caught were heavily influenced by very high catches, especially of seals, reported by some fishermen (Tables 3 and 4).

Table 1

Results of 1990 phone survey to monitor bycatch of small cetaceans. (n = 235 fishermen).

Gear type	Number of fishermen using gear	Bycatch of small cetaceans: Mean catch/ fisherman	SD	% of fishermen with some bycatch
Groundfish gillnets	190	0.91	3.57	12.6
Salmon gillnets	74	0.27	0.89	10.7
Lumpfish gillnets	109	0.05	0.40	2.8
Codtrap	135	0.01	0.08	1.1
Capelin traps	94	0.00	0.0	0.0

Table 2

Results of 1990 phone survey to monitor bycatch of seals. (n = 235 fishermen).

Gear type	Number of fishermen using gear	Bycatch of small cetaceans: Mean catch/ fisherman	SD	% of fishermen with some bycatch
Groundfish gillnets	190	5.56	18.55	24.2
Salmon gillnets	74	0.36	2.09	1.4
Lumpfish gillnets	109	6.20	13.61	38.5
Codtraps	135	0.03	0.28	14.8
Capelin traps	94	0.01	0.10	1.1

Table 3

Frequency of small cetacean groundfish gillnet bycatch reported in 1990 phone survey (n = 235 fishermen).

No. of small cetaceans reported caught in 1989	Frequency	% of Interviewees	Cumulative %
0	159	83.7	83.7
1	10	5.3	88.9
2	7	3.7	92.6
3	2	1.1	93.7
4	4	2.1	95.8
6	1	0.5	96.3
12	3	1.6	97.9
15	2	1.1	98.9
25	1	0.5	99.4
30	1	0.5	100.0

Table 4

Frequency of seal groundfish gillnet bycatch reported by 235 fishermen in 1990 phone survey.

No. of seals reported caught in 1989	Frequency	% of Interviewees	Cumulative %
0	769	88.0	88.0
1	19	2.2	90.2
2	7	0.8	91.0
3	14	1.6	92.6
4	4	0.5	93.0
5	3	0.3	93.4
6	6	0.7	94.1
7	3	0.3	94.4
8	4	0.5	94.9
9	1	0.1	95.0
10	10	1.1	96.1
11	1	0.1	96.2
12	4	0.5	96.7
15	4	0.5	97.1
17	2	0.2	97.4
20	7	0.8	98.2
22	1	0.1	98.3
25	2	0.2	98.5
30	2	0.2	98.7
40	1	0.1	98.9
50	7	0.8	99.8
96	1	0.1	99.9
100	1	0.1	100.0

The effect of interviewer's affiliation was not significant but the sex of the interviewer was. Female interviewers more frequently were given reports of 'whales' ($p<0.0002$) or 'porpoises' ($p<0.013$) than were male interviewers. This reflects terms used by interviewers and did not, in this case, affect frequency in the final categories. The two interviewers with fishing experience were given higher estimates of small cetacean bycatch and fish landings than were interviewers without fishing experience.

We were unable to reach 28% of the fishermen designated for a second interview; thus there were only 25 recall interviews.

When asked about their bycatch in groundfish gillnets a second time, these 25 fishermen changed reports fairly frequently; 16 out of 25 (64%) changed answers in at least one of four categories (Table 5). Fishermen who reported a low bycatch in the first phone interview made relatively few changes in all categories. Only 8.2% made changes in their second bycatch reports if on the first report numbers were 0–2; 84.6% of fishermen made changes in bycatch reports on the second call if they had estimated bycatch of three or more on the first call. The direction of changes was random (52.6% up; 47.4% down). If fishermen changed their estimate of 'seabirds' between calls ($n=11$) and reported some bycatch in other categories ($n=5$), they also tended to change their estimates in at least one of the other category (80%).

Table 5

Bycatch reports of whales, dolphins, seals and seabirds: Changes between two phone calls in the same fishing season. Total fishermen = 25; number that change answer in at least one category on the second call = 16.

No. animals reported on first call	No. fishermen reported	No. fishermen that changed	Change to
'Whale/dolphin'			
0	24	0	
2	1	0	
'Small whale'			
0	22	0	
1	2	0	
15-20	1	1	60-70
90	1	1	12
'Seals'			
0	17	3	12; 2-3
3-4			
1	1	0	
2	1	0	
2-3	1	0	
6	1	1	12
8	1	1	6-7
12-15	1	1	12
200	2	2	50-50; 100
'Seabirds'			
0	13	2	'few' 15-6
'few'			
1	1	0	
2	2	2	0; 10-12
12-15	1	1	6-12
12-200	1	1	40-50
25	1	1	100
100	2	1	70

There were substantial differences among interviewers in the numbers of changes of estimates which occurred when they were involved in the second interviews. Ratios of changed estimates on second interviews conducted were 2/6 (33%), 8/9 (89%), 4/7 (57%) and 2/3 (67%) for the four interviewers.

In situ interviews concerning the immediately previous season

Results of *in situ* interviews with 37 fishermen are presented in Table 6. All fishermen approached for an interview agreed and were scored by the interviewer as 'very helpful'. Most of these interviews were conducted in the presence of other fishermen; frequently fishermen, usually crewmen, present during the interview added or corrected information given by the interviewee.

Examination of logbooks

Initially, 45 fishermen contacted agreed to maintain log books of fishing effort, fish catches and marine mammal bycatch; 22 (49%) actually returned their log books monthly during 1990. Analysis of log book records of bycatch is presented in Table 7.

Table 6

Bycatches of small cetaceans and seals reported in *in situ* interviews (n = 37 fishermen).

Gear type	No. of fishermen using gear	Mean no. small cetaceans	% fishermen reporting any catch	Mean no. seals	% fishermen reporting any catch
Groundfish gillnets	28	1.07	35.7	16.9	46.4
Salmon gillnets	10	0.30	30.0	0.0	0.0
Salmon gillnets	12	0.50	16.7	5.4	33.3
Codtraps	16	0.06	6.0	0.1	6.0

Table 7

Bycatch of marine mammals reported in groundfish gillnets in 1990 by logbooks. (n = 22 fishermen).

Animals	Total no. reported bycatch	Mean bycatch per fisherman	% of fishermen reporting any catches
Small cetaceans	22	1.0	31.8
Seals	115	5.23	59.0

Phone interviews concerning catches from a previous decade

Participants in the 1980 study of bycatch were difficult to re-contact. Of 100 in the initial sample only 62% had current phone numbers. Of those, 14.5% were not successfully contacted; 19.3% were either retired or dead; 17.7% had left fishing. Twenty-nine were successfully re-contacted and interviewed. In 1980 these 29 individuals had reported a mean catch of 5.4 small cetaceans; 55% of them had reported catching at least one small cetacean in 1980.

When asked in 1990 to recall their 1980 bycatch, 11 fishermen (37.9%) could not remember and would not guess while 18 (62.1%) gave estimates. Typically fishermen who had reported high estimates of bycatch in 1980 were the individuals who in 1990 could not remember or would not give estimates. Of fishermen that did recall 1980 catches, 24% recalled reported catches without changes, 21% made lower estimates and 17% made higher estimates in 1990. The recalled mean estimate of 1980 catches was 1.3 small cetaceans; 39% of the fishermen reported catching at least one small cetacean.

When asked to give their impression whether bycatches of small cetaceans were 'up' or 'down' 21% indicated they 'couldn't tell', 3% said the 'catches were up', 10% said catches were 'about the same', and 62% said 'catches were down'. These estimates generally agreed with reported 1990 catches (average 1.1 small cetacean); 27% of these fishermen reported catching at least one small cetacean in 1990.

Phone interviews with payment for samples

Overall, the mean bycatch of small cetaceans reported by fishermen participating in the payment for samples experiment was 0.34 during the 1989 season. When the numbers are corrected to include catches not reported initially but were discovered by later phone interviews, mean catch was 0.48; 19.6% of fishermen in the sample caught at least one small cetacean.

Comparison of the groups (Table 8) indicate that the highest catches of small cetaceans were reported by individuals who received $25 for reporting each catch. Their catches were substantially higher than those of fishermen receiving lower remuneration. However, when fishermen in all groups were questioned in phone interviews at the end of the season about reported and unreported bycatch, the effects of motivational differences which could account for reported vs unreported catches were not clear. Fishermen in the $25 group had both the highest number of reported and unreported catches.

DISCUSSION

Bycatch monitoring methods

Methods used to obtain data to estimate bycatches in groundfish gillnets in 1989 are compared in Table 9. Differences cannot be simply explained.

Some variation may have resulted from the relatively small samples of some methods and a site bias – some areas had higher sample density than others. Differential distribution of seals and small cetaceans might explain the higher catches reported in *in situ* interviews. In phone interviews, where the sample size was larger and data could be clustered by regions, there were large differences in bycatches reported from different areas. We believe that some of these differences reflect relative abundance of animals in the areas. However, in other regions our sample size is too small to make comparisons. Methods to estimate bycatch should be carefully checked for potential site bias.

Fishermen who reported large numbers of animals as bycatch were the same individuals who were most likely to change their estimated catches. They tended to change consistently in that if they changed estimated catches of one species group, they were likely to change estimated catches of other species.

Information obtained by re-phoning fishermen to verify their reports bycatches given a decade earlier shows a similar pattern. It was the fishermen that reported large bycatches that could not recall earlier bycatch numbers and changed them in the 1990 interview. In these interviews it is interesting that the fishermens' impressions of changes in bycatch agree with the trend in the numerical data they provided.

The 'pay for samples' approach may be considered the most reliable method for obtaining reliable estimates of bycatch, although totals may have been affected by animals caught but not reported; 7 of 26 (26.9%) small cetaceans were not reported because fishermen released them alive, they dropped out of the net before recovered, or they were rotten on discovery. However, the percentage of fishermen catching at least one animal did not change much following end-of-season phone interviews. This method gave lowest bycatch estimates.

Data obtained in a social context, as in the *in situ* interviews seemed to have the advantage of several individuals verifying and correcting estimates of bycatch made by the principal interviewee. Interviewers agreed

Table 8

Small cetaceans reported by fishermen in program monitoring bycatch with different incentives. All participants were Newfoundland inshore fishermen who agreed to report and save dead small cetaceans during 1990 (June - Sept.). *Participants were called in October 1990, thanked for their participation and asked by interviewers how many animals they had actually captured during the season.

Classification Interviewees	No. interviewed	Sm. cetaceans reported caught	% fishermen that caught at least 1	Actual no. caught*
Volunteer	5	2	20	none
No pay	20	0	0	2
$10/catch	10	1	10	none
$25/catch	21	16	30	5

Table 9

Mean number of seals and small cetaceans reported caught in groundfish gillnets and percentage of fishermen that reported catching them: comparison of different monitoring methods used during 1990.

	No. fishermen interviewed	Mean no. seals caught/ fishermen	% fishermen reporting any seal catches	Mean no. small cetaceans caught/ fishermen	% fishermen reporting any cetacean catches
Phone interview	190	5.56	12.0	0.91	12.6
In situ interview	28	16.96	46.4	1.07	35.7
Logbooks	22	5.23	59.0	1.00	31.8
Payment experiment	56	-	-	0.48	19.6

that face-to-face contacts with fishing crews who were known from past contacts resulted in the most reliable, comprehensive estimates of bycatch. Maintenance of log books by volunteers, followed by end-of-season *in situ* interviews is probably the best monitoring method. However, only about one-half of our log book volunteers, paid $50 for their efforts, completed books and returned them. Perhaps more would be returned for higher pay. The high investment of time, and perhaps money, and the relatively low return make costs of this method a major disadvantage.

It is not clear that any single method is best. Each had problems with reliability of reports and potential sample bias. Costs in time and money to conduct such investigations, as well as practical situational factors, may be reasonable basis for selecting any particular method.

However, incorporating reliability checks into each method does give a basis for evaluating estimates of bycatches. Whether the reliability check is a social one where fishermen report their catches in the presence of peers, motivational, double checking numbers with second interviews or requiring the proof of a dead body, some procedure is necessary to evaluate the adequacy of the method.

Bycatch counting and distribution

Reports from fishermen using various methods resulted in distributions which were markedly skewed. Most fishermen reported catching no or few animals. When re-interviewed these numbers were reliably recalled. A few fishermen reported higher catches but their estimates used scales which were not continuous or linear; recall of higher estimates was more variable. Mean sizes of reported bycatches generally appeared correlated with variability of reports.

Distributions with such characteristics are difficult to summarise. Arithmetic means fail to adequately characterise them; means inordinately reflect the less reliable high estimates of fishermen. Mathematical transformations might be useful so that bycatch data can be adequately described statistically, but it is not clear which type of transformation is best.

Conclusions

We conducted these investigations of bycatch methodology to help us obtain the most reliable data possible on bycatches of about 30,000 inshore fishermen scattered along 17,000km of coastline. While we have not found a single monitoring methodology which is clearly best, the studies have allowed us to reach the following conclusions:

(1) numerical estimates of bycatch are, at least in part, a function of methodology used;
(2) interviewer and motivational variables influence estimates of bycatch which fishermen provide;
(3) to understand the adequacy of any methodology it is necessary to check the reliability of estimates on bycatch in order to interpret them;
(4) counting scales of fishermen are not continuous or linear. Higher bycatch estimates are more variable than lower ones. Mathematical transformations are necessary.

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Is There Common Cause for Dolphin Capture in Gillnets? A Review of Dolphin Catches in Shark Nets off Natal, South Africa

V.G. Cockcroft

Centre for Dolphin Studies, Port Elizabeth Museum, P.O. Box 13147, Humewood 6013, Republic of South Africa

ABSTRACT

Biological, environmental and physiographic data pertaining to the capture of common (*Delphinus delphis*), bottlenose (*Tursiops truncatus*) and Indo-Pacific hump-backed (*Sousa chinensis*) dolphins captured in shark gillnets set off Natal, South Africa, between January 1980 and December 1988 were analysed. Examined individually, these data provide insights into the social organisation and biology of the three species and suggest a number of reasons why each dolphin species may be incidentally captured in gillnets. There were, however, few commonalities when comparing data for the different species. Generally, this indicates that dolphins occurring around nets are prone to capture. The implications of this for capture prevention or reduction and the modification of gear are discussed. Recommendations regarding the continued deployment of shark nets off Natal and the management and conservation of small cetaceans elsewhere are proposed.

KEYWORDS: INCIDENTAL CAPTURE; INDIAN OCEAN; COMMON DOLPHIN; BOTTLENOSE DOLPHIN; INDO-PACIFIC HUMP-BACKED DOLPHIN; BEHAVIOUR; MANAGEMENT; OCEANOGRAPHY; FEEDING; MOVEMENT

INTRODUCTION

The incidence of small cetacean capture in gillnets and traps, in both high seas and coastal waters, is diverse and widespread in all oceans (Beverton, 1985) and can be viewed as the greatest single cause of their mortality (IWC, 1994). Consequently, the elimination or reduction of such catches is of prime importance in the management and preservation of existing stocks. Unfortunately, there has been little progress in perfecting methods of preventing or reducing captures, particularly where socio-economic realities conflict with management and conservation.

The results of experiments to modify either the setting of nets, such as sub-surface placement, or their acoustic properties have been equivocal at best (e.g. Murison, 1986; Peddemors *et al.*, 1990). With hindsight, the failure of these attempts, particularly the latter, was to be expected. The assumptions on which much of this research was based were unfounded and little fundamental research into the causes of incidental capture was undertaken prior to the commencement of most of these studies. As a priority therefore, establishing the causes of and sequence of events leading to incidental capture are fundamental in formulating methods of capture prevention or reduction.

Off Natal on the east coast of southern Africa (Fig. 1), numbers of small cetaceans are caught incidentally in non-commercial gillnets set off beaches frequented by tourists. These nets are set to catch sharks and reduce the probability of shark/bather interaction. Incidental catches of dolphins in these nets commonly include three species, common dolphin (*Delphinus delphis*), Indo-Pacific hump-backed dolphin (*Sousa chinensis*) and Indian Ocean bottlenose dolphin (*Tursiops truncatus*) (Cockcroft, 1990). Assessments of population numbers of the latter two species in Natal waters suggest that their continuing incidental mortality may lead to their decline in the Natal region (Ross *et al.*, 1989; Cockcroft, 1991; Cockcroft *et al.*, 1992a; 1992b). Concern for this decline prompted the initiation of an experimental programme into methods of preventing dolphin capture (Peddemors *et al.*, 1991) and an assessment of biological, environmental and physiographic factors implicated in the capture of bottlenose dolphins (Cockcroft, 1992).

This paper examines these parameters for common and hump-backed dolphin catches and re-examines those pertaining to bottlenose dolphin captures (Cockcroft, 1992). Firstly, this is done in an effort to determine which of these factors may be important in the capture of the individual species. Secondly, it is an attempt to compare the apparently pertinent factors for each species to ascertain which, if any, may be common to more than one species.

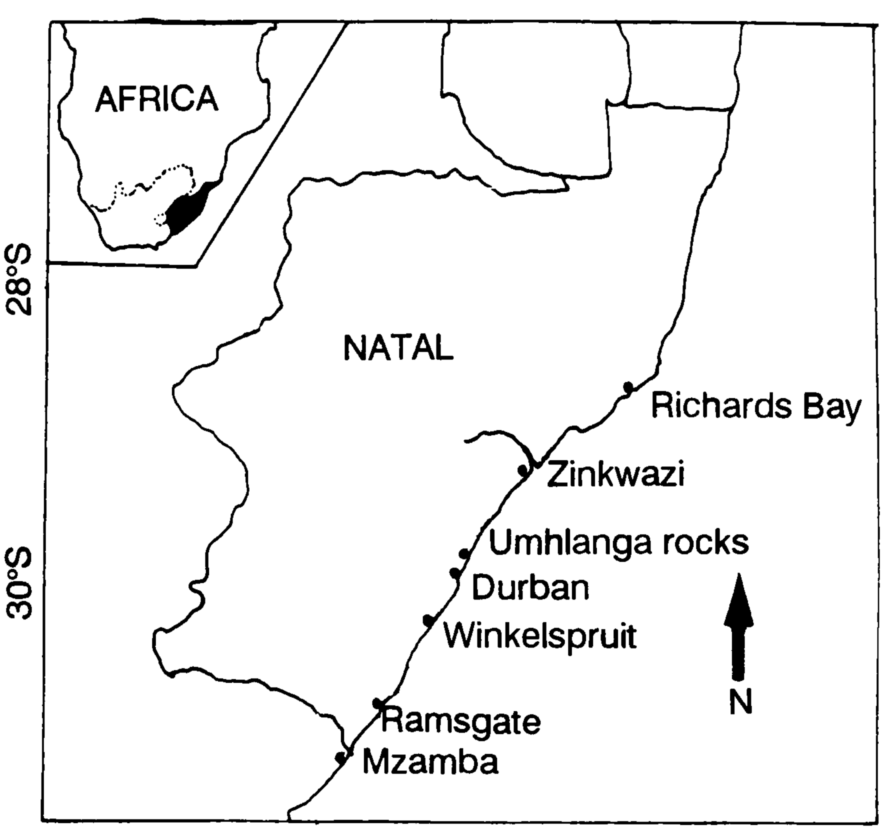

Fig. 1. Natal on the east coast of southern Africa. Shark gillnets, to catch and reduce the populations of sharks, are positioned some 500m off-shore at 44 bathing beaches between Richards Bay and Mzamba.

STUDY AREA, MATERIALS AND METHODS

The locality, distribution and specifications of all Natal Sharks Board (NSB) net installations off Natal, South Africa (Fig. 1), are provided by Cockcroft (1990). Necropsies performed on all dolphins retrieved from the nets between 1980 and 1988, inclusive, provided biological data, such as length, weight and sex. Additionally, the proportional fullness of the stomach was estimated from the weight of solid food remains in the stomach as a proportion of the estimated maximum weight of prey the stomach could hold. This was assumed to be equal to the maximum fluid volume of the stomach (*sensu* Cockcroft and Ross, 1990), but slightly modified from this previous assessment in that all liquid was removed from stomachs before fluid volume estimates were made.

Environmental parameters for each capture were taken from daily records of sea temperature, water visibility, wave height and current direction, all routinely collected by NSB staff during daily net inspections of each netted beach. The physiography of each net installation was obtained from underwater surveys undertaken by staff of the NSB. Thus, for each species a serial matrix containing biological, environmental and physiographic data for each captured dolphin was constructed.

The data matrix (Table 1) for each dolphin species consisted of both ordinal and nominal data, of different measurements and scales and was analysed using both univariate and multivariate statistical techniques. The latter analyses were found to be unsuitable because of the mixture of ordinal and nominal data and the serial nature of the matrices, which, importantly, contained data only for captured dolphins. Consequently, the individual matrices were analysed separately, such that each factor field within the matrix was examined for serial randomness and skewness. Where either of these tests showed significant patterns, this was taken to be an indicator of the significance of that factor field.

Table 1

Variables included in the matrix of biological, environmental and physiographic parameters examined to determine factors contributing to the catch of dolphins in shark gillnets off Natal.

1. Locality of capture.
2. Year of capture.
3. Month of capture.
4. Day of capture.

Biological characteristics

5. Sex (male or female).
6. Age/Maturity class (calves, juvenile males, juvenile females, resting females, pregnant females, lactating females, mature males).
7. Weight (kg).
8. Length (cm).
9. Age (GLGs).
10. Number of animals caught simultaneously.
11. Percentage fullness of stomach.

Environmental characteristics

12. State of the tide (two days either side of spring tide, two days either side of neap tide, mid tide).
13. Water visibility on day before capture (m).
14. Water visibility on day of capture (m).
15. Difference between 13 and 14.
16. Temperature on the day before capture (°C).
17. Temperature on the day of capture (°C).
18. Difference between 16 and 17.
19. Current direction (northerly, southerly, offshore).
20. Swell height (m).

Physiographic characteristics

21. Net in which caught (locality specific).
22. Channel at the net.
23. Reef under the net.
24. Reef in the net area other than under net.
25. Type of reef (bare rock, flora covered).
26. Substratum type (rock, rock+algae, rock+sand, sand, mud).
27. Distance of net from shore (m).
28. Depth of water at net (m).

RESULTS

Between January 1980 and December 1988, 250 bottlenose, 290 common and 53 hump-backed dolphins were retrieved from the Natal shark nets (Cockcroft, 1990). The geographic distribution and length and sex composition of these dolphins have been previously described (Cockcroft, 1990) and these results are not presented again here. Where variables within either the common or hump-backed dolphin capture matrices appeared significant, they are presented here. Additionally, those variables apparently significant in bottlenose dolphin capture (Cockcroft, 1992) were analysed for common and hump-backed dolphins and the results are presented here.

Biological characteristics (variables 5 to 11 – Table 1)

Stomach fullness

The degree of stomach fullness of captured bottlenose dolphins was assessed by Cockcroft (1992), but is re-assessed here for comparison with common and hump-backed dolphins.

Regressions for plots of measured stomach fluid volume against dolphin weight are given for all three species (Table 2) and have the form:

$$\text{Stomach volume} = a + b \times \text{dolphin weight}$$

All three species showed a high correlation between the measured fluid volume of the stomach and body weight. Mean common dolphin stomach fullness was calculated as 16.3%, with a modal value of about 12%. The values for hump-backed dolphins were 11.7% and 9.8%, respectively. A re-calculation of these values for bottlenose dolphins show that mean stomach fullness was 35.7%, while modal fullness was 23.7%. The latter mean fullness figure is some 30% less than that calculated for bottlenose dolphins by Cockcroft (1992), but reflects the proportion of solid remains in the stomach once all liquid was removed, whereas the original estimates were made without removing residual liquid.

Table 2

The relationship and correlation between the measured maximum fluid volume of a dolphins stomach and its weight (cf. text). Regressions have the form: Stomach volume = $a + b$ x dolphin weight.

	a	*b*	*r*	*n*
Common dolphin	-2456.75	58.00	0.86	29
Bottlenose dolphin	-1017.92	39.79	0.72	32
Humpback dolphin	0	61.38	0.91	16

Group capture

Captures retrieved from the same net on the same day were considered to be group or multiple captures and treated as single events, although the precise time of any capture was unknown.

Of the 250 bottlenose dolphin captures, 186 (74.4%) were single captures, while on 32 occasions (64 dolphins – 25.6%) two dolphins were captured in the same net and on the same day (Cockcroft, 1992). Of the 32 double captures, 25 (50 dolphins – 20% of total catch) were apparently of mother and calf pairs. The relationship of one of these pairs and three others captured subsequently has been verified electrophoretically (Durham *et al.*, In press).

Of the 216 common dolphin captures for which accurate capture dates are available, single captures occurred on 104 (48.1%) occasions. Multiple captures accounted for 112 (51.9%) captures; 29 (58 dolphins) double captures, three of three dolphins, one of four dolphins, three of five together, two of six together and two of seven dolphins captured in the same net on the same day. Of the 112 multiple captures, only nine included calves small enough (<155cm) to be considered under maternal care and possibly captured with their mothers.

The date of capture was known only for 43 of the hump-backed dolphin captures. Of these, 37 (86%) were single captures, while in three (six dolphins – 14%) instances mother and calf pairs were captured. The relationship of two such pairs captured during 1989 has been established electrophoretically (Smith, unpublished data).

Environmental characteristics

No correlation patterns were found for the majority of environmental parameters (variables 12 to 20 – Table 1) in either the hump-backed or common dolphin capture matrices. The results of analyses for those factors which appeared of significance in the capture of bottlenose dolphins are, however, presented here.

Current direction

The majority of bottlenose dolphins were captured on days when the current direction was significantly different to that normally prevailing (Cockcroft, 1992).

The majority (82%) of common dolphin captures occurred during the months June through September, inclusive. Consequently, the frequency of current directions at which common dolphins were captured was compared with the frequency of actual current directions for these months only. The distribution of current directions in the common dolphin capture matrix (63.7% southerly and 36.3% northerly) did not differ significantly from the actual distribution in the environmental data (61.4% and 38.6%, respectively) ($Chi^2=0.26$, $p>0.01$).

Over 70% of all hump-backed dolphins were captured at the four northernmost netted beaches (Cockcroft, 1990) and, therefore, current direction distributions in the capture matrix were compared only with those for these beaches. There was a significant difference between current direction distributions in the capture matrix (29% northerly and 71% southerly) and the collected data (51% and 49%, respectively) ($Chi^2=19.5$, $p<0.01$).

Temperature and turbidity

The seasonality of bottlenose dolphin capture showed a direct correlation with seasonal temperature, but not with seasonal water turbidity (Cockcroft, 1992).

A similar correlation was found for common dolphins, where mean monthly water temperatures, but not mean monthly turbidity, were significantly correlated with capture frequency ($r=-0.64$, $p<0.05$ and $r=0.56$, $p>0.05$, respectively). In contrast, hump-backed dolphin captures at the four most northerly beaches were not significantly related to either mean monthly temperatures ($r=-0.23$, $p>0.05$) or mean monthly turbidity ($r=0.14$, $p>0.05$) at these beaches.

Physiographic characteristics of netted beaches

Cockcroft (1992) found that the physiographic characteristics of net installations (variables 21 to 28 – Table 1) where bottlenose dolphin captures occurred, were apparently of no significance in capture.

Similarly, analyses of the beach physiographic parameters in the common and hump-backed dolphin capture matrices indicated no patterns other than the geographic distribution of captures discussed by Cockcroft (1990). Neither hump-backed nor common dolphins were captured in the same nets repeatedly. Although a large proportion of hump-backed dolphin captures occurred at Richards Bay, there was no significant pattern in sequential captures, i.e. dolphins were not consistently captured in the same nets.

Catch rates

Unlike bottlenose and common dolphins, there was no relationship between the number of hump-backed dolphin captures along the entire coast and the number of nets set at any beach (Cockcroft, 1990). However, catches at the four most northerly beaches were significantly correlated with the number of nets set ($r=0.98$, $p<0.05$). Mean annual catch rates/km of net for bottlenose and common dolphins along the entire netted coast are 0.0074 and 0.0086, respectively. The mean annual catch rate/km of net for hump-backed dolphins at the four most northerly beaches only is 0.0146. Mean annual catch rates/km of net for bottlenose dolphins in areas where estimates of population size are available are: 0.0098 for the estimated 520 dolphins between Zinkwazi and Umhlanga (8.6km of net) (Cockcroft *et al.*, 1992b); 0.0065 for the estimated 350 dolphins between Winkelspruit and Ramsgate (13.3km of net) (Cockcroft *et al.*, 1992a) (Fig. 1).

DISCUSSION

An analysis of net catches reveals a number of important features of the animals captured, some or all of which are likely to be directly implicated in their capture. Obviously, seasonal and geographic differences in net catches will reflect the movements and distribution of a particular species, i.e. a dolphin species will only be captured in areas coincident with its occurrence. Presumably, a species inhabits an area because the environmental conditions and oceanographic features of the area are favourable and provide for its biological needs, including its food resources. Environmental and oceanographic conditions and their fluctuations within an area will be of importance because they may influence the localised distribution of dolphins or their prey and, consequently, the probability of dolphin capture. In addition, given a knowledge of mesh dimensions and, thus, any possible net selectivity, the sex and size composition of any catch will reflect that of the dolphins coming into contact with the nets, giving an indication of any distributional differences or age and sex segregations. Of obvious importance in this context is the behaviour of dolphins when in netted areas. For example, they may be attracted to nets, or display net avoidance behaviour.

Examined individually, and in light of the above, the capture matrices for bottlenose, hump-backed and common dolphins reveal some possible clues for the capture of these species and also some information on the distribution and life history of each species.

Bottlenose dolphin

The majority of captures were of young suckling or just weaned calves and lactating females, with many of these being mother and calf pairs. Captures were slightly seasonal, occurring mainly during the austral winter and spring. Catches were random in netted areas, excluding the most northern netted beach, and catch rates were directly related to the number of nets set. Captures occurred under significantly different current regimes than those normally prevailing and the stomachs of dolphins were apparently fairly full at capture (Cockcroft, 1990; 1992).

These findings led to the conclusion that a combination of several factors is probably implicated in bottlenose dolphin capture (Cockcroft, 1992). Firstly, bottlenose dolphins were captured in all areas where they and nets co-occur. Secondly, lactating females and often mother and calf pairs, were either abundant within the population or were more prone to capture, possibly because they occur more commonly around the nets. This is supported by feeding studies, which indicate some age and sex class segregation within groups, with lactating females and calves feeding preferentially in the inshore region close to the nets (Cockcroft and Ross, 1990). Thirdly, further evidence for the role of feeding in capture is provided by the observation that the stomachs of most adults seemed quite full at capture, implying that the dolphins were feeding or had just fed. Fourthly, captures were in some way linked to current movement, possibly because this influences prey movements.

Hump-backed dolphin

Catches showed a distinct sex and size class bias, the majority were either adolescents or mature dolphins, particularly large males, with very few young calves or lactating females (Cockcroft, 1990). It is possible that, unlike bottlenose dolphins, hump-backed dolphin lactating females and calves occur only infrequently in the inshore netted region and may not forage there preferentially. As multiple captures occurred only infrequently and all were apparently mother and calf pairs, it seems likely that mothers and calves are in close association when in the inshore area. This is supported by observations in Plettenberg Bay, where young hump-backed dolphin calves seldom move about on their own and normally travel only with larger groups (Saayman and Tayler, 1979).

Most captures were single incidents, of either adolescents or mature, larger males, suggesting that these size and sex classes may be more numerous than other size classes. Alternatively, these sex and size classes could be more mobile and forage close inshore, where they come into contact with nets more often. All inferences, however, indicate some form of age and sex class segregation of hump-backed dolphin groups within the areas they inhabit.

The consistently greater hump-backed dolphin catch at the four most northerly netted beaches and the significant correlation between the number of nets set and catch rates at these beaches, indicates these dolphins are probably more numerous in this area than anywhere else along the coast, a conclusion supported by NSB sighting rates (NSB, unpublished data). These facts also suggest that hump-backed dolphins may either be resident here or frequently pass through this area. Interestingly, bottlenose dolphins are seldom caught at the four northerly beaches (Cockcroft, 1990), indicating that these two species have slightly different habitat requirements, possibly related to the different prey species taken (Cockcroft and Ross, 1983).

Unlike bottlenose dolphins, feeding appears to be of little significance in hump-backed dolphin captures, with the stomachs of most dolphins being almost empty at capture. In addition, neither water temperature nor clarity seem to be significant factors in their capture. This is partly supported by other studies of hump-backed dolphin distribution, which showed that water temperature was not a significant factor in determining seasonal occurrence in Plettenberg Bay (Saayman *et al.*, 1972).

The current direction on the day of capture for the majority of hump-backed dolphins was significantly different to that normally prevailing. Interestingly, a similar but opposite situation pertains to bottlenose dolphin captures. More bottlenose dolphins were captured when the current direction was northerly, although southerly currents were most common at the beaches where entanglements occurred. In contrast, a greater proportion of hump-backed dolphins was caught on days when a southerly current was prevalent, though northerly currents were usual at the four most northern beaches. In interpreting the significance of this for bottlenose dolphins, Cockcroft (1992) surmised that because captures of bottlenose dolphins seemed directly influenced by feeding activity, current direction was implicated as it influences the movement and abundance of prey species. However, given the lack of evidence for a connection between capture and feeding in hump-backed dolphins, this does not appear to apply for this species. Thus, the reasons for the significance of current direction are unknown, although, in Plettenberg Bay, Saayman and Tayler (1979) observed the onset of feeding with the rising tide, presumably because this influenced local prey movements and abundance. It is possible that captures of hump-backed dolphins occurred as they moved close inshore with the rising tide at the onset of feeding. Regrettably, the time of capture of dolphins was unknown, although this may be an important parameter in assessing the contribution of tidal and other rhythmic influences on behaviour and capture (Cockcroft, 1991).

Common dolphin

Common dolphins make a northward, seasonal migration into Natal waters during the austral autumn, returning to more southerly waters in the spring and summer (Cockcroft and Peddemors, 1990b). This migration appears closely linked to the movement of the pelagic shoaling Natal sardine (*Sardinops ocellatus*) into Natal waters (Cockcroft, 1990; Cockcroft and Peddemors, 1990a), as this fish constitutes the major prey of common dolphins in Natal waters (Cockcroft and Ross, 1983; Young and Cockcroft, in press). As a consequence and because the presence of common dolphins in the inshore region is probably influenced by the movement of fish shoals, there were no geographical distributional biases in the catch of common dolphins in Natal (Cockcroft, 1990). Given the probable importance of prey in the movements of common dolphins into netted areas, it is unclear why this was not evident in the degree of stomach fullness, particularly as the highest annual dolphin catch occurred in conjunction with the most extensive fish shoal movement inshore (Cockcroft, 1990).

None of the environmental or physiographic factors seemed of any significance in common dolphin captures. However, there were clear differences in the sex and size classes of dolphins captured. Significantly greater numbers of female than male dolphins were captured, particularly sexually mature females, and also fairly large numbers of older, weaned calves (Cockcroft, 1990). The sex and size class composition of the population are unknown. But, the preponderance of sexually mature females and older calves in the catch may reflect the composition of dolphins partaking in the annual migration. Cockcroft (1990) has suggested that common dolphin females use the plentiful resources provided by the annual fish migration to wean their calves and replenish their energy reserves for the following pregnancy and lactation. Some further evidence for this is provided by data from a mass stranding of 15 common dolphins at Hluleka (31°47′S, 29°18′E) on 6 December 1990 (mid austral summer). Of these dolphins, only one was a mature male, one was a 179cm weaned male calf and 13 were mature females, of which 11 were pregnant (Cockcroft, unpublished data). If the catch is representative of those dolphins making the migration, it suggests that common dolphins have an age and sex class segregation covering a large area of their distributional range off the east coast of southern Africa.

CONCLUSIONS

Although the examination of the individual capture matrices may provide some clues to the capture of individual species, there are few evident common factors when comparing matrices and the subsequent interpretation of individual catch patterns. As a result, the present data offer only a few possible relationships between the captures of all three species.

In view of the apparent influence of food resources on the movements and distribution of dolphins (Norris and Dohl, 1980), the results of attempts to assess whether dolphins were feeding or not at capture, by using estimates of the degree of stomach fullness, were equivocal and unexpected. Although this could be a product of the rather crude assessment method used, the differences among the three species suggest, at least, that feeding activity or its timing play a different role in the capture of each species. An appraisal of the importance of feeding behaviour prior to and during capture of these and other dolphin species in gillnets needs urgent attention in the effort to understand why captures occur.

However, feeding is not the only reason why dolphin groups may move into certain areas or aggregate (Norris and Dohl, 1980). In addition, these movements are likely to occur following specific entrained rhythms (Klinowska, 1986). Thus, the apparent lack of a pattern in the degree of stomach fullness may imply that, at least in some instances and to a varying degree for the different species, dolphin occurrence at the nets and their capture were not related to feeding. In other words, movement around and aggregation at nets may occur for a number of reasons and at various times during the day, all for different reasons. Consequently, one might not expect to find patterns within the existing capture matrices, although in this light, the observed age and sex class biases may be regarded as evidence for short-term rather than long-term segregations. Obviously, observation and recording of captures and the preceding circumstances would clarify this to some extent. Experimentation with captive animals may also provide insights into the precise circumstances surrounding capture.

Interestingly, all three dolphin species captured in the shark nets show some evidence of age and sex class biases, implying some segregation within areas. Although such segregations are relatively well known (e.g. Wells *et al.*, 1980; Kasuya and Jones, 1984; Monami, 1992) and probably play an important role in determining the composition of catches in an area, the reasons for them and their relevance in these three species are as yet unclear. However, the biases in catch composition obvious in the incidental capture of many cetacean species probably reflect only the occurrence of certain classes in netted areas, i.e. it is unlikely that segregation itself causes incidental capture.

A further common factor found is, of course, that all three species occur in the vicinity of some or all the nets at certain times. Although there are no data on the relationship between net expanse, dolphin numbers and catch rates, it seems likely that an increase in either net expanse or dolphin numbers would increase catch rates and *vice versa*. Some support for this is given by the fact that for areas where population estimates of bottlenose dolphins are available, catch rates appear directly proportional to the number of dolphins present. However, this relationship may be complicated by several behavioural factors including attraction or avoidance of nets, epimeletic behaviour and multiple captures.

The differences in the frequency of multiple captures among the three species may reflect their natural history and the reasons for their capture. Only for the common dolphin were more animals caught in multiple than single captures. Very few bottlenose and no hump-backed dolphin multiple captures occurred, other than mother and calf pairs, implying different social organisation and/or feeding strategies. For both species the multiple captures that did occur involved calves with either lactating females, other adults or adolescents, perhaps reflecting epimeletic behaviour among mothers or 'relatives', and calves (Cockcroft and Sauer, 1990). Nevertheless, the occurrence of multiple captures in all three species implies that, unless all multiple captures occur simultaneously, which is unlikely, one of the two or more dolphins caught must be aware of the other's capture, but is nevertheless captured itself.

This leads to the question of possible capture, escape and recapture. Of the 250 bottlenose, 290 common and 53 hump-backed dolphins captured between 1980 and 1988, none appeared, from external examination, to have been captured before. This suggests that either no escapes occurred or that all escapees avoided subsequent capture. However, on 21 August 1990, a heavily lactating female bottlenose dolphin (PEM N1797) recovered from the nets showed distinct and unmistakable net scars at the insertion of her flippers, indicating that sometime previously, she had been captured in a net and escaped (Cockcroft, unpublished data). As she was not accompanied by a calf, epimeletic behaviour was probably not the cause of her capture in this instance. This limited information suggests that escapes are extremely uncommon and that dolphins are unaware of the danger that nets pose, even after an escape from entrapment.

This raises some interesting questions regarding a dolphin's perception and interpretation of nets and whether they pose a threat. These and other considerations must be addressed if active and passive devices are to be used to 'caution' dolphins against nets and prevent their incidental capture. Given the largely unsuccessful results of previous attempts to eliminate captures through such methods (Hembree and Harwood, 1987), it may be that these are intractable problems and that alternative methods of capture prevention may be necessary.

The apparent lack of common factors implicated in the capture of bottlenose, common or hump-backed dolphins is interesting. It implies that either the data collected and examined did not include the salient parameters, or that there is little or no connection in the reasons for capture between species. Although observations of the circumstances immediately prior to and at the precise moment of capture would provide essential information on the mechanisms of capture, the evidence from this study indicates that capture simply results from the presence of dolphins around nets, for whatever reason. This raises the obvious question, to which we have no single consistent answer, of why dolphins occur around nets? Intuitively, it seems likely that this would be a function of the specific biological needs of the various species, including that to harvest food resources (Beverton, 1985).

If dolphin incidental captures are inevitable wherever they and nets co-occur, how can captures be reduced or prevented? One obvious solution is the removal of all nets where dolphins occur, although for many areas, this may be impractical for socio-economic reasons. Another alternative is net modification.

For shark nets off Natal, Cockcroft (1990; 1992) has suggested that one method of reducing catches of bottlenose dolphins would be to increase the mesh size, because the body dimensions of the smallest dolphins caught were the same as that of the net mesh. This solution would be of no obvious benefit to common and hump-backed dolphins however, where the smallest dolphins captured were substantially larger than the size of the net mesh. For those species, the removal of all shark nets seems warranted. It is unwise to adversely effect the inshore environment (van der Elst, 1979), including the depletion of dolphin stocks, when an annual average of only three shark attacks, of which 0.7 are fatal, occurs along the entire South African coast (Compagno *et al.*, 1989). Unfortunately, the relevant authorities are reluctant to accept this solution, citing the 'fears' of the tourists and the possible loss of tourist income should nets be removed. Given this and the data presented here, selective net removal from certain areas and in specific months, in combination with net modifications, could reduce the overall incidental catch of these three species.

This study suggests that the management of specific 'fisheries' needs to be formulated on a species specific level but that this becomes difficult or almost impossible where dolphin catches are species diverse. Consequently, a compromise may be inevitable, where the marine environment may increasingly suffer the same fate as the terrestrial and be partitioned into conservation or natural areas and exploitable zones. How this could be done given the large migrations of many dolphin species is unclear. It is possible that these reserves could be modelled on defined areas, as terrestrial refuges are, or they may be more liberally defined to encompass isobath boundaries for coastal dolphins or temperature boundaries for oceanic species.

In conclusion, although the examination of the catch and biology of an individual species provides some insight into the reasons contributing to its capture, there appears to be few or no common causal factors, apart from the presence of nets and dolphins in the same area. The incidental entanglement of dolphins, and perhaps other marine mammals, thus appears to be simply a function of their presence in netted areas. The mechanisms and causes of capture may differ or be similar between species. As a consequence, the solution to the problem lies in either the removal or selective removal of all nets or the establishment of areas or boundaries within which fishing is not permitted. In view of the danger gillnets pose many dolphin stocks and species (IWC, 1994), solutions to the problem are urgent.

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A Review of Studies on Attempts to Reduce the Entanglement of the Dall's Porpoise, *Phocoenoides dalli*, in the Japanese Salmon Gillnet Fishery

Yoshimi Hatakeyama, Ken Ishii, Tomonari Akamatsu

National Research Institute of Fisheries Engineering, Ebidai, Hasaki-machi, Ibaraki, 314–04, Japan

and

Hideo Soeda, Tetsuya Shimamura and Takahito Kojima

College of Agriculture and Veterinary Medicine, Nihon University, 3–34–1, Shimouma, Setagaya-ku, Tokyo 154, Japan

ABSTRACT

Dall's porpoises, *Phocoenoides dalli*, were often incidentally caught in the Japanese salmon gillnet fishery in the North Pacific. In order to investigate the reasons for entanglement, their auditory characteristics and capabilities and their responses to gillnets were examined. Dall's porpoises emit short high frequency pulses ranging from 135 to 149kHz, with a pulse width of 50 to 60μs and a source level of 165 to 175dB re 1μPa. When chased toward a gillnet in open sea, they have been observed to change their swimming direction to avoid it by either swimming along it or diving underneath it. They are thus capable of avoiding entanglement. Estimated target strengths of a float, leadline, lead and netting were –25, –33 –39, and –55dB, respectively. Approximate estimates of Dall's porpoise's detection ranges for the leadline and netting were found to be 30 and 8m, respectively. Active and passive acoustic devices were tested with the aim of reducing the incidental catch. Four types of sound generator (SG-1 to 4) in the frequency range of 20 to 150kHz were developed on the basis of the frequency components of clicks and observed responses to sounds. Air-tube threads to increase the net target strength were also used. Incidental catches were monitored on the fishing ground and catch decrease rates (DRs) estimated. The DRs of the sound generators (with the exception of SG-4) were 3–16% and the DR in the case of the gillnet with three air-tube threads in the centre portion was 8–20%. As for SG-4, entanglement was concentrated in the portion of the net where SG-4 was not attached and the sound wave was weak. The target strengths of a rope, vinyl string and blister sheet are much larger than that of the netting. Experimental operations using gillnets equipped with these reflectors were conducted on the fishing ground. The detection abilities of other cetaceans, such as the harbour porpoise (*Phocoena phocoena*), white whale (*Delphinapterus leucus*) and the bottlenose dolphin (*Tursiops truncatus*) were also examined.

KEYWORDS: INCIDENTAL CAPTURE; FISHERIES; NORTH PACIFIC; DALL'S PORPOISE; HARBOUR PORPOISE; WHITE WHALE; BOTTLENOSE DOLPHIN; ACOUSTICS; BEHAVIOUR; MORPHOLOGY/ANATOMY; LIVE-CAPTURE; REVIEW.

INTRODUCTION

In the Bering Sea and the North Pacific, marine mammals, particularly Dall's porpoises (*Phocoenoides dalli*), are often incidentally caught in the gillnets used by the Japanese mothership salmon fishery. There are two 'forms' of Dall's porpoise, the *truei*-type and the *dalli*-type (Kasuya, 1978; Miyashita and Kasuya, 1988; Amano and Miyazaki, 1992). Only the latter is taken in the mothership fishery.

The Japanese mothership salmon fishery targetted salmon using driftnets in the North Pacific. From 1978–1986 four fleets operated, each comprising one mothership (7,000 to 9,000GRT) and 43 catcher boats (96 to 127GRT). Each catcher boat used 15km-long gillnets with a net depth of 6m. The fishing season lasted from 1 June to 31 July.

The US Fishery Conservation and Management Act (FCMA) became effective on 1 March 1977. In conjunction with its implementation, the 1972 US Marine Mammal Protection Act (MMPA) was amended and its applicable range was increased from 12 to 200 n.miles from the US coast. It became mandatory for Japanese fishing fleets operating within the US 200 mile zone (EEZ) to obtain a general permit under the MMPA. After several hearings, a permit was issued in June 1977.

Article X of the International Convention for the High Seas Fisheries of the North Pacific Ocean includes a provision concerning scientific research activities with respect to marine mammals incidentally caught in fishing for anadromous species. Japan and the USA signed a Memorandum of Understanding (MOU) on Dall's porpoise in connection with Article X. Thereafter, the MOU was revised and signed twice (on 3 June 1981 and 5 June 1984) corresponding to each renewal of the permit for the incidental take of Dall's porpoises in the mothership salmon fishery in the US EEZ.

The MOU required that studies be conducted on gear modification to reduce the incidental catch rate of marine mammals. In accordance with the 1981 amended MOU, field trials were initiated with modified gear. In addition, the December 1982 amendment to the North Pacific Fisheries Act (NPFA) required that the use of new fishing gear and/or techniques to reduce porpoise mortality should be phased into the commercial operations according to a specified timetable. The amendment also stipulated that the General Permit (1981–3) issued should be extended for three years until 9 June 1987. The number of Dall's porpoise taken by Japanese vessels in the US EEZ was limited to 5,500 per year from 1981 to 1986.

In order to fulfil these requirements, in 1981 the National Research Institute of Fisheries Engineering (NRIFE) began a programme entitled 'Urgent studies on the development of techniques to prevent incidental catch of marine mammals in the salmon driftnet fisheries' (National Research Institute of Fisheries Engineering, 1982). Since 1982, NRIFE has cooperated with Nihon

University and Kamogawa Sea World. In 1989, the Ocean Research Institute of University of Tokyo was commissioned by the Fisheries Agency of Japan to examine the physiology and anatomy of the eyes of the Dall's porpoise.

In addition, the mothership salmon fishery industry organised a 'Marine Mammal Project Team' comprising experts in fishing operations. They conducted field trials from 1981 to 1987. In accordance with the provisions of the MOU and the NPFA, these two groups conducted basic biological and acoustic studies and tested modified gear in fishing operations in order to try to prevent incidental catches of Dall's porpoises.

A Public Hearing was held at Seattle in the US in December 1986 and a general permit was again issued to the fishery in May 1987, reducing the quota to a total of 6,039 between 1987 and 1989. However, after a successful law suit by the environmental conservation groups and Alaskan native peoples against the US Government, the general permit was suspended. Since then, a small number of Japanese catcher boats have operated in a limited area (outside the US and Soviet EEZs).

This report summarises documents submitted to the International North Pacific Fisheries Commission (INPFC) and recent papers in Japanese on the efforts to reduce the incidental catch problem.

ACOUSTIC STUDIES

Until recently, only four acoustic studies of Dall's porpoise had been published. Three reported only low frequency clicks with a peak energy below 10kHz (Ridgway, 1966; Schevill *et al.*, 1969; Leatherwood and Ljungblad, 1979). The fourth, Awbrey *et al.* (1979) described detailed characteristics of the high frequency clicks used for echolocation with peak energy levels of between 120–160kHz; the source level of the clicks was not measured. Those authors also estimated the Dall's porpoise's auditory capability from cochlear morphology. On the basis of an estimation of the target strength of the net and a porpoise's ability to detect echoes from the net, they doubted whether Dall's porpoises could acoustically perceive monofilament gillnets.

Examination of the vocal and auditory abilities of Dall's porpoises and observations of their responses to sound and objects such as gillnets can most easily be carried out on captive animals. To this end, capture experiments were conducted in the winter of 1982/83 along the Sanriku coast near Ozuchi, Iwate Prefecture, and in the summers from 1983 to 1985 in the Sea of Okhotsk foreshore of Utoro, Shari Town, Hokkaido (National Research Institute of Fisheries Engineering, 1982; Taketomi, 1984).

Various methods of entrapment involving harpoons, tailgrabs, hoopnets and drift gillnets were tried. All attempts to live-capture porpoises which approached the vessel were unsuccessful. Furthermore, when three or four vessels tried to chase porpoises towards gillnets, they either scattered or successfully avoided the nets, again resulting in no captures.

On 7 May 1984, three Dall's porpoises from a group of 20 were captured using a mackerel purse-seine 10 n.miles off Hitachi City, Ibaraki Prefecture. Only one was alive on retrieval (a 160cm, 76.5kg, male) and it was put in a pool at the Oarai Aquarium. On 10 May, it was transferred to Kamogawa Sea World where acoustic studies were carried out. However, attempts to feed it with frozen, live or minced fish failed and it died on 19 May (Hatakeyama and Shimizu, 1985).

From 8–13 September 1986, a one-boat purse-seiner fleet (four vessels) chartered by the Japan Marine Fishery Resource Research Centre carried out scouting and capture experiments on Dall's porpoises in the waters off Kushiro, Hokkaido. Three animals were caught on 10 September and five on 11 September with a tuna purse-seine. However, only one (a 220cm male) survived. It was fed for seven days from 10–16 September in a pool in the National Fish Farming Centre for Culture-based Fisheries, Akkeshi Station in which it died. Since it did not beat its tail, two floats were attached to its head so that it could swim slowly by itself (Hatakeyama *et al.*, 1987).

Waveform characteristics of clicks

Dall's porpoises

On 2 June 1982 in calm seas, about 10 Dall's porpoises swam around a stationary salmon research vessel in the Bering Sea. Two to four individuals appeared to be interested in the hydrophone hanging over the port side and repeatedly approached to within 1–2m of it. Recordings were made for about 10 min., during which only the auxiliary engine (310HP) was operating. The results (Hatakeyama, 1983) are listed in Table 1 (No. 1). No low frequency components were found. Data reported by Awbrey *et al.* (1979) are also listed in Table 1 (No. 4) and a comparison with our results shows that: (1) the 'total numbers of clicks' are similar; (2) our maximum 'pulse width' is considerably narrower; (3) the maximum 'interclick intervals' are almost equal; (4) our minimum 'interclick interval' is shorter; and (5) we found that each click consisted of 1 or a series of 2 to 4 pulses whereas Awbrey *et al.* reported that all signals were single or double pulses of constant frequency.

An acoustic study of the animal caught in the mackerel purse-seine off Hitachi City was carried out at the Oarai Aquarium on 9 May and at the Kamogawa Sea World on 10 May 1984. A total of 33 series of clear clicks was obtained during a 72 minute recording. No whistles or clicks with frequencies below 20kHz were found (Hatakeyama and Shimizu, 1985). The analysed results are listed in Table 1 (No. 3). Both frequency and sound pressure were smaller than those measured in the Bering Sea. These differences are probably due to the stress of capture and the small pool environment. The sound pressure of the clicks emitted by the Dall's porpoise was the same as found for a bottlenose dolphin in the pool. The high frequency and the narrow pulse width of the clicks emitted by the Dall's porpoise is advantageous in detecting smaller and finer objects (such as the thread of a net) and estimating distances between objects with greater resolution. However, the narrow beam width due to the high frequency is a disadvantage when searching quickly through a wide area and this may create problems in avoiding wide obstacles such as a gillnet through 'instantaneous' judgment.

Animals reared in small pools or net enclosures need not echolocate at maximum power and probably adjust their normal acoustic activities to suit the environment. The source level of clicks was low in the pool and high (when presumably paying much more attention to the environment) in the open sea.

A Dall's porpoise was caught by harpoon in the North Pacific Ocean in June 1986. Recordings were made for one hour. Ten or more emissions of clicks were found in the tape. The clicks were analysed with an FFT analyser (Ishii *et al.*, 1989) and the results are listed in Table 1 (No. 2). As the animal was seriously wounded, it is difficult to compare the data with those for free swimming animals. If the sounds were emitted intentionally for help or alarm, they may be of value in playback experiments.

On 27 January 1983, a 190cm male of the *truei*-type was caught by harpoon. Recordings were made for about 8 minutes at a distance of 3–4m, during which over 10 series of clicks were recorded. Four series of clearly recorded clicks were selected and three clicks of each series were analysed by Hatakeyama (1984a). The analysed results are listed in Table 1 (No. 5).

Harbour porpoise in captivity

Although it is difficult to catch Dall's porpoises and keep them in captivity for any length of time, the related harbour porpoise (*Phocoena phocoena*) has been successfully kept in several aquaria. We have therefore attempted to obtain information on the echolocatory ability of the Dall's porpoise by analogy through experiments using harbour porpoises. There has been considerable amount of published information on the clicks and echolocatory abilities of harbour porpoises (van Dudock, 1960; Busnel *et al.*, 1965; Busnel and Dziedzic, 1967; Zaslavskii *et al.*, 1969; Andersen, 1970a; b; Dubrovskii *et al.*, 1971; Møhl and Andersen, 1971; Pilleri *et al.*, 1980), although their reactions to gillnets have not been previously reported.

In January 1987, therefore, we studied the waveform characteristics of clicks emitted by three captive harbour porpoises kept in a pool (17x12x3.5m) at Kamogawa Sea World (Hatakeyama *et al.*, 1988). Horse mackerel, *Trachurus japonica* and sillaginoid, *Sillago sihama* (both species are 10–15cm in length) were thrown into the pool and clicks were recorded while the porpoises approached and echolocated the fish.

Four series of clicks with considerably high sound pressure were selected and 48 clicks were analysed in total. Our results and those of Møhl and Andersen (1971) are listed in Table 1 (No. 6 and 7). Our source level is about 20dB higher, probably because the pool was larger and because the three porpoises competed for the food.

Detailed analyses indicated the following characteristics: (1) the band width of clicks ranged from 9 to 33kHz with a mean value of 21kHz; (2) the clicks included about 9 cycles of narrow band sine waves which gradually increased and usually reached a maximum at the fourth cycle.

In comparison with the Dall's porpoise, the frequency of clicks emitted by the harbour porpoise is 12kHz lower, the pulse width is 11μs shorter and the click is a single pulse. The mean frequency of the peak spectrum is 130kHz and close to the upper hearing limit of the harbour porpoise (Andersen, 1970a). This suggests that the harbour porpoise lays more stress on reflectivity and distance/angle resolution than on auditory sensitivity.

ABILITY TO DETECT GILLNETS

Reaction of Dall's porpoises to gillnets

The following reactions were observed when chasing Dall's porpoises toward the gillnet in the capture experiment conducted in the coastal area off Hoddaido in August 1983 (Taketomi, 1984). In general, the porpoises changed their swimming direction in front of the net and then swam along the net or dived to avoid it. However, in one case two Dall's porpoises swam ahead of a third and dived about 4–5m in front of the net but the third rushed into the net, broke through it and escaped as shown in Fig. 1.

Dall's porpoises were observed swimming around gillnets from a salmon research vessel that was retrieving gear in July 1983 (Hatakeyama and Shimamura, 1984). Two out of three Dall's porpoises in a school dived under the net but the third one following became entangled in the intermediate portion of the net. On two occasions a Dall's porpoise was seen to pass through a hole (1.5m wide x 1.0m high) in the upper portion of the net without changing its swimming speed (3–4ms^{-1}).

In contrast to the above examples, on one occasion at sunset in June 1989, we observed the first of a group of three Dall's porpoises rush into and break through a net while the two following animals changed their swimming direction in front of the net.

These observations suggest that, during daytime at least, porpoises are able to detect the presence of the net. Although both visual and acoustic cues may aid in detection, the former are probably weak given the generally cloudy conditions and the nature of sea water. It seems that Dall's porpoises have sufficient echolocatory ability to recognise nets and even small holes in the netting, and thus that entanglements arise because they are not always echolocating and searching when swimming in open sea. In addition, animals which approach the net perpendicularly at high speed can break through it; entanglement probably occurs if the angle of approach is acute and/or they are swimming slowly. The problems may be exacerbated at night, particularly during 'sleep'. This should be studied further and, for example, it should be ascertained whether they swim slowly near the sea surface while sleeping.

Table 1

Waveform characteristics of clicks.

No.	Species	Environment	Peak frequency (kHz)	Source level (dB)	Pulse width (μs)	Interclick interval (ms)	Total no. of clicks in a series	Remarks	Reference
1	Dall's porpoise	Open sea	135-149	165-170	50-60	8-150	9-47	Free swimming	This paper
2	Dall's porpoise	Open sea	125-135		70	15-70	36	Caught by harpoon	This paper
3	Dall's porpoise	Pool	90-115	155	15-60	9-48	64-176	Caught by seine	This paper
4	Dall's porpoise	Open sea	120-160		50->1,000	13-143	9-40	Free swimming	Awbrey *et al.* (1979)
5	True's porpoise	Open sea	122-136	137-168	40-210	2-14	20-148	Caught by harpoon	This paper
6	Harbor porpoise	Pool	125-140	158-162	29-83	10-123	4-23	Entered the set net	This paper
7	Harbor porpoise	Pool	110-150	132-149	100	20	14		Møhl and Andersen (1971)

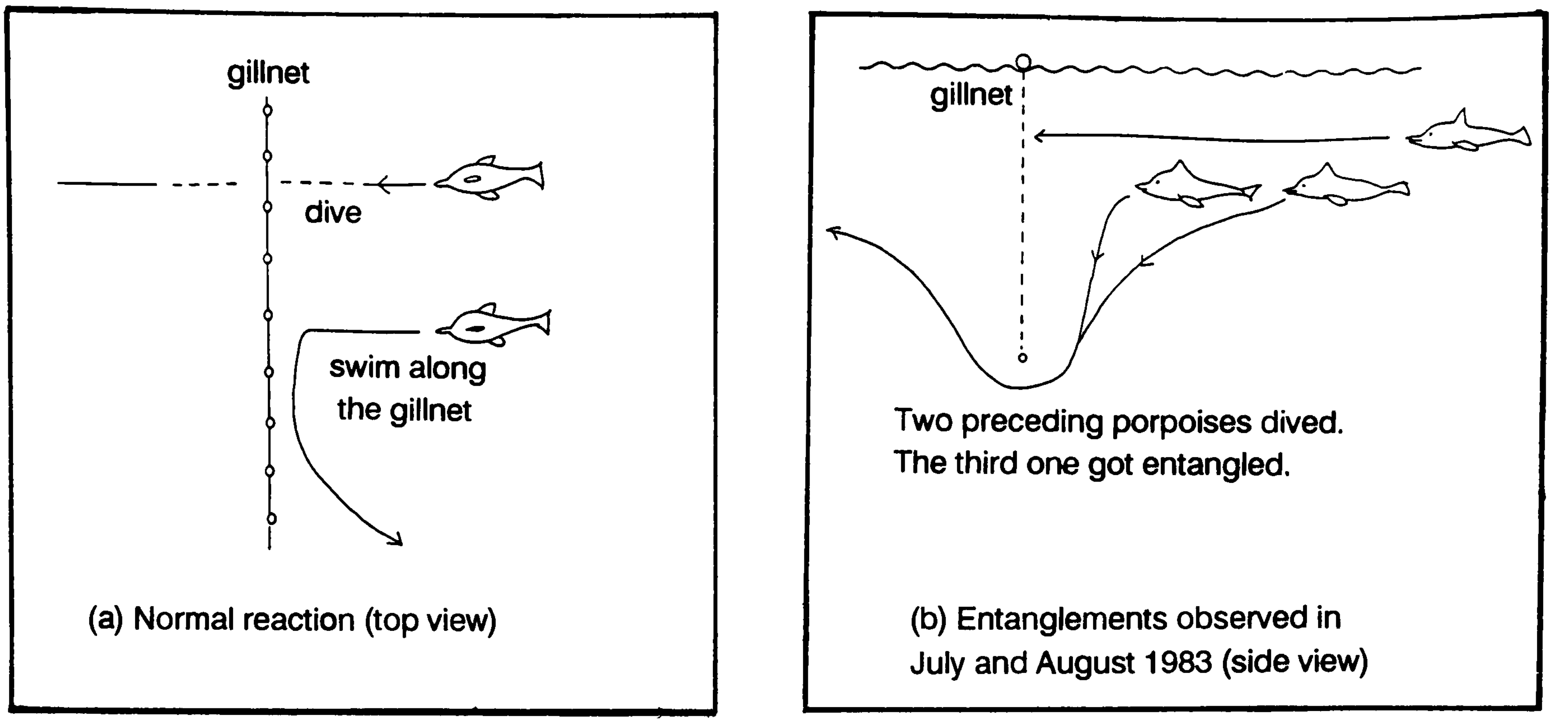


Fig. 1. Reaction of Dall's porpoises to gillnets in the open sea.

Target strength of the gillnet

Hatakeyama (1984b) measured the target strengths (TSs) of the net components (thread, netting, float, lead and line) using ultrasonic pulses (143kHz, pulse width of 100μs) similar to those of the clicks of Dall's porpoise. The results are given in Table 2.

The transmitting directivity was 16° at 6dB down point and the distance between the transmitter and reflector was 1m. The diameter of the ultrasonic beam at the position of the reflector was 28cm. The reflected wave was measured with a hydrophone (*B&K* 8103) whose receiving directivity was broad at 143kHz.

The results showed that the TSs of float, lead, leadline and netting were –25, –39, –33 and –55dB, respectively. The float and leadline reflect sound waves which are 10 to 30 times greater than those reflected by the netting. Pence (1986) reported that the TS of netting was –50dB at a frequency of 200kHz and a 3dB beam width of 20°.

To compare his result with ours, it is necessary to correct for the differences of the beam width (ϕ) and frequency (f) between the two measuring systems. On the condition that $\phi$is narrow and an amplitude of a reflected wave is proportional to the square root of an area of a reflecting portion of the netting, the TS is proportional to log ϕ. The TS is also proportional to $20\log f^{3/2}$ (Welsby and Goddard, 1973). The corrected TS is –56dB, almost equal to our result.

From the relationship between the TS and the length or area of the reflector in the beam, the TSs for a unit length of the leadline and for a unit area of the netting are –27 and –43dB, respectively.

The mesh size of the net is 114mm and the total area of the netting in the beam is 620cm^2. The total length (L) of the nylon monofilament in this area is about 2m. The TS of coiled nylon monofilament (total length 10m) is 54dB as shown in Table 2. Since the TS is proportional to log L, the TS of the netting without a knot is estimated to be –61dB. If the diameter of the knot is 2mm, its TS is –80dB following Rayleigh (1945). There are 20 knots within this area and the presence of knots will affect the TS, depending upon the phase of the reflected waves from the knots.

In 1984, directivities of ultrasonic reflection from the float and leadline whose TSs were large, were measured for 50 and 100kHz pulses. The maximum target strength (TS_{max}) and the angle width (α) at which the TS becomes 6dB smaller than the TS_{max} were obtained (Hatakeyama and Ishii, 1985). For example, TS_{max}'s and α's of the float, lead and leadline at 100kHz were –27dB and 5°, –35dB and 60°, and −32dB and 9° respectively. An example of the reflection directivity of the float at 100kHz is shown in Fig. 2.

Although the reflection from the float and leadline is strong perpendicular to their long axis (0°), when angles become

Table 2

Target strengths, materials, sizes and weights of measured samples.

Measured sample	Target strength(dB)	Material	Size and weight*
Commercial monofilament	-55	Nylon	d=0.5m, ms=114mm, a=148x185cm
Commercial monofilament	-54	Nylon	d=0.5mm, l=10m, ϕ=11cm, t=28
Lead	-39	Lead	d_1=21mm, d_2=10mm, l=31mm, w=75g
Float	-25	Vinyl chloride	Max d_1=46mm, d_2=9mm, l=154mm, w=50g
Leadline	-33	Poli propilene	d=7mm, l=69cm

* ms = mesh size; a = area; d = diameter; d_1 = outer diameter; d_2 = inner diameter; ϕ = diameter of coil; t = number of turns; l = length and w = weight.

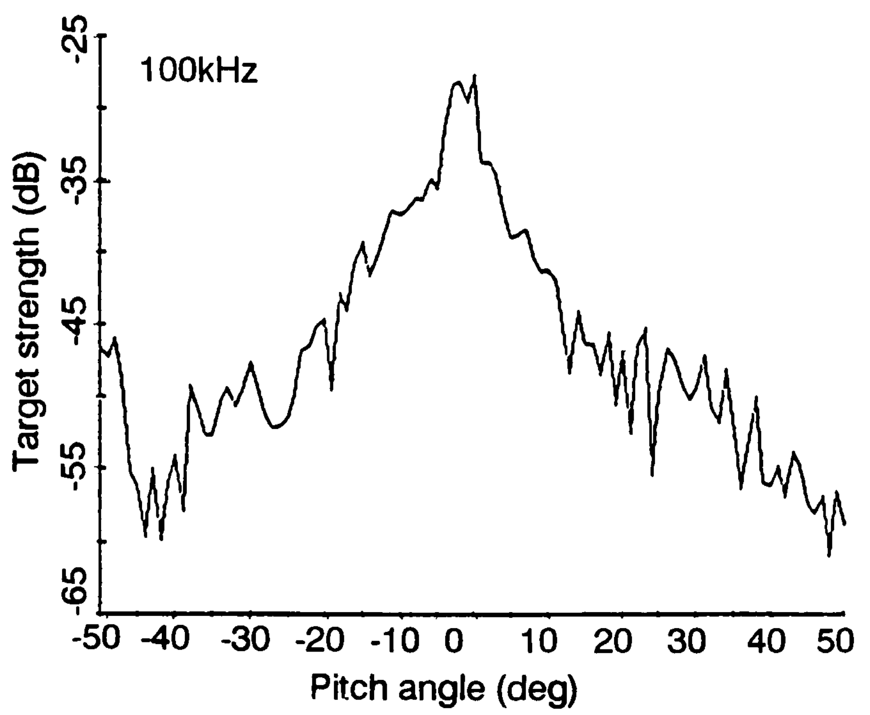


Fig. 2. Reflection directivity of a float.

larger than around 10°, the TSs decline suddenly and reflections become as weak as those from the netting. At these angles the detection range of the porpoise is short.

Maximum detection range of Dall's porpoise

A key parameter that must be determined is the distance at which Dall's porpoises can detect a salmon gillnet.

There are two ways of calculating the maximum detection range. In the first, the range (R_1) is estimated on the assumption that the auditory threshold, corrected for click duration, is equal to the received echo level (Hatakeyama, 1984b). In the second, the range (R_2) is calculated by the sonar equation in which the detection threshold (DT) is determined from data of detection experiments using bottlenose dolphins (Au, 1988a; b). As the distance between the porpoise and gillnet becomes greater, there is an increase in number of floats and lead, the length of the rope and the area of the netting, that are within the ultrasonic beam. This will result in an increase in the TS of the 'net'.

For the first method, as an approximation, the TSs of the leadline and netting were assumed to be constant at values of –25 and –50dB, respectively and a Dall's porpoise click was assumed to have a major frequency component of 145kHz, a pulse width of 50μs and a source level of 168dB. The absorption coefficient was 37dBkm^{-1}. The auditory threshold of Dall's porpoise at 145kHz was estimated to be 55dB by Awbrey *et al.* (1979) from morphological cochlea data. However, other available auditory data on Dall's porpoise were so few that those for bottlenose dolphins and humans were used to calculate the corrected auditory threshold. As a result, the R_1s for the leadline and netting were 30 and 8m, respectively.

In the second method, the TS is assumed to change with the distance between the porpoise and reflecting object. The noise-limited transient form of the sonar equation applicable to a dolphin was expressed in dBs (Au, 1988a):

$$DT_E = SE - 2TL + TS_E - (NL - DI)$$

where: DT_E = detection threshold; SE = source energy flux density; TL = transmission loss; TS_E = target strength; NL = background noise level; and DI = receiving directivity index.

Transmitting and receiving directivities are closely related to the porpoise's echolocation ability. However, in the absence of available Dall's porpoise data, the two directivities were assumed to be equal to those of the white whale, i.e. 6° (Au *et al.*, 1988). The DI was calculated to be 22dB following Au (1988a). The DT_E is equal to $\log(E_E/N_O)$, where E_E is the echo energy flux density and N_O is the noise spectral density. The average DT_E in the bottlenose dolphin experiments was 10dB.

The R_2s were calculated for three peak-to-peak source levels ($SL_{p\text{-}p}$ = 160, 170 and 180dB) and four noise levels (NL=30, 40, 50 and 60dB re 1μPa^2/Hz). As an example, the DT_E was calculated as a function of the distance for NL=30dB and $SL_{p\text{-}p}$=160dB as shown in Fig. 3. The R_2s for the netting and leadline were found to be 10 and 34m, respectively (Table 3). R_1 is nearly equal to the R_2s for three combinations of NL and $SL_{p\text{-}p}$, namely, 30 and 160dB, 40 and 170dB, and 50 and 180dB.

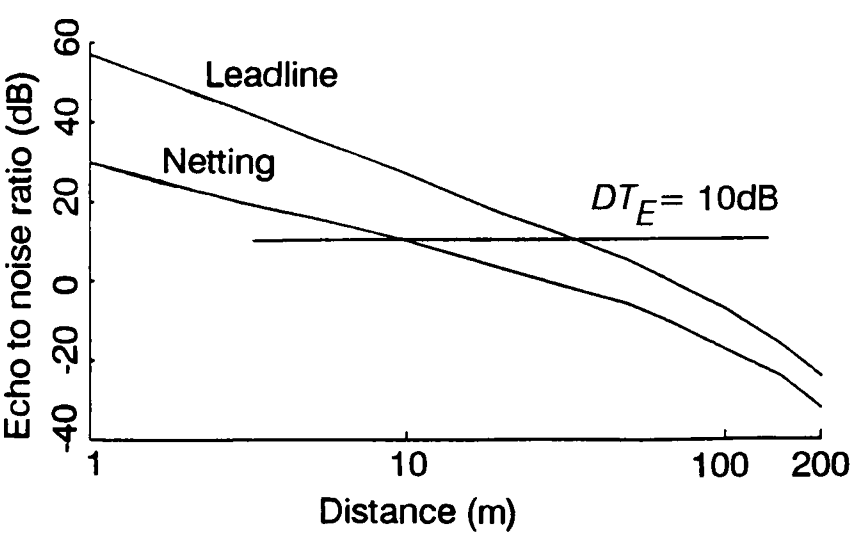


Fig. 3. Determination of maximum detection range, R_2(m), when NL=30dB and $SPL_{p\text{-}p}$=160dB.

Table 3

Maximum detection range $R_2(m)$.

SPLp-p (dB)	Net material	NL(dB) 30	40	50	60
160	Netting	10	3.2	1.0	0.21
160	Leadline	34	16	7.6	3.6
170	Netting	27	10	3.2	1.0
170	Leadline	66	34	16	7.6
180	Netting	67	27	10	3.2
180	Leadline	114	66	34	16

The assumptions inherent in the R_1 estimate have not yet been experimentally determined. However, the DT used in R_2 has been determined from many detection experiments, albeit using bottlenose dolphins. This suggests that the R_2 approach is more reliable but given the paucity of information on the auditory and detection abilities of the Dall's porpoise, both values should be considered as preliminary and be corrected in the future.

Despite this, it seems clear that echolocating Dall's porpoises can recognise objects such as a whole gillnet, at a long distance. On approach they become increasingly careful and can detect thin elements such as the netting itself. Thus echolocating animals should normally avoid getting entangled.

Discrimination between gillnets and fish

As discussed previously, the net TSm^{-2} and leadline TSm^{-1} are –43 and –27dB, respectively. These TSs change with distance, because of their spatial extent in the ultrasonic beam, whereas the TS of a fish does not. The average TS of the fish is assumed to be –30dB.

The TSs as a function of the distance between the porpoise and reflectors are shown in Fig. 4. Assuming that the discrimination threshold between two reflectors is 6dB, the porpoise can discriminate the fish from the netting at shorter ranges (<25m) and discriminate the leadline from the fish at longer ranges (>20m). Pence (1986) reported that at a range of about 30m, a porpoise approaching a net could no longer distinguish it from the floats bobbing on the surface and leadlines suspended 10m below the surface.

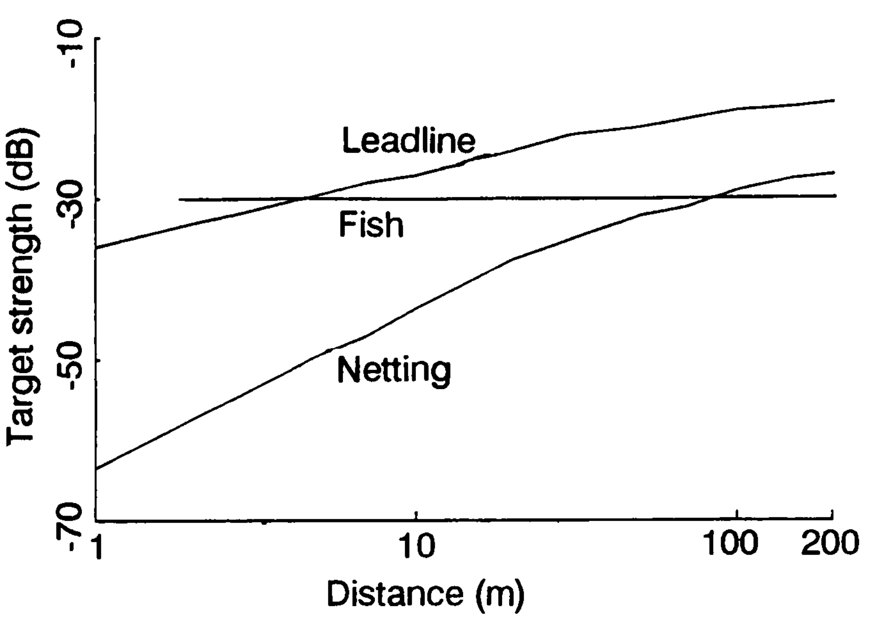


Fig. 4. Target strengths of leadline, fish and netting as a function of distance.

However, it is important to determine whether porpoises can detect two reflectors separately when they sweep echolocation beams from a small TS reflector to a large TS reflector. They appear to have a wide dynamic range of acoustic detection mechanisms, given that they can detect even a small hole in the netting near the surface and also the netting between the floatline and leadline.

Eyesight of Dall's porpoise

The eyesight of Dall's porpoises was examined under a research programme granted to the Ocean Research Institute, University of Tokyo, by the Fisheries Agency of Japan from 1989 to 1991. In 1989, the character of the retina and the distribution of photoreceptors and ganglion cells in the eye was investigated in order to provide basic data for the elucidation of the mechanism of incidental entanglement in gillnets (Murayama *et al.*, 1989).

The eyes were sampled within 24 hours of death. After fixation with Bouin solution or with 10% formalin, the retina including the choroid was excised from the eye cup. Segments of the retina were embedded in paraffin and sectioned at 4 or 12μm and these sections were stained with hematoxylin and eosin. The retina was prepared as a wholemount and stained with cresyviolet. The choroids were stained following the Van Gieson method. All specimens were examined under a light microscope. The results are summarised below.

(1) The retina consists of 10 layers as in other mammals. Much of the pigment in the pigment epithelium layer accumulates in the peripheral area of the retina. Cone and rod nuclei can be distinguished in the outer nuclear layer. The number of cells in the outer nuclei layer is much larger than in the inner, usually considered a characteristic of nocturnal animals.
(2) Density of photoreceptors is high near the optic disk. Few ganglion cells exist near the optic disk but they increase in number with increasing distance from the optic disk. The highest density of ganglion cells (G) is 10–12mm from the optic disk.
(3) The tapetum lucidum in the choroid seems to be composed of collagen. Most tapetum lucidum is found at the fundus and very little at the periphery.
(4) There is little qualitative or quantitative difference between the eyes of the Dall's porpoise and the bottlenose dolphin.

Experiments on the gillnet detection ability of other species

Pacific white-sided dolphin, bottlenose dolphin and false killer whale

In 1981, the ability of three species (1 Pacific white-sided dolphin, *Lagenorhynchus obliquidens*, 3 bottlenose dolphins, *Tursiops truncatus*, and 1 false killer whale, *Pseudorca crassidens*) to detect a gillnet was examined in an experimental pool (20x14x3.5m) at the Kamogawa Sea World (National Research Institute of Fisheries Engineering, 1982).

The results are summarised below. No species differences were determined.

(1) All dolphins detected the existence of the nylon monofilament (0.5mm in diameter) through echolocation.
(2) If one dolphin swam into the salmon gillnet at high speed, it broke through the net without getting entangled. After that, other dolphins approaching the net could precisely detect the hole and pass through the opening in the net.
(3) The individual components of the net such as the floatline, leadline and rope each represented a barrier for the dolphins.

White whale visual recognition of a gillnet

Since small cetaceans may also recognise both nets and their prey visually, at least during daylight at short distances, gillnet recognition experiments (using eyesight only) were carried out in 1982 and 1983 on a white whale, *Delphinapterus leucus*, at the Kamogawa Sea World, by shutting off the ultrasonic pulses of clicks (Soeda *et al.*, 1986).

The underwater irradiance in the pool ranged from 340 to 650lux. The experimental equipment (Fig. 5) was set at a distance of 7m from the start line of the white whale. The animal was conditioned to indicate when it recognised a thread or netting in the equipment. The recognition 'action' was made after stopping briefly in front of the equipment. The recognition time (RT) taken from its first stop to indicating its recognition represents the difficulty in recognition (Table 4).

Experiments with various thicknesses and colours were conducted 20 times or more. Using a chi^2 analysis, significant results were observed for thread itself of 0.6 or 1.2mm diameter and red, blue, black or white, and for net of 0.6 or 1.2mm diameter threads and red, black, white, colourless (air tube thread) and/or green i.e. the whale could recognise some combinations better than others. It could not recognise thread or net of 0.25mm diameter.

Table 4

Mean recognition time (sec) and standard deviation (SD) for each material, white whale visual experiment.

Diameter or colour	Recognition time (Mean±SD) (sec)	
	Thread	Netting
1.2(mm)	1.84±0.53	1.41±0.50
0.6(mm)	2.04±0.52	1.52±0.47
Red	1.61±0.50	0.95±0.18
Blue	1.63±0.41	1.21±0.29
Black	1.53±0.42	1.02±0.25
White	1.87±0.61	1.13±0.50
Colourless		1.24±0.48
Green (Air-tube)		1.22±0.29

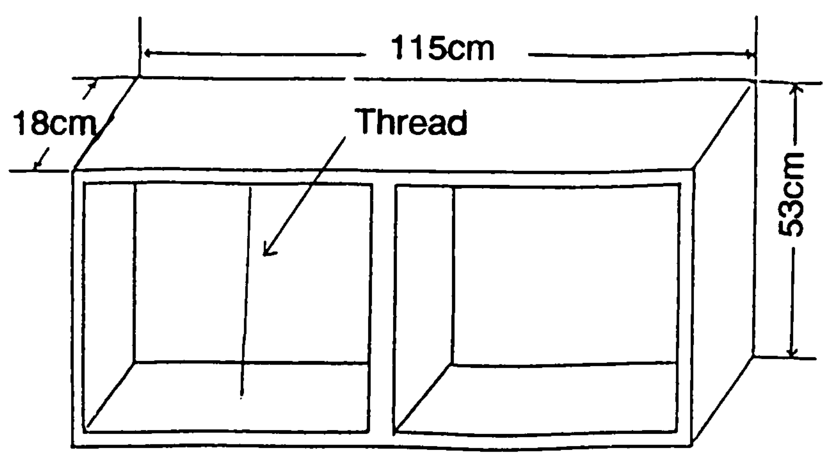


Fig. 5. Experimental equipment to show net materials to beluga.

The *RT* values were shorter for both thread and net of 1.2mm diameter than for 0.6mm, but the differences were not significant. Net was more easily recognised than thread of the same diameter (significant difference in *RT*). Although *RT* values for thread increased through the sequence black, red, blue and white, the only significant difference was observed between black and white. For the net, the *RT* values increased through the sequence red, black, white, blue, green and colourless. There were significant differences between red and blue, colourless or green, and between black and blue or green, i.e. recognition ability differs with net colour.

White whale echolocatory recognition of a gillnet

In 1985, experiments on the acoustic recognition of the netting were conducted using a white whale (blindfolded with eye cups) in the Kamogawa Sea World (Hatakeyama *et al.*, 1986). The netting was folded four times. First, the animal was trained to place its lower jaw on the rack and take a fixed position and direction. It was then trained to detect the object by echolocation only and take different actions according to its judgment as to whether the object was present or not. The object was shown to the animal directly by the trainer.

At a range of 4m, the rate of correct response was 75%. This is probably less than the likely range in the open sea, as disturbance by reflective waves from the concrete walls of the pool and from the hand of the diver increased as the distance became larger.

Bottlenose dolphin behaviour and a gillnet

The reaction of three bottlenose dolphins to a gillnet was observed in February 1986 (Hatakeyama and Ishii, 1987). As shown in Fig. 6, three dolphins were held in a net enclosure which was partitioned equally with a salmon gillnet (45m long, 3m deep, 115m mesh size). They could move freely to other areas either by passing through spaces at both ends of the gillnet or passing under the gillnet or the floating pier. To more easily observe dolphin behaviour at night, a small flashing buoy (15cm in length, 7.5cm in diameter) was attached to one animal. The flash interval was 3sec. The behaviour was recorded on video tape.

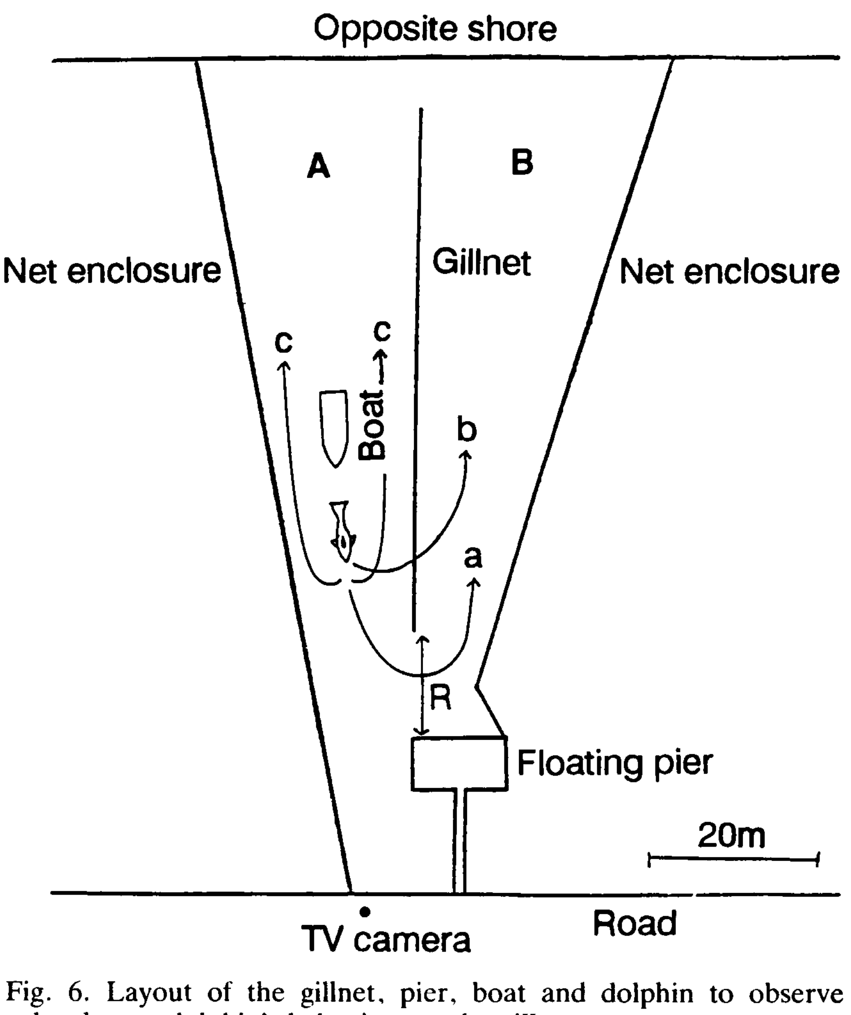


Fig. 6. Layout of the gillnet, pier, boat and dolphin to observe bottlenose dolphin's behaviour to the gillnet.

Three situations were considered: (1) when they were swimming freely under ordinary conditions (day and night); (2) when they were chased; and (3) when they were feeding on fish attached to the gillnet.

Fig. 7 shows the frequency distribution of distances between the gillnet and the dolphins. Dolphins seldom went closer than 1m to the gillnet. For the experiment with chased dolphins, the length (*R*) of the rope between the edges of the pier and gillnet was varied from 0 to 10m. With *R*=5 or 10m, the dolphins passed easily under the rope ('a' in Fig. 6). When *R*=0m, on most occasions the dolphins passed the boat many times ('c'); on one occasion they passed under the gillnet ('b').

For the 'feeding' experiment, weak cotton thread was bound around the tail of 25–28cm mackerels, *Pneumatophorus japonicus japonicus*, and they were hung from the floatline at the side of area B and kept at a depth of 0.5 to 1m. Even when the dolphins were hungry, they fed on the fish attached to the gillnet without getting entangled. They were conducting careful echolocation with a horizontal shake of their heads.

In all categories, the dolphins fully detected the existence of the gillnet and did not get entangled in the gillnet.

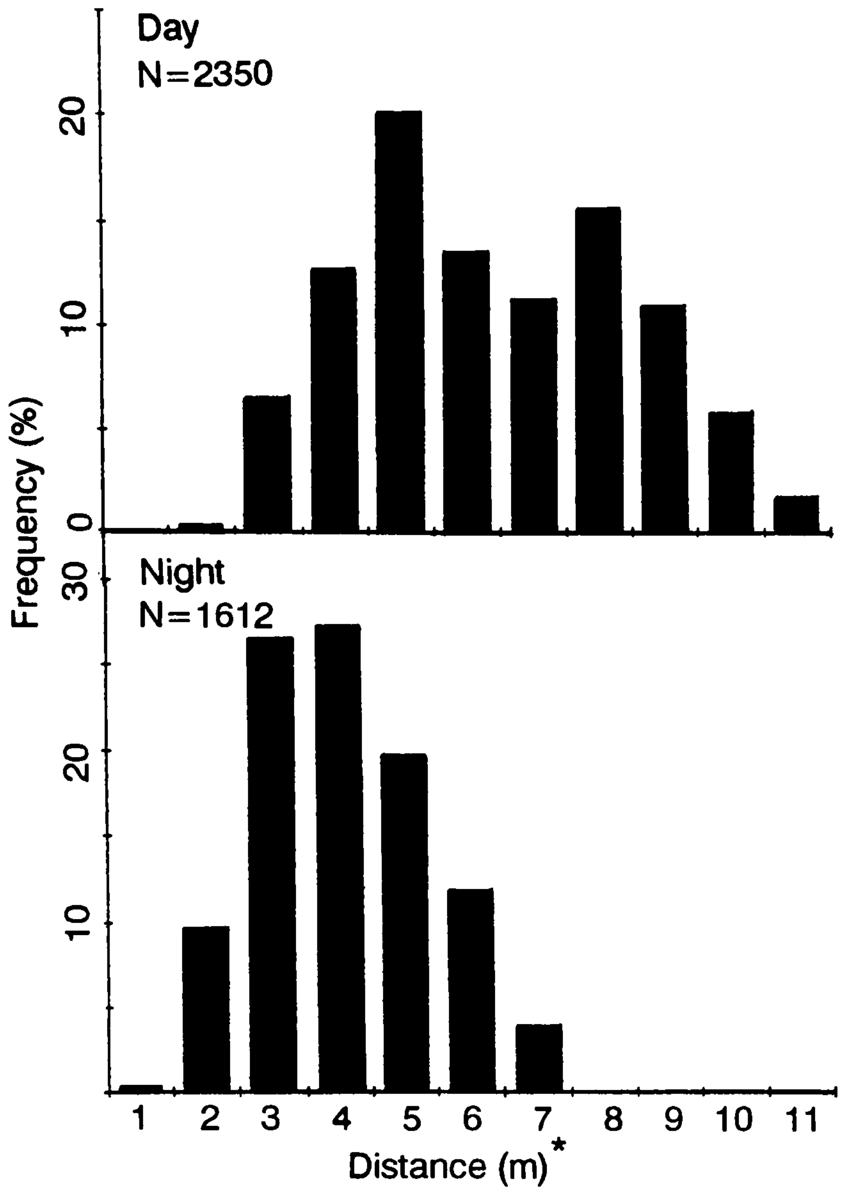


Fig. 7. Distribution of distances between the dolphin and gillnet. *Distance ranging from N-1 to N(m) is regarded as N(m).

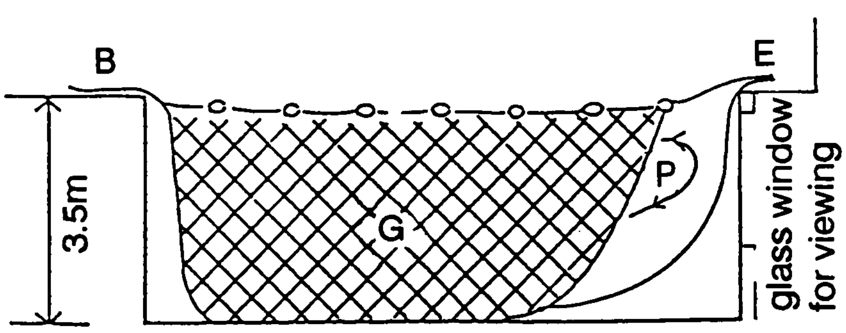


Fig. 8. Side view of the gillnet in the experimental pool.

Reaction of harbour porpoises to gillnets in a darkened pool
Since salmon gillnets are set from evening to the following morning, it is important to observe the reaction of animals to gillnets in a darkened pool; in 1987, this was done for two harbour porpoises using a nightscope in front of the glass window (Hatakeyama *et al.*, 1988).

Table 5

Harbour porpoise behaviour near the gillnet.

Time (h:m:s)	Pattern of behaviour	Swimming speed (cm/s)	Time (h:m:s)	Pattern of behaviour	Swimming speed (cm/s)
18:47:00 [1]			18:59:59	3' lower	
57:48	2' middle	121	19:00:16	3' middle	
58:03	2' middle	97	29	2' lower	106
10 [2]			41	2' lower	166
37	3' lower		53	2' lower	146,225
56	3' lower		1:07	1 upper	
59:09	2' upper	132	26	1 lower	
25	2' lower	94	40	2 middle	
35	2' lower	224	2:03	2' lower	
37	3' middle		22	1 middle	
49	3' upper		32 [3]	4 middle	85

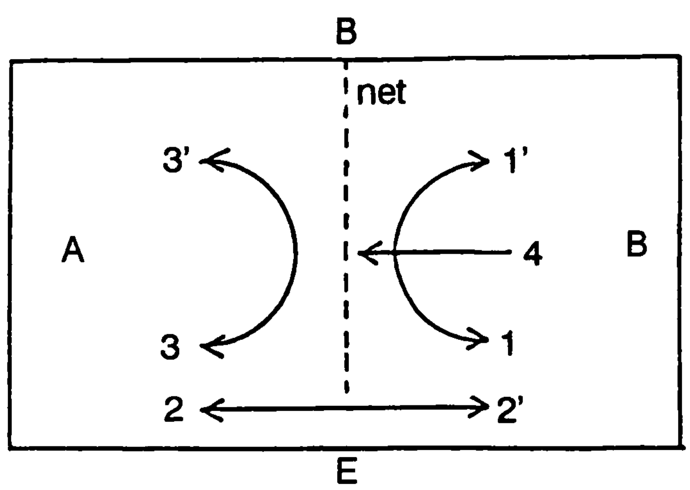
[1] Start time. [2] The net was completely set in the pool. [3] One porpoise got entangled.

All mercury lamps over the experimental pool were turned off. The underwater irradiance was 1.4lux. vertically and 0.9lux. horizontally and conditions were such that nearby netting at a distance of about 2m could be seen dimly by the naked human eye accustomed to the darkness. The salmon gillnet was cut and remodelled to a small-sized gillnet (4m in height, 15m in length) as shown in Fig. 8; there was some space between the rope and net.

Reactions to the gillnet were categorised by pattern (Fig. 9, Table 5). The animals passed between the rope and net eight times and made nine U-turns immediately in front of the net. One porpoise approached the net at a right angle, 4mins 22secs after the net had been set. Whilst turning counter-clockwise immediately in front of the net, its caudal fin became entangled in the middle of the net.

The maximum detection ranges of harbour porpoise for the leadline and netting were estimated to be 9m and 2m, respectively, from an echo level and corrected auditory threshold. The echo level was calculated by taking account of distance-related variations in the areas of the reflecting portions. The auditory threshold of 68dB at 130kHz for a sound of 1.5sec (Andersen, 1970a) was corrected for the pulse width (43μs) of clicks emitted by harbour porpoises.

These estimated detection ranges are based on simplified models of the gillnet and reflection mechanism, and from the auditory characteristics of a dolphin from another family. Gillnets set in the sea will change their configurations in a complex three-dimensional manner. It is clear that further studies are required on the reflection of the ultrasonic pulse waves and the Dall's porpoise's ability to detect the gillnet. However, it should be noted that the echolocation ability of the Dall's porpoise will be better than that of the harbour porpoise because the source level, pulse width and frequency of its clicks are more suitable for echolocation.



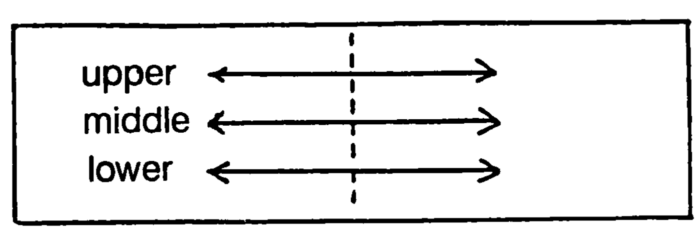


Fig. 9. Patterns of harbour porpoise's behaviours near the gillnet.

RESPONSES TO SOUND WAVES AND OBJECTS

It is important to observe the response of porpoises to a variety of sound waves and objects in order to examine the likely success of different active and passive methods to prevent their incidental catches.

Dall's porpoise on the high seas

Sound projection experiments in the Bering Sea

Although it is difficult to make detailed observations of the behaviour of Dall's porpoises around a vessel in open seas and thus to evaluate quantitatively their responses to ultrasonic pulses, we attempted to do this as little or no such information exists.

The following ultrasonic pulses were projected toward Dall's porpoises which approached the stationary salmon research vessel in the Bering Sea: pulses with frequencies of 75, 115 and 143kHz in July 1983 (Hatakeyama and Shimamura, 1984) and randomly generated 20–50kHz pulses in July 1984 (Taketomi *et al.*, 1985). The specifications of the pulse generators are listed in Table 6.

Swimming behaviour was observed in relation to the ultrasonic beam of the transmitter hung at the side of the vessel (Fig. 10). Results from the 1983 experiments suggested that the response to the 115kHz pulses was strongest. When the source level was 196dB or more, they made a quick U-turn as they became aware of the beam even at distances of 20 to 40m. It appeared that the porpoises regarded the beams as barriers.

At 143kHz, with a fixed sound source level of 210dB and varied pulse width of 100μs to 50ms, the animals showed avoidance responses more frequently to the greater pulse width. Responses to 75kHz pulses were the weakest but frequent avoidance occurred at a source level of 228dB.

In the experiments using randomly generated 20–50kHz pulses, reaction frequently entailed avoiding the ultrasonic beams or making a sudden dive when entering the beams.

Sound projection experiments in the Okhotsk coast off Hokkaido

A series of experiments were carried out in the Okhotsk Sea off east Hokkaido (Taketomi *et al.*, 1985; Ishii et al., 1986). The following types of sound wave were projected toward Dall's porpoise resting at the surface as the boat (about 2GRT) approached: ultrasonic pulses of 24 or 50 kHz and randomly generated 20–50kHz pulses in August 1984 and ultrasonic pulses of 24kHz and a vocalisation of killer whale in August 1985 (Table 6).

A total of 14 trials was conducted, two with 50kHz pulses, two with killer whale sounds, three with randomly generated 20–50kHz pulses and seven with 24kHz pulses. In addition 21 control trials were conducted in which no sounds were emitted while the boat approached. Transmission loss of sound pressure is calculated for each type of sound wave and shown in Fig. 11.

If Dall's porpoises were found 2–3km from the boat, they were slowly approached up to 500–600m. In general, they showed two types of reaction to the boat at this

Table 6

Specifications of sound generators used in the experiments of sound projection.

Frequency (kHz)	Source level (dB)	Directivity (°)	Pulse width (ms)	Interval (ms)	Experiment year (Field)
75	158-228	5x8 [1]	0.5	250	1983 (Bering)
115	177-222	3.5x9	0.5	250	1983 (Bering)
143	150-210	8	0.1-50	10-500	1983 (Bering)
20-50	186 at 35kHz	360x60 at 50kHz	PCM 1-109 (at random) FM continuous	PCM 10-226 (at random)	1984 (Bering, Okhotsk) 1985 (Okhotsk)
24	208	72x58	1-10	30-500	1985 (Okhotsk)
50	214	40	1-10	30-500	1985 (Okhotsk)
0.2-20 (Killer whale)	160	360			1985 (Okhotsk)

[1] Horizontal x vertical.

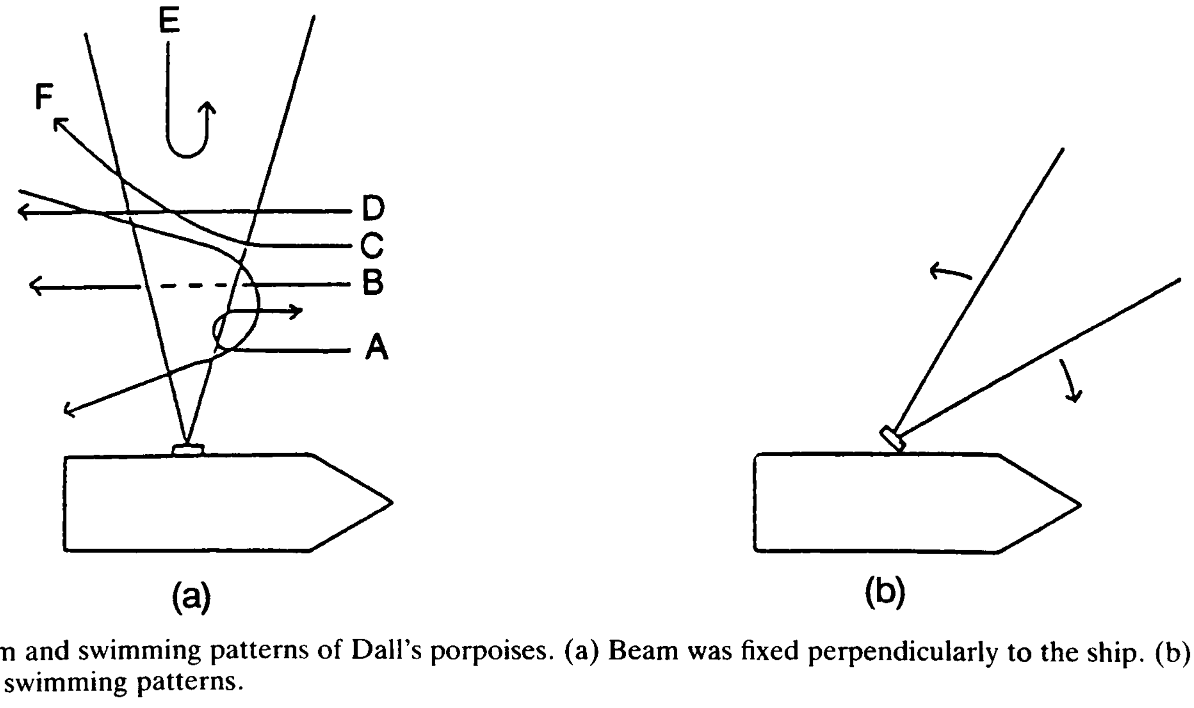


Fig. 10. Ultrasonic beam and swimming patterns of Dall's porpoises. (a) Beam was fixed perpendicularly to the ship. (b) Beam was swept to the porpoise. a-f: typical swimming patterns.

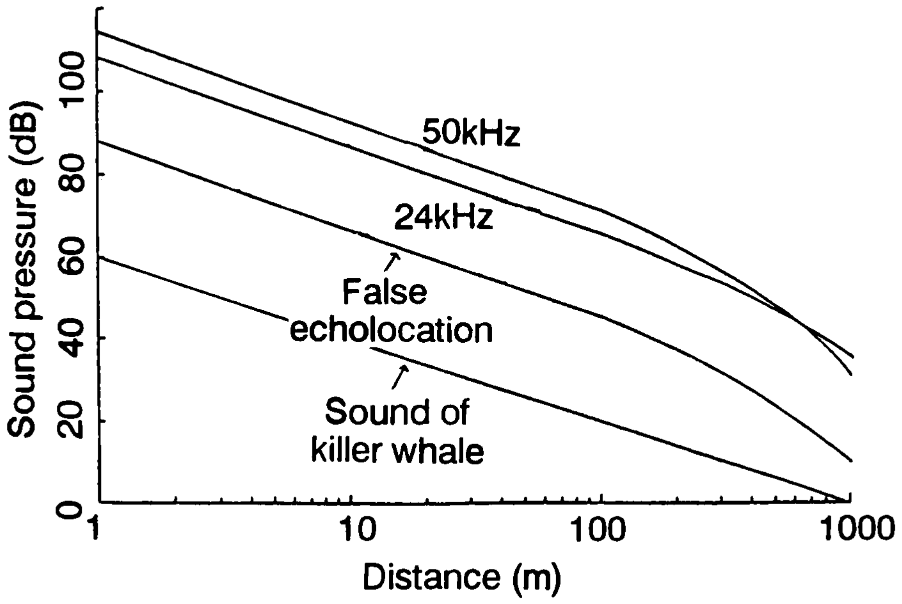


Fig. 11. Sound pressure of each sound projected to Dall's porpoise as a function of distance.

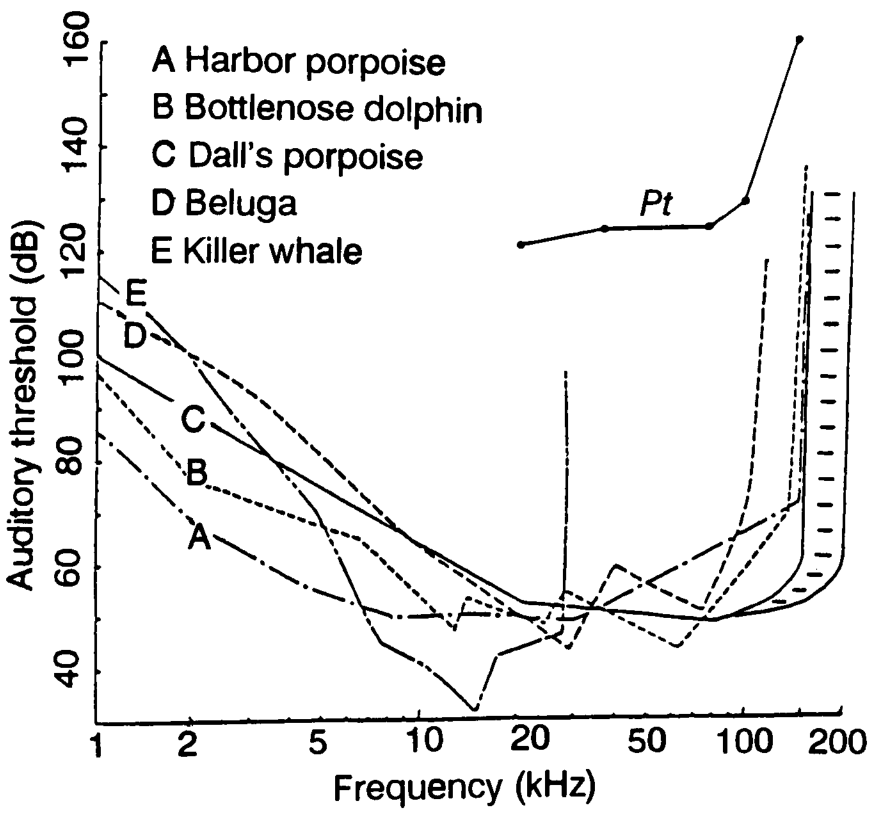


Fig. 12. Sound pressure (*Pt*) where Dall's porpoise began to respond to supersonic pulses. Auditory thresholds of Dall's porpoise and other species. From Awbrey *et al.* (1979).

distance when no sound was emitted: either to remain at the sea surface or to suddenly dive and disappear. When ultrasonic pulses were emitted from distances of 100–700m, the animals immediately became disturbed and swam rapidly away, splashing at each surfacing. No escape response was apparent during the killer whale sound experiments; after 2–3 minutes the animals swam away.

A captured live Dall's porpoise in a pool

Response to sound waves

Hatakeyama and Shimizu (1985) reported the observed responses of a Dall's porpoise captured in May 1984 to sound waves. The animal did not respond to potential food items thrown into the pool (anchovies, *Engraulis japonica* (about 7cm in length) or sardines, *Sardinops melanosticta* (about 20cm in length)) either as prey or merely as a source of underwater sound as the fish hit the water (when anchovies were thrown in the source level ranged from 140 to 150dB and the spectrum peak was between 1 and 3kHz).

Low frequency sounds (the source level was 171dB at the depth of 50cm and the spectrum peak was between 2 and 2.5kHz) were produced by striking the inner wall of the concrete pool (7x5x3m) six times but the porpoise did not seem to be frightened and did not change its swimming behaviour.

These experiments suggest that the Dall's porpoise is not sensitive to low frequency sound waves at pressure levels of up to about 170dB.

Randomly generated ultrasonic pulses 20 to 50kHz were projected twice toward the Dall's porpoise, with the sound pressure adjusted to 178dB at the position of the porpoise. The animal was clearly disturbed and this was indicated by: (1) an increase of four times its 'normal' respiration rate; (2) changing from its 'normal' circular swimming pattern; (3) constantly swimming at the surface to avoid the pulses.

Experiments were also conducted on the animal live-captured in 1986 and kept in the pool (5.1x5.7x2.0m) of the National Fish Farming Centres. Ultrasonic pulses ranging from 20 to 143kHz were projected towards the animal from a distance of 2m. The sound pressure (*Pt*) at which responses began was examined in 10dB increments (Hatakeyama *et al.*, 1987). The animal had floats on either sides of his body and in the absence of sounds swam slowly around the pool in a clockwise direction. When the pulses were emitted, two types of response were noted: movement to avoid the sound and irregular breathing or the emission of sounds in the air.

The *Pt*s at a pulse width of 1ms and the estimated auditory threshold (Awbrey *et al.*, 1979) of Dall's porpoise are shown in Fig. 12. The Pts between 20 and 100kHz range from 122 to 130dB and this sound pressure is approximately 70dB higher than the auditory threshold. The *Pt* increases drastically to 158dB at 143kHz and the auditory threshold deteriorates in a similar way. As the pulse width is reduced by a factor of about 10 (e.g. 10–1ms or 1–0.1ms at 143kHz) the *Pt* increases by 10dB, similar to the case of bottlenose dolphin (Johnson, 1967). The audible frequency range of the Dall's porpoise is similar to that for the bottlenose dolphin and harbour porpoise.

Responses to objects

When a white nylon rope (10mm in diameter) was stretched on the water surface of the pool (7x5x3m), the porpoise swam in a circle with its head up furiously blowing up in the air with splashing sounds on one side of the rope. It did not attempt to dive under the rope. The animal appeared to be both aware and cautious of the rope. No reaction was observed when the rope was stretched 10cm above the water surface.

In experiments where nylon monofilaments (0.6 or 1.2mm in diameter) were hung at intervals of 35 or 70cm, as the diameter of the threads became larger and the interval became smaller, the porpoise was more aware of the existence of the threads and the time it took to swim between the threads became longer. Since the porpoise emitted few clicks while passing through the interval, recognition of the existence of the threads seemed largely to have been visual (Hatakeyama and Shimizu, 1985).

SOUND GENERATORS

Specifications of sound generators

Specifications of all sound generators are listed in Table 7. The four types of sound generators (SG-1 to 4) were constructed on the basis of the frequency components of clicks and responses to ultrasonic pulses (National Research Institute of Fisheries Engineering, 1982; Hatakeyama, 1983; 1986).

Table 7

Specifications of sound generators tested in the actual fishing ground.

Type	Frequency (kHz)	Source level (dB)	Directivity (°)	Waveform τ	Waveform t	Waveform t'	Waveform T	Size (mm) D*	Size (mm) L*	Weight (kg)	Power supply	Life time (days)	Test year
SG-1	9	140	360	100ms [1]	4s		4 min.	83	406	0.786	Dry cell 1.5Vx4	60	1981-1984
SG-2	145	185	360x40 [2]	50ms	3s			380	797	20	Dry cell 12Vx2	30	1983-1986
SG-3	135-150	185	360x40 [2]	100μs	7-28ms [3]		3s	380	797	20	Dry cell 12Vx2	30	1983-1986
SG-4	20-50	186	360-60	1-109ms	10-226ms	9-110ms [4]	6s	380	797	20	Battery 12Vx2 [5]	1	1985-1989

[1] 4 pulses in 16 sec. in every 4 min. [2] Horizontal x vertical. [3] 47 pulses in 0.6 sec. in every 3 sec. [4] Pulses and FM sounds in 1 sec. in every 6 sec. [5] 300-400 times rechargeable battery. Discharge and charge once a day. D = Maximum diameter; L = length.

Given the lack of available data in 1981, SG-1 was developed by the marine mammal project team on the basis of the whistle of bottlenose dolphin.

SG-2 and 3 took into account information obtained in 1983 concerning the frequency components of clicks emitted by the Dall's porpoise. SG-2 emitted 145kHz ultrasonic pulses repeatedly with a constant period. Its pulse width (50ms) was 1,000 times greater than that of clicks made by Dall's porpoises to stimulate their auditory sense with the duration time (energy quantity) and to attract their attention by disturbing their echolocation. SG-3 emitted 135–150kHz pulses similar to those used in echolocation by Dall's porpoises, by changing the pulse interval. SG-4 (manufactured in 1985) emitted random ultrasonic pulses and FM continuous waves of 20 to 50kHz which had been found to affect Dall's porpoises in a series of three experiments in 1984.

The electronic circuit of SG-1 was installed in a plastic case whilst those of the other sound generators were installed in buoys (Fig. 13).

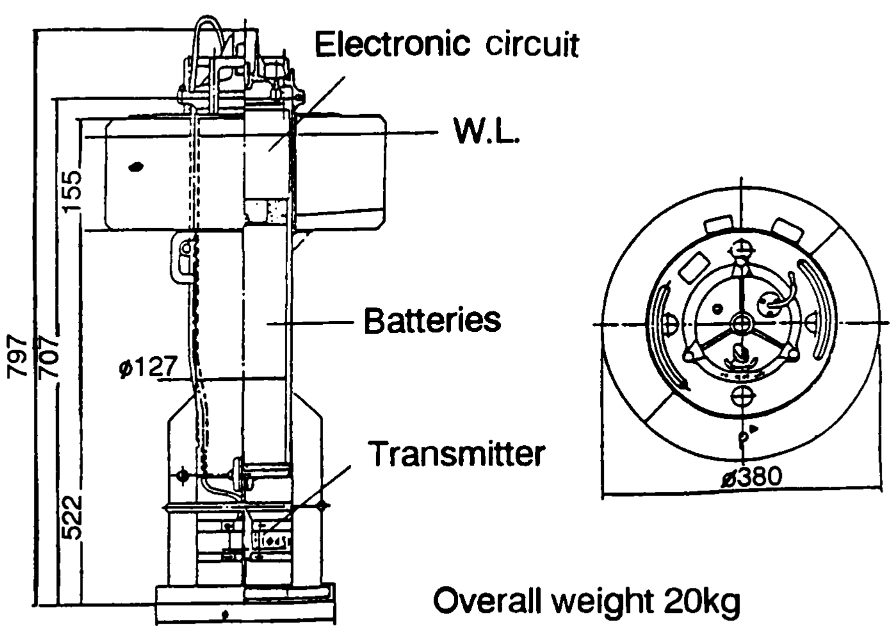


Fig. 13. Sound generator (SG-2, 3 and 4).

Results of tests in the mothership fishery

The four types of sound generators were tested in the mothership salmon fishery and the results from 1983 to 1986 are shown in Table 9 (Kumagai *et al.*, 1984; Ogiwara *et al.*, 1985; 1986; 1987; Snow, 1987).

Decrease rates (DR) of the entanglement for SG-1 to 3 were 3–16%, smaller than expected. The DR for SG-4 was 19% in 1985. SG-1 was not used after 1985 given its low DR and difficulty of use.

In the experiments using SG-4 (Hatakeyama, 1986; 1987; 1988), there was a concentration of the entanglement in that portion of the gillnet where no sound generator was attached and the sound wave was weak. A total of 3–4 SG-4s per net were attached to positions either near both ends of the gillnet or on one half of it. The horizontal distribution of the entanglement is given in Table 8.

Porpoises incidentally taken were concentrated in sections 7–9. The CPUEs for the horizontal sections 1 to 6 which appeared to be within sound range and for the

Table 8

Horizontal distribution (%) of Dall's porpoises entangled in the test nets equipped with SG-4.

Test year	Horizontal section 1	2	3	4	5	6	7	8	9	Total number Porpoise	Total number Operation
1985	▲ 0	9.1	▲ 0	36.4	36.4	9.1	▲ 0	0	▲ 9.1	11	34
1986	12.5	▲ 0	0	▲ 0	▲ 0	12.5	25.0	12.5	37.5	8	32
1987	8.3	▲ 8.3	8.3	▲ 0	▲ 16.7	8.3	8.3	16.7	25.0	12	60
1989	0	▲ 11.1	11.1	▲ 0	▲ 0	0	11.1	33.3	33.3	9	30
Average of ordinary nets (1984-6)	12	12	11	9	9	9	10	13	15		

▲ = Positions of sound generators.

Table 9

Number of marine mammals incidentally taken by modified gears, decrease rate (DR) and statistical tests.

Year	Classification	Set	Incidental take			U test[1]		chi² test[2]		t test[3]	
			No.	CPUE	DR(%)	Whole[4]	Adjacent[5]	Whole	Adjacent	Whole	Adjacent
1983	Standard boats	5,051	2,033	0.347	0						
	AT-1	627	195	0.311	10.4	0.378	0.390	3.985			
	AT-2	627	197	0.314	9.5	0.378	0.057	1.450			
	SG-1	209	65	0.311	10.4	0.435		6.466*			
	SG-2	209	63	0.301	13.3			3.846			
	SG-3	209	61	0.292	15.9	0.128		8.887*			
1984	Standard boats	4,462	1,479	0.331	0						
	AT-1	2,134	647	0.303	8.5	1.498	2.205*	3.448	6.187*	1.913	2.322*
	SG-1	194	62	0.320	3.3	0.509		2.186			
	SG-2	194	61	0.314	5.1	0.023		2.222			
	SG-3	194	60	0.300	6.6	0.669		8.223			
1985	Standard boats	2,000	926	0.445	0						
	AT-1	3,200	1,173	0.358	19.6	4.763**	5.294**	23.446**	29.525**	5.268**	5.232**
	AT-3	320	116	0.354	20.4	1.782		4.090			
	SG-2	164	69	0.421	5.4	0.234		1.539			
	SG-3	164	66	0.402	9.7	0.387		0.278			
	SG-4	13	13	0.317	28.8	1.138		1.839			
1986	Standard boats	1,000	422	0.388	0						
	AT-1	3,366	1,041	0.309	20.4	4.112**	5.282**	19.198**	31.427**	6.812**	3.922**
	MT-1	272	76	0.279	28.1	2.282*		7.149			
	AT-1 + SG-2	136	43	0.316	18.6	0.510		3.290			
	AT-1 + SG-3	136	39	0.287	26.0	1.384		3.213			
	AT-1 + SG-4	34	8	0.235	39.4	1.220		2.045			

[1] U Test: Number of times of entanglement. [2] chi Test: Frequency. [3] t Test: CPUE. [4] On the whole. [5] Adjacent boats. Classifications - AT-1: 3 air-tube threads in the central portion; AT-2: 5 air-tube threads in the central portion; AT-3: 3 air-tube threads in the upper portion; MT-1: Multi threads in the central portion; SG-1: 9kHz sound generator; SG-2: 145kHz sound generator; SG-3: 135-150kHz sound generator; and SG-4: 20-50kHz sound generator. * Within the level of 5%. ** Within the level of 1%.

Table 10

Comparison of CPUE between near and far horizontal section groups from sound generators.

Test year	Horizontal section	
	Near group (1-6)	Far group (7-9)
1986	0.09	0.56
1987	0.15	0.30
1989	0.10	0.70
1986 (ordinary net)	0.32	0.35

horizontal sections 7–9 at which the sound pressure was weak were calculated (Table 10). The former were much smaller than the latter. Given the relatively small sample sizes involved, it is not appropriate to statistically analyse the data. The purpose of the experiment was to determine whether the approach was considered worthy of further attention, and this is clearly the case.

Effective range of SG-4

The effective sound pressure of SG-4 was examined under conditions where Dall's porpoise was facing the sound generator (Hatakeyama *et al.*, 1987). The sound pressure (*Pt*) at which Dall's porpoise began showing a response was 126dB. Since the increase step of sound pressure in the experiment was 10dB, the true value of the *Pt* was in the range of 116 to 126dB. The frequency characteristics of the projector rendered the sound pressure to be a maximum at 35kHz. The auditory threshold (TH) at 35kHz was estimated to be 51dB by Awbrey *et al.* (1979). The TH represents the sound pressure at which Dall's porpoise would barely hear the sound wave whereas the *Pt* represents the sound pressure at which Dall's porpoise would show an external response. There presumeably is an intermediate sound pressure (*Pc*) that would draw the Dall's porpoise's attention to the sound.

The effective range was obtained on the points of intersection between an attenuation curve of the sound and above parameters as shown in Fig. 14 and Table 11 (Hatakeyama, 1987). Dall's porpoises were observed to jump and flee when the sounds were projected from distances up to 700m. The effective range based on the value of *Pt* is 440–740m and this upper limit is close to the experimental value (700m).

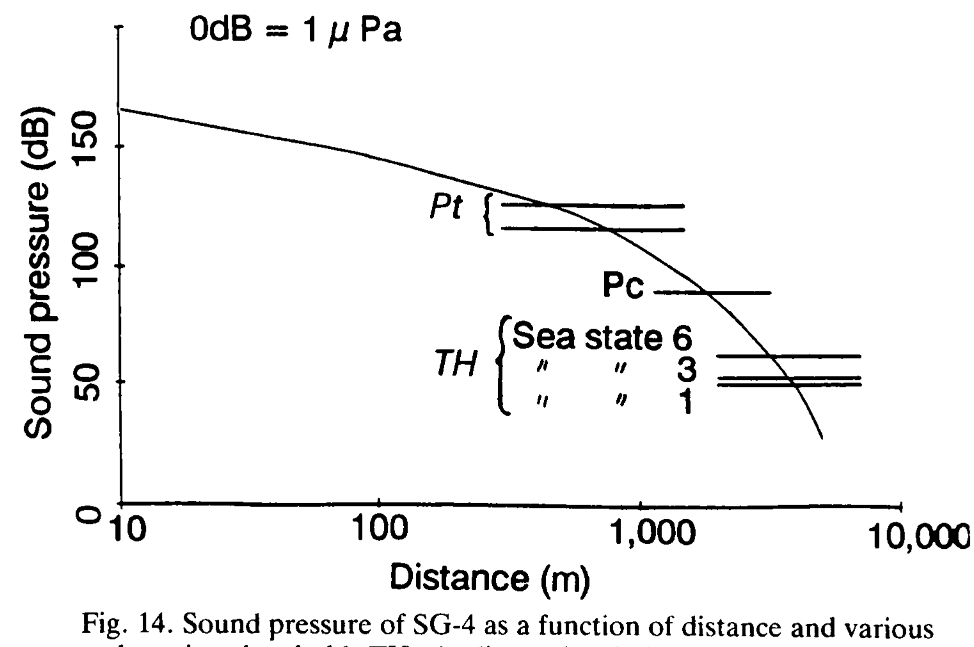


Fig. 14. Sound pressure of SG-4 as a function of distance and various detection threshold. TH: Auditory thresholds masked by ambient sea noise.

Table 11

Effective range(m) of SG-4.

Detection threshold		Effective range(m)
	Sea state 1	4,000
TH	Sea state 3	3,800
	Sea state 6	3,300
	Pc	1,900
	Pt	440-740

GEAR MODIFICATION

Gillnets with air-tube nylon threads

Awbrey *et al.* (1979) recommended that attempts be made to weave air-filled line into the net in order to increase the net target strength and thereby decrease mortality. Accordingly, the marine mammal project team conducted an experiment using air-tube nylon threads (outer diameter about 0.6mm; ratio of inner to outer diameter about 0.5). The TS of the gillnet with three air-tube threads was larger by 3 to 4dB than that of the ordinary net.

The project team monitored the incidental take and calculated its decrease rate (DR), comparing CPUE (number of incidental take/net) of the modified net with that of the standard unmodified net (Kumagai *et al.*, 1984; Ogiwara *et al.*, 1985; 1986; 1987; Snow, 1987). Four types of modified nets were used: 3 air-tube threads in the central portion (AT-1); 5 air-tube threads in the central portion (AT-2); 3 air-tube threads in the upper third of the net (AT-3); and 3 multi-filament threads in the central portion (MT-1). The results from 1983 to 1986 are listed in Table 9. The DRs of AT-1 to 3 were in the range of 8 to 20%.

Multi-filament thread has a higher (about 10dB) target strength than nylon monofilament and the obtained DR was 28%. Two statistical tests were used to examine the results: a test using entanglement frequency rate (U Test) was used for those cases where the sample size was small, e.g. for AT-1; a test using frequency distribution of the entanglement (chi^2 test) was also used. A significant difference (1% level) was found for 1985 and 1986 (Table 9). In addition, since 1984, the sample size has become sufficient to compare CPUEs for the two types of gillnets using the t-test; significant differences were found for 1985 and 1986 at the 1% level (Snow, 1987).

Gillnets equipped with reflectors

A total of 13 operations were conducted by a research vessel from 2–28 June 1986 with a set of 135 tans (1 tan=45m) of gillnet (Hasegawa *et al.*, 1987). Gillnets of five types were used. Types A to D were equipped with reflectors such as vinyl string, rope and sheets of blister plastic packaging material (Fig. 15). Type E, the control, comprised ordinary nets.

The target strengths of these objects are larger than that of the netting by 20 to 40dB, if the porpoises approach the net at a right angle. However, when they approach it at a diagonal angle, the reflected waves have a tendency to decrease abruptly. The mean values of the numbers of salmon caught per tan were 3.4 in type A (total length (TL) = 195 tans), 3.5 in type B (TL = 260 tans), 3.3 in type C (TL = 260 tans), 3.4 in type D (TL = 195 tans) and 3.7 in type E (TL = 845 tans). Although the values for the modified nets were smaller than for the control net, they were not significantly different.

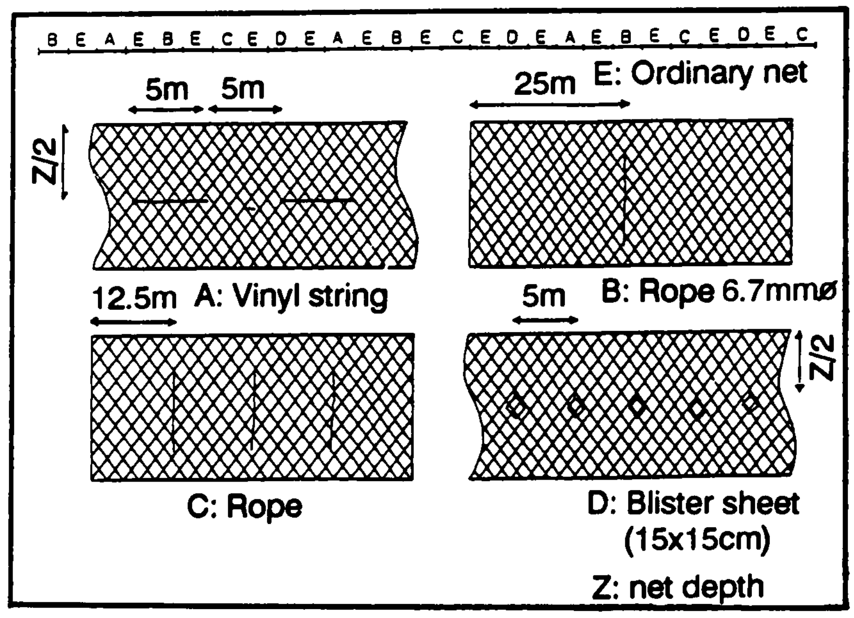


Fig. 15. Schema of experimental gillnet with reflectors.

A total of five Dall's porpoises became entangled during the 13 operations, 1 in type B net, 2 in type C net and 2 in type E net. It was assumed that the vertical ropes had no alerting effect on Dall's porpoise. Given the small sample sizes it is not surprising that no significant differences were apparent between the modified and unmodified nets. If this approach is to be pursued, the experimental procedures must be greatly enlarged.

CONCLUSION

It is very difficult to successfully live-capture a Dall's porpoise. In addition, although we eventually succeeded in live-capturing two Dall's porpoises with purse-seines, we did not succeed in feeding them.

Dall's porpoises in the Bering Sea emit short high frequency (135–149kHz) pulses with pulse widths of 50–60μs and source levels of 165–175dB re 1μPa. When chased toward gillnets in open sea, they changed their swimming direction in front of the net, either swimming along it or diving and passing under it. This fact shows that they have a highly resolutive echolocation ability and normally can avoid getting entangled in gillnets during the daytime.

Measured target strengths of a float, leadline, lead and netting were –25, –33, –39 and –55dB, respectively. The rough estimates of their detection ranges for the leadline and netting were found to be 30 and 8m, respectively.

Responses to sounds showed that Dall's porpoises are insensitive to low frequency (<3kHz) sounds with a sound pressure of up to 170dB, but are noticeably sensitive to ultrasonic pulses of 20 to 143kHz. Responses to objects suggested that they are aware and cautious of a rope on the water surface.

Four types of sound generator (SG-1 to 4), air-tube threads and reflectors such as rope were tested aiming to reduce the incidental catch. The decrease rates (DR) of the entanglement for the sound generators except SG-4 were 3 to 16% and the DR of the gillnet with three air-tube threads in its centre portion was 8 to 20%. As for SG-4, there was a concentration of entanglements in the portion of the net where it was not attached.

Although the numbers of salmon caught per unit length (tan) for nets with reflectors were smaller than that for the ordinary net, there was no significant difference between them. A total of 3 Dall's porpoises became entangled in the nets with vertical ropes. The vertical ropes probably have no alerting effect.

Although the harbour porpoise can detect netting at a short distance, one porpoise became entangled in a gillnet in a darkened pool. Judging from the waveform characteristics of clicks, the echolocatory ability of the harbour porpoise is worse than that of the Dall's porpoise. Bottlenose dolphins fully detected the existence of the gillnet and did not get entangled either at night or during the day.

From visual experiments with white whales, it was found that the netting is more easily recognised than the thread and that there are colour differences in recognition ability. The eyes of Dall's porpoises were examined and compared with those of bottlenose dolphins. The histological characteristics were similar. Neither the distribution of cells nor the mean ratio of the density of photoreceptors to that of ganglion cells were significantly different.

A number of questions concerning Dall's porpoises must be clarified in the future, including the following.

(1) How frequently and 'seriously' do they conduct echolocation during the day and night in the open seas?
(2) Which members conduct echolocation when swimming in a group?
(3) Do they respond to sounds such as alarm or distress calls emitted by other porpoises?
(4) At what distance can they recognise the net by eyesight at various light levels?
(5) When do they 'sleep'? At what depth and speed do they swim while sleeping? What are their sensory contacts with the environment at night?

Items (1) and (5) can be examined with a radio telemetry system. If the sensitivities of their auditory and visual organs are weak during sleep, a passive method will not be effective in reducing their entanglement rates and strong stimuli will be required to awaken them. If they swim near the water surface at night, especially during sleep, nets set a few meters below the water surface should be effective.

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Sonar Detection of Gillnets by Dolphins: Theoretical Predictions

Whitlow W.L. Au

Hawaii Institute of Marine Biology, Marine Mammal Research Program, PO Box 1106, Kailua, Hawaii 96734, USA

ABSTRACT

The detection and avoidance of gillnets by echolocating dolphins is examined by using the generalized sonar equation along with target strength values of nets and dolphin sonar detection data. Acoustic reflection data were obtained for several types of nets and associated gear by ensonifying them with simulated bottlenose dolphin sonar signals. Threshold detection ranges corresponding to a 90% probability of detection were calculated as a function of a dolphin's peak-to-peak source levels for: (a) monofilament gillnet used in the salmon mothership fishery, (b) Macah tribal cord setnet, (c) a twisted polyester rope 'poly rope' and (d) household light switch chain.

From calculations based on the measured ability of Atlantic bottlenose dolphins (*Tursiops truncatus*) to detect targets in noise, detection ranges for a monofilament drift gillnet should vary from 1.2m for a source level of 140dB re 1μPa to 25m for a source level of 190dB. The Macah tribal cord setnet should be detected at least twice as far as the monofilament gillnet. The results indicated that most dolphins should be able to detect a monofilament gillnet at sufficiently long ranges to avoid entanglement. The sonar detectability of nets can be enhanced considerably by attaching poly rope or light switch chain on the nets. Some reasons as to why dolphins get entangled in nets which they should be able to detect with their sonar are discussed.

KEYWORDS: INCIDENTAL CAPTURE; FISHERIES; BEHAVIOUR; ATLANTIC BOTTLENOSE DOLPHINS; DALL'S PORPOISE; HARBOUR PORPOISE; SPINNER DOLPHINS; FALSE KILLER WHALE; ACOUSTICS

INTRODUCTION

Coastal and high seas gillnet fisheries result in the incidental take of large numbers of small cetaceans and the global extent of such takes is described in IWC (1994). Dall's porpoise (*Phocoenoides dalli*) are incidentally taken in high seas salmon and squid driftnet fisheries (Jones, 1984; 1988). Dall's porpoises and harbor porpoises (*Phocoena phocoena*) are also caught in coastal salmon gillnet fisheries in Alaska (Matkin and Fay, 1980) and Washington (Gearin *et al.*, 1990). Harbor porpoises are incidentally taken in gillnets off California (DeMaster *et al.*, 1985; Peltier *et al.*, 1993) and in waters off Maine (Read and Gaskin, 1988). Bottlenose dolphins (*Tursiops* sp.) and spinner dolphins (*Stenella longirostris*) were caught by gillnets in the northern Australian seas (Harwood *et al.*, 1984). Thousands of small cetaceans die annually in coastal driftnets off Sri Lanka (Leatherwood, 1994). These references are but a few examples of the pervasive problem of incidental take of small cetaceans by gillnets throughout the world. Nearly every species of small cetacean is affected. If gillnet fisheries are to continue to be used in cetacean habitats, methods to reduce or eliminate entanglement are urgently needed.

Dolphins possess a sophisticated sonar system that should assist them in detecting and avoiding nets. Yet the continual problem with entanglement has led some to assume that gillnets, especially those constructed of nylon monofilament lines are 'acoustically invisible'. However, Au and Jones (1991) clearly showed that monofilament gillnets will reflect acoustic energy and that an echolocating dolphin should be able to detect a monofilament gillnet at a sufficient range to avoid entanglement. In this study, the biosonar net detection problem will be examined in a different manner to that of Au and Jones (1991) and the maximum detection ranges of nets and associated gear will be calculated as a function of the dolphin sonar source level. The Atlantic bottlenose dolphin (*Tursiops truncatus*) will again be used as the model. Reliable target detection and related acoustic data exist for only a few cetacean species such as the bottlenose dolphin (Au, 1988b) and the false killer whale (*Pseudorca crassidens*; Thomas and Turl, 1990). Unfortunately, few echolocation data exist for some of the phocoenids such as the Dall's and harbor porpoises, two species that are commonly caught in gillnets.

TARGET STRENGTH MEASUREMENTS

Target strength measurements were performed at the Naval Ocean Systems Center Hawaii Laboratory test pool using a monostatic echo measurement system that transmitted a broadband dolphin-like echolocation signal. Details of the measurements are given by Au and Jones (1991). The simulated dolphin echolocation signal resembled the sonar signal of the bottlenose dolphin, having a peak frequency (frequency of maximum energy) of 122kHz and a 3dB bandwidth of 37kHz. The transducer had a 3dB beam width of approximately 8° in the horizontal plane and 13° in the vertical plane. At the measurement distance of 2.4m, the effective area covered by the transducer's beam was rectangular, 0.34m by 0.55m. The nets were laid out with a minimum of tension applied so that their shapes were not rigid but resembled wavy curtains.

Target strength can be defined in several ways when dealing with short broadband signals such as dolphin echolocation signals. Target strength is often determined by using the peak-to-peak values of the incident and reflected sound pressure levels, and is denoted as TS_{pp} here. However, if an energy detection scheme is used to process echoes then target strength needs to be defined as the ratio of the incident and reflected energy flux density, and is denoted as TS_e. Au *et al.* (1988) have shown that the bottlenose dolphin processes sonar echoes like an energy detector with an integration time of approximately 264μs. Therefore, the received energy flux density should be integrated up to 264μs, resulting in a third target strength definition, TS_{tt}, applicable to *T. truncatus*. All three target strengths will be given since it is not clear which is most applicable to other species of dolphins. Although the animal's bandwidth for the detection of click signals is not known, the critical ratio measured with narrow band signals may be used as an estimate. The critical ratio measurements of Johnson (1968) and Au and Moore (1984) indicate that bottlenose dolphins process narrowband sounds with a filter having a Q (ratio of center frequency to bandwidth) of about 12.

Fishing equipment investigated

Three nets/fishing gear will be considered in this study, along with a household light switch chain.

(1) *Commercial monofilament gillnet* used in the salmon mothership fishery, constructed of 0.49mm diameter nylon monofilament lines with a 10cm mesh size (distance between parallel lines of the webbing).
(2) *Macah tribal setnet* used for salmon fishing in the state of Washington, constructed of 0.97mm diameter twisted (3 strands of 0.25mm diameter) cord with a 20.3cm mesh size.
(3) *Poly rope*, 0.635cm diameter twisted polyester rope.
(4) *Household light switch chain* consisting of chrome plated nickel beads, 0.3cm diameter spaced 0.4cm apart, center to center.

Target strength results

Waveforms and frequency spectra of echoes from the commercial monofilament gillnet are shown in Fig. 1, for different angles of incidence. The echo waveforms are relatively complex with many highlights, at all angles of incidence. With such complex echo structures, TS_e and TS_{tt} will generally be higher than TS_{pp} because the echo is considerably longer than the projected signal. Target strength varied little with angle of incidence. This probably was a result of the net being suspended like a wavy curtain which produced relatively similar echoes for different angles of incidence. The Macah tribal setnet also had similarly complex echo structures with little variation in target strength with incidence angles between 15 and 45°.

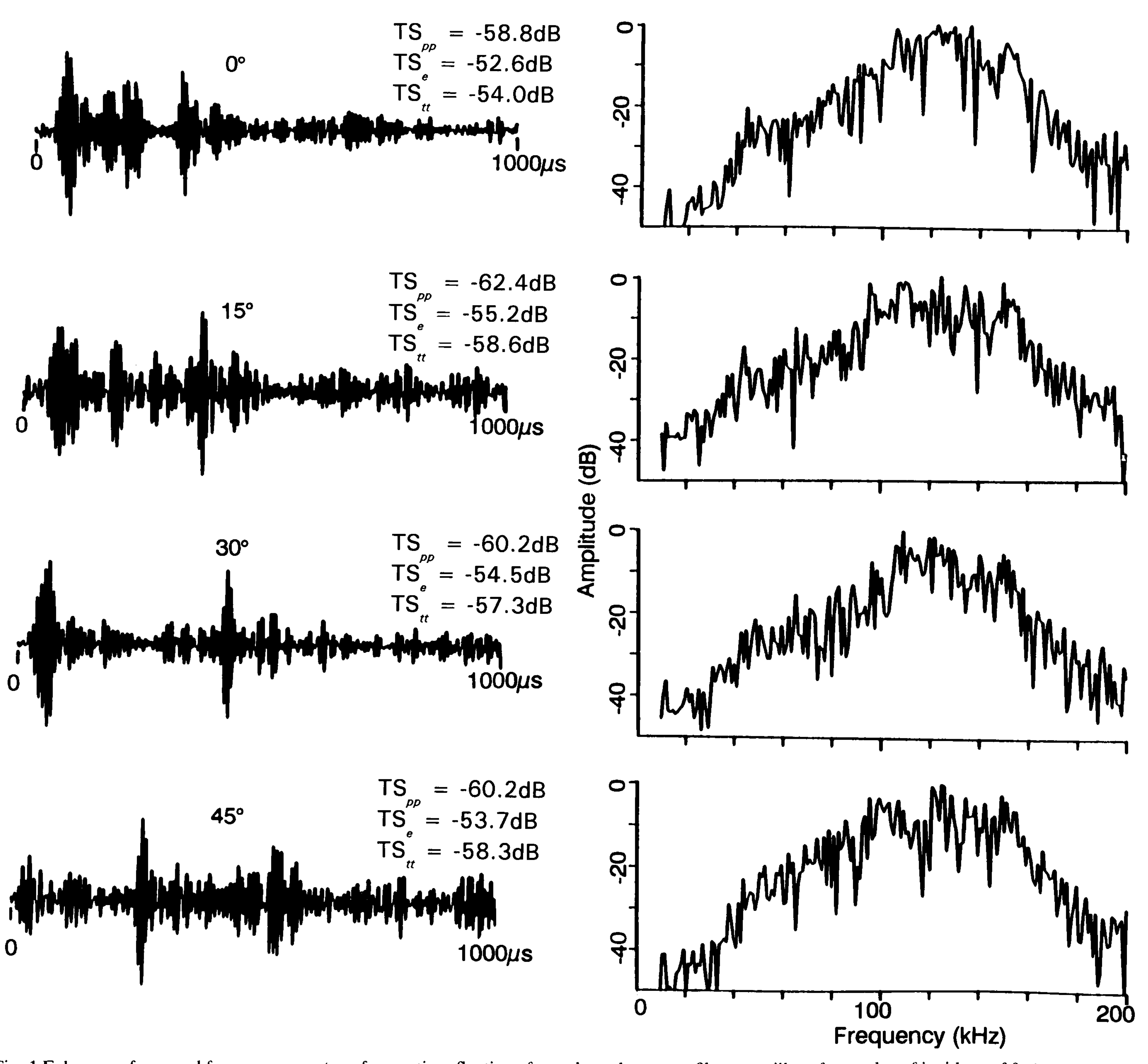

Fig. 1 Echo waveform and frequency spectra of acoustic reflections from the nylon monofilament gillnet for angles of incident of 0, 15, 30 and 45°. The target strength based on peak-to-peak amplitude (TS_{pp}), energy in a 1ms window (TS_e) and energy in the 264μs integration window of *Tursiops truncatus* (TS_{tt}) are also included.

Target strength values for the nets and gear are presented in Table 1. The monofilament gillnet had the lowest target strength making it the most difficult object to detect. The Macah tribal setnet had the higher target strength of the two nets. The echo waveform for the poly rope and the light switch chain, which were dangled vertically in front of the transducer, consisted of a single click resembling the incident signal. Therefore, the three types of target strength were the same for the associated gear. The unsoaked poly rope had the highest target strength. When the rope was left in the water for 24hrs, air bubbles trapped between the fibers dissipated and the target strength decreased by about 6dB. The target strengths of the rope and light switch chain were at least 20dB greater than the monofilament gillnet. This means that the acoustic reflectivity of a monofilament gillnet can be increased substantially by attaching objects such as the poly rope or light switch chain to it.

Table 1

Target strength (dB) of the gillnets and associated gear.

Net type	Incident angle	TS_{pp}	TE_e	TS_{tt}
Commercial gillnet	0°	-58.8	-52.6	-54.0
	15°	-62.4	-55.2	-58.6
	30°	-60.2	-54.5	-57.3
	45°	-60.2	-53.7	-58.3
Macah tribal setnet	0°	-36.7	-36.2	-36.2
	15°	-49.3	-43.6	-43.7
	30°	-55.8	-47.7	-49.4
	45°	-56.1	-46.8	-49.8
Poly rope (unsoaked)	0°	-25.8		
Poly rope (soaked)	0°	-33.0		
Light switch chain	0°	-36.5		

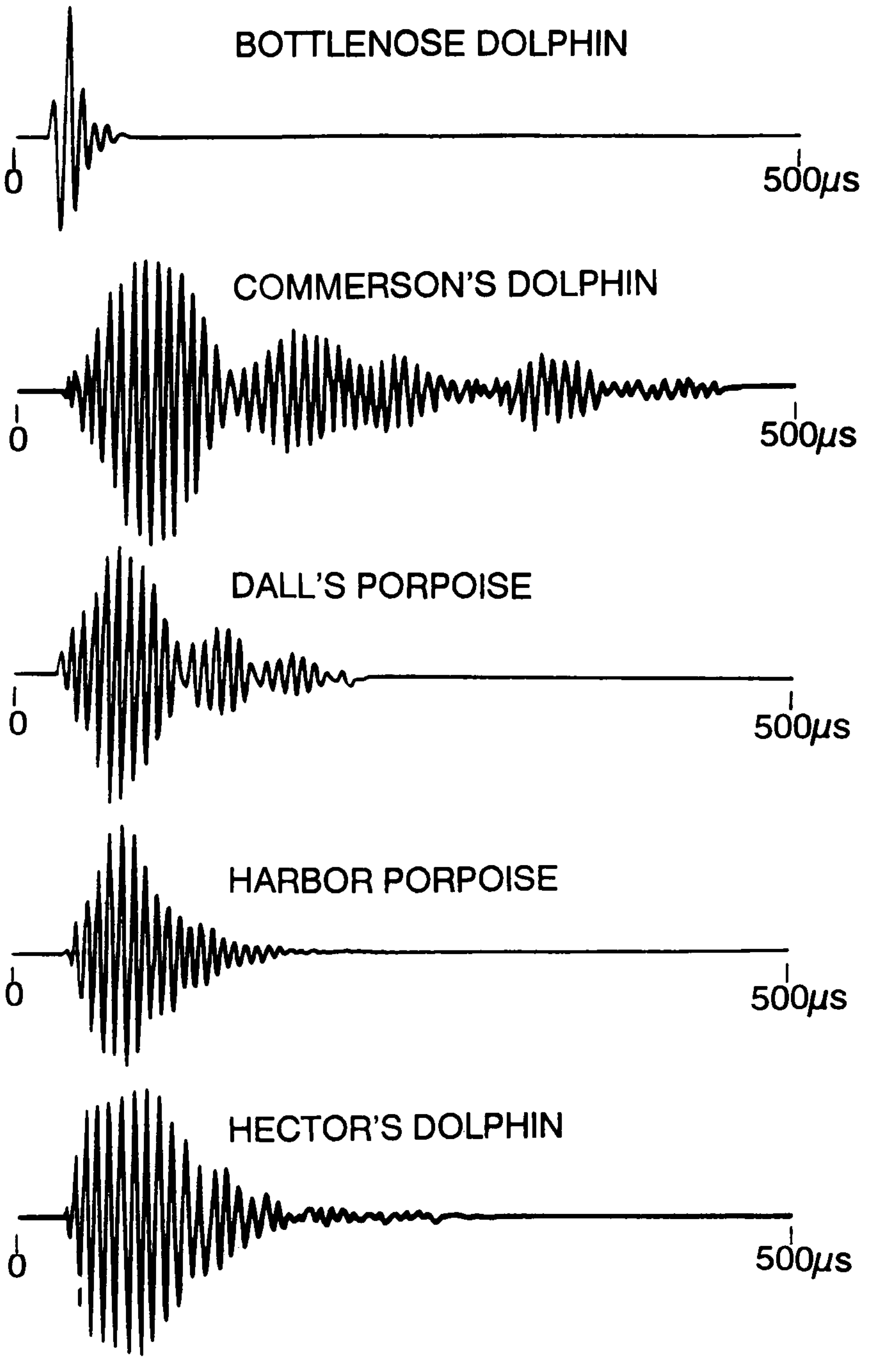

Fig. 2. Examples of sonar signals of (a) bottlenose dolphin (Au, 1980), (b) Commerson's dolphin (Evans *et al.*, 1988), (c) Dall's porpoise (Hatakeyama and Soeda, 1990), (d) harbor porpoise (Kamminga and Wiersma, 1981), (e) Hector's dolphin (Dawson, 1988).

Target strength for harbor porpoise signals

The sonar signals of small cetaceans from the phocoenid family (Kamminga and Wiersma, 1981; Evans *et al.*, 1988; Hatakeyama and Soeda, 1990) and the genus *Cephalorhynchus* (Dawson, 1988; Evans *et al.*, 1988; Dawson and Thorpe, 1990) are considerably different to those used by bottlenose dolphins (Au, 1980), white whales, *Delphinapterus leucas* (Au *et al.*, 1987) and the false killer whale (Thomas and Turl, 1990). The sonar signals of these small cetaceans tend to have narrower bandwidths, longer durations, higher peak frequencies and lower amplitudes. Examples of echolocation signals for the bottlenose dolphin and some of the smaller odontocetes are shown in Fig. 2. Note how much shorter the bottlenose dolphin signal is compared with the other signals. The reflection of a harbor porpoise sonar signal from the gillnet can be estimated mathematically by calculating the transfer function of the gillnet and convolving it with the signal of interest. Au and Jones (1991) performed this calculation for a Dall's porpoise signal. The monofilament gillnet echo for the *Phocoena* signal shown in Fig. 2 is presented in Fig. 3 for a 0° incident angle. There is little difference in the target strength based on energy between the results shown in Figs 1 and 3. The structure of both echoes is equally complex with many highlights. The frequency spectrum of the echo obtained with the *Phocoena* signal is narrower because of the narrower bandwidth of the *Phocoena* signal.

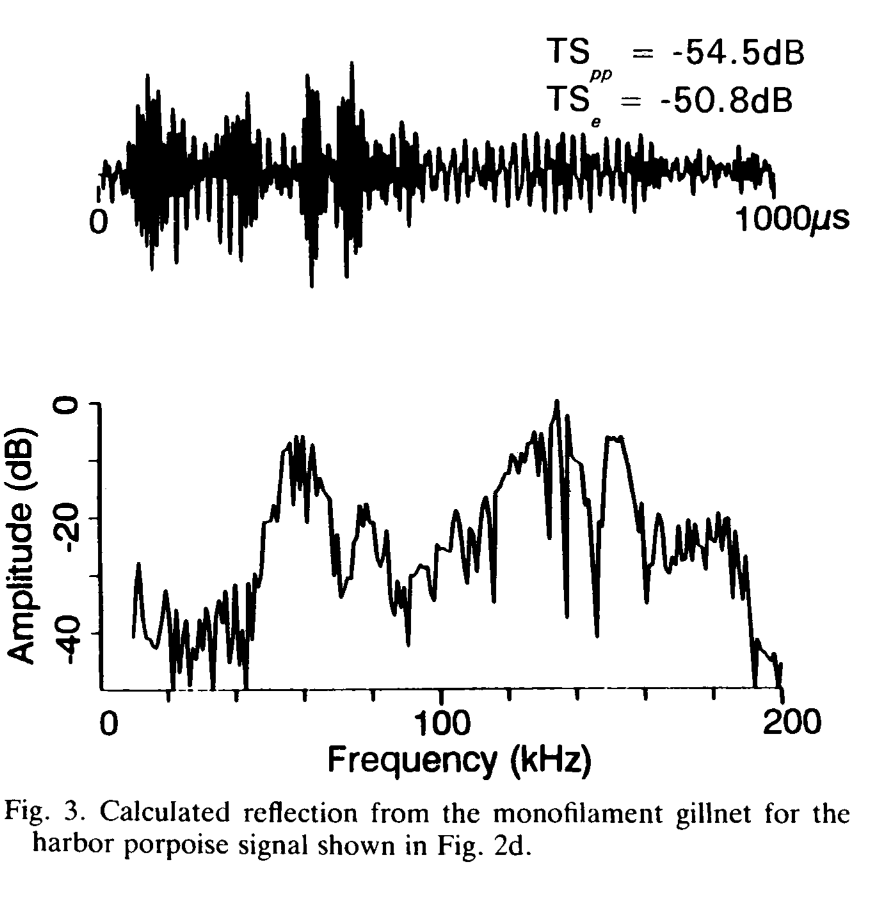

Fig. 3. Calculated reflection from the monofilament gillnet for the harbor porpoise signal shown in Fig. 2d.

PREDICTION OF BIOSONAR DETECTION RANGES OF GILLNETS

The simplest and most accurate way of predicting the ranges at which echolocating dolphins can detect gillnets is to use target detection data obtained under controlled conditions and extrapolating the data for different conditions. Unfortunately, there are few data on biosonar detection in noise except for *Tursiops truncatus* (Au, 1990). The target sensitivity of *Tursiops* has been measured by three equivalent methods: (1) the range of a 7.62cm diameter water-filled sphere was increased until the dolphin could no longer detect it (Au and Snyder, 1980; Murchison, 1980); (2) a 7.62cm sphere was used at different target ranges and the amount of masking noise was increased until the dolphin could not detect the target (Au and Penner, 1981; Turl *et al.*, 1987); and (3) an electronic simulated target was fixed at a range of 20m and its target strength progressively decreased until the dolphin could not detect it (Au *et al.*, 1988). The results of all of these studies are summarized in Fig. 4 with the percent correct response plotted against the received echo energy-to-noise (*E/N*) ratio. The echo energy used in Fig. 4 was calculated with the click signal having the maximum energy for each experimental trial. The solid curve is the best-fit 3rd order polynomial curve and the dashed lines indicate the signal-to-noise ratio needed for the dolphin to achieve a 90% correct response performance (approximately 14dB).

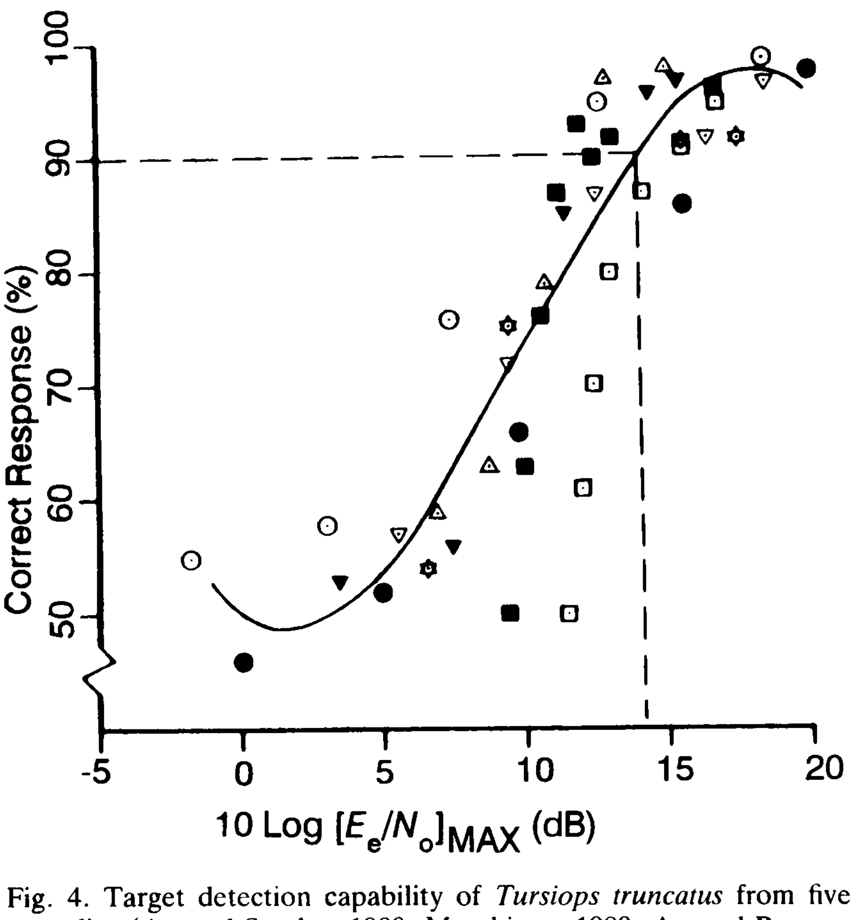

Fig. 4. Target detection capability of *Tursiops truncatus* from five studies (Au and Snyder, 1980; Murchison, 1980; Au and Penner, 1981; Turl *et al.*, 1987; Au *et al.*, 1988). The solid curve is a 3rd order polynomial fit to the data.

The dolphin target detection performance shown in Fig. 4 can be used to estimate the detection range for a gillnet by using the sonar equation. The noise-limited form of the sonar equation modified for dolphin sonar signals can be expressed in dB as (Au, 1988a):

$$DT_E = \underbrace{SE - 2TL + TS_{tt}}_{\text{echo energy}} - \underbrace{(NL - DI_R)}_{\text{noise energy}} \qquad (1)$$

here: DT_E = detection threshold; SE = source energy flux density; TL = one way transmission loss; TS_{tt} = target strength based on energy with *Tursiops*' integration time window; NL = noise level; and DI_R = receiving directivity index.

Although SE is used in the sonar equation, peak-to-peak sound pressure level (SL) is more commonly used in describing the levels of dolphin signals. Au (1988a) derived a simple relationship between SE and SL by expressing the signal as $A \cdot s(t)$ where A is the peak amplitude and $s(t)$ is the waveform function ($|s(t)| \leq 1$), so that

$$SE = SL - 6 + 10 \text{ Log } \left(\int_O^T s^2(t)\, dt\right) \qquad (2)$$

The log integral term for a typical *Tursiops* signal in Kaneohe Bay is approximately –52dB. Therefore, $SE = SL - 58$dB for *Tursiops*.

The one way transmission loss can be expressed simply as the spherical spreading loss plus an absorption term,

$$TL = 20 \log R + \alpha(f_p)R \qquad (3)$$

where: R = target range in metres and $\alpha(f_p)$ = the absorption coefficient evaluated at the peak frequency of the dolphin sonar signal.

For short ranges (<25m), absorption losses will be small and can be ignored.

The received directivity index in the sonar equation was determined by Au and Moore (1984) and their results are shown in Fig. 5 with the received directivity index plotted as a function of frequency. The directivity index was found to vary with frequency according to the equation:

$$DI_R = 16.9 \text{ Log} f(\text{kHz}) - 14.5 \text{ dB} \qquad (4)$$

The sonar equation may be used to calculate the ranges at which an echolocating *Tursiops* should be able to detect a monofilament gillnet 90% of the time. I will assume that the typical deep water noise spectral density shown in Fig. 6 is applicable. For sea state conditions between 0 and 3, the noise at 120kHz is at the thermal limit and is equal to 27dB re 1μPa²/Hz (Albers, 1965). The noise then increases linearly to 33dB for sea state 6. Substituting $SE = SL - 58$ (from Equation 2) into Equation 1, DT_E = 14dB (from Fig. 5), and DI_R = 21dB (from Equation 4), we obtain the following equation:

$$40\text{Log}R = \begin{cases} SL + TS_{tt} - 79 & SS\ 0\text{–}3 \\ SL + TS_{tt} - 84 & SS\ 6 \end{cases} \qquad (5)$$

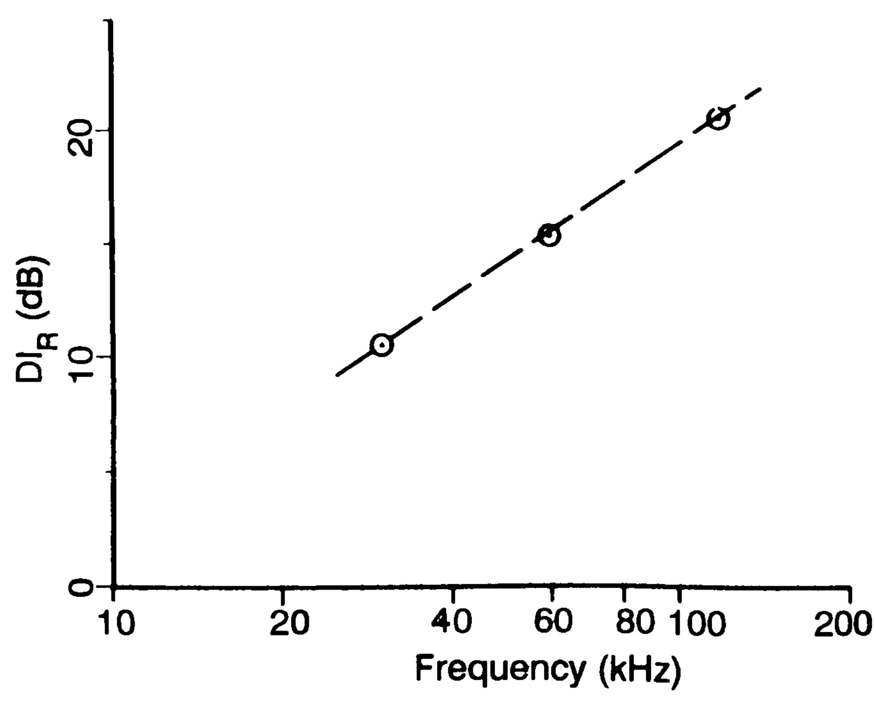

Fig. 5. Receiving directivity index as a function of frequency for *Tursiops truncatus* (Au and Moore, 1984).

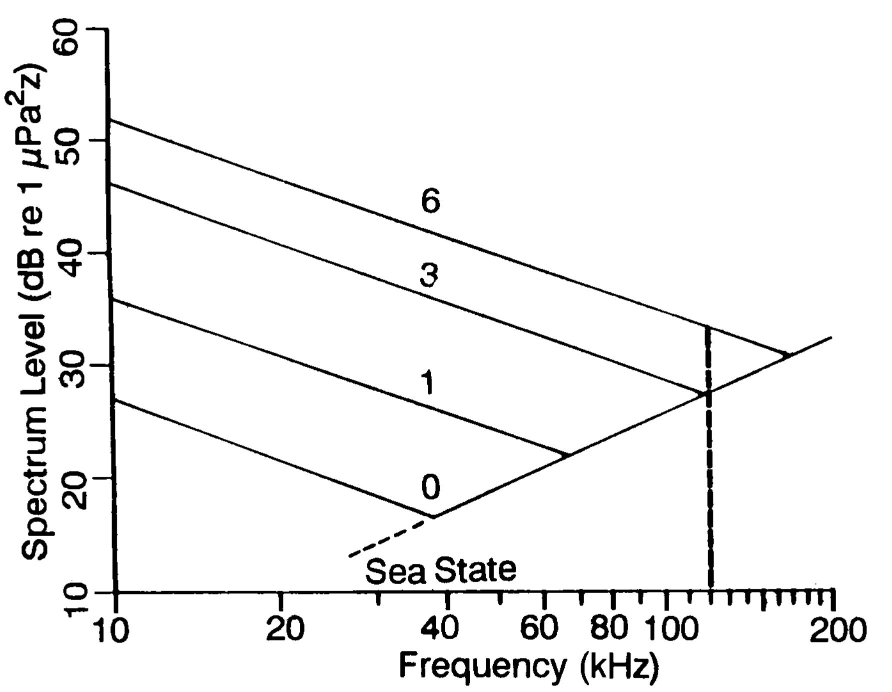

Fig. 6. Deep-water ambient-noise levels for sea states 0 to 6 (Albers, 1965).

The 90% probability of detection range for *Tursiops truncatus* emitting signals with different peak-to-peak source levels are shown in Fig. 7 for sea states between 0 and 3. Equation 5 was used to generate the curves shown in Fig. 7. The calculated results indicate that if *Tursiops* emitted signals with a source level of 140dB re 1μPa, it should be able to detect a monofilament gillnet at a range of at least 1.2m, and for a source level of 190dB the detection range should increase to at least 25m. The detection ranges for the Macah tribal setnet are also shown in Fig. 7. Since the Macah tribal setnet had a higher target strength than the monofilament gillnet, its detection ranges were correspondingly greater. These detection ranges are sufficiently long for a swimming echolocating dolphin emitting signals with source levels of 155–160dB to detect a gillnet in time to avoid the net.

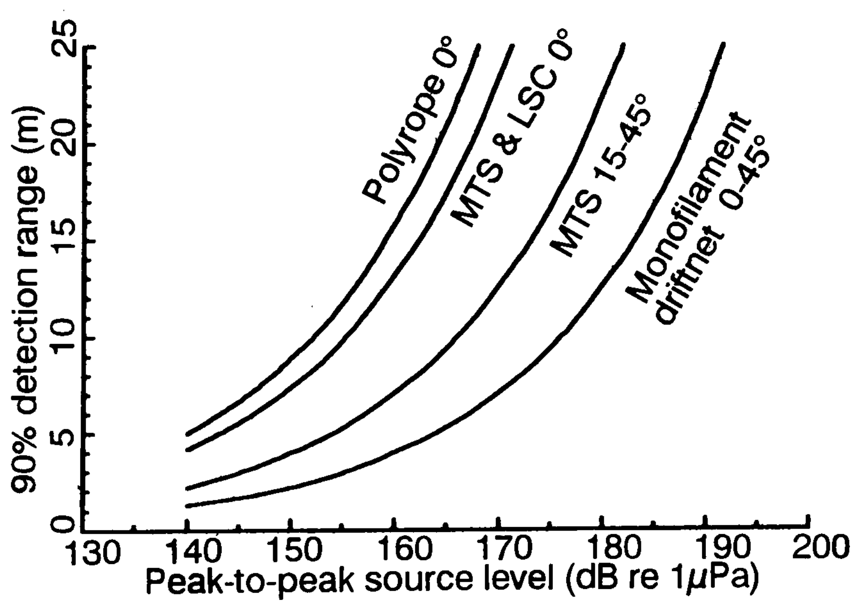

Fig. 7. Predicted biosonar detection of gillnets and associated gear by a *Tursiops truncatus* as a function of the peak-to-peak source levels. The detection range for the light switch chain (LSC) and the Macah tribal setnet (MTS) at 0° incident angle is identical.

The detection ranges for the poly rope and the light switch chain are also shown in Fig. 7. The target strengths used for both objects were obtained at normal incident where the reflection is highest. The amount of reflection will drop off substantially as the angle of incident deviates from the normal incident. However, the use of the normal incident value for poly rope and light switch chain interwoven vertically, horizontally and diagonally, into a gillnet seems appropriate. Both of these items will not be taut but will follow the geometry of the net, and will take on an undescriptive, irregular and slack geometry. An echolocating dolphin will most likely scan a net from various aspects as it swims and will probably experience many occasions in which the rope or chain within the sonar beam will be nearly perpendicular to the beam resulting in relatively high-amplitude echoes. Therefore, the detection range of a gillnet can be increased substantially by attaching poly rope or light switch chains to the net.

Tursiops typically emit signals with source levels in the vicinity of 220dB in detection experiments performed in Kaneohe Bay (Au, 1980) and so the low source levels used in Fig. 7 are extremely conservative for *Tursiops* but may be more in line with phocoenids. Hatakeyama and Soeda (1990) recorded source levels of 165–170dB re 1μPa for Dall's porpoises in the open ocean, and 152–157dB in a tank. They also reported source levels close to 160dB for three *Phocoena phocoena* in a tank. With a source level of 160dB, a dolphin should be able to detect a monofilament gillnet at a range of 4m and a Micah tribal cord setnet at 7 to 13m. For a given peak-to-peak source level, some of the smaller cetaceans (signals shown in Fig. 2) may be able to detect a gillnet at roughly 20 to 30% longer ranges than *Tursiops* because they typically emit longer signals containing on the order of 5dB more energy.

DISCUSSION AND CONCLUSIONS

The target strength measurements and sonar detection range calculations indicate that echolocating *Tursiops* and other odontocetes should be able to detect gillnets at long enough ranges to avoid entanglement. This conclusion is supported by observations and experiments performed by Hatakeyama and his colleagues in Japan (see review by Hatakeyama *et al.*, 1994). Hatakeyama *et al.* (1986) found that a white whale had a 50% detection range of 5.5m with a salmon gillnet used as the target. The animal used relatively low amplitude clicks of approximately 182–189dB re 1μPa in this tank experiment, which is considerably lower than 210–225dB for a white whale measured in Kaneohe Bay (Au *et al.*, 1987). Hatakeyama and Ishii (1987) constructed a net enclosure in a cove that was partitioned with a salmon gillnet to house three bottlenose dolphins. Night observation of one of the dolphins with a flashing marker light attached to it indicated that it did not approach closer than 3–5m from the gillnet. Hatakeyama and Soeda (1990) observed Dall's porpoises around a salmon research vessel in the Bering Sea as gillnets were being retrieved. They saw two Dall's porpoises out of three in a group dive and pass under the gillnet and reappear on the other side. However, the third one became entangled in the net. They also twice observed a Dall's porpoise passing through a 1.5m wide, 1.0m high hole of a damaged gillnet without changing its swimming speed of 3–4ms^{-1}. On another occasion they found a school of Dall's porpoises along the coastal area of east Hokkaido and set a gillnet (1,300m long, 6m deep). The porpoises were chased toward the gillnet with four boats. Upon approaching the net the porpoises changed direction and swam along the net or dived and passed under the net. In one case, two porpoises out of a group of three dived suddenly when they were about 4 to 5m from the net and surfaced about 10m on the other side. The third animal swam into the net and broke through it. Hatakeyama and

Soeda (1990) concluded that Dall's porpoises can detect gillnets by echolocation and can also distinguish holes within nets. Hatakeyama and Soeda (1990) also observed the behavior of harbor porpoises in a tank that was partitioned with a salmon gillnet. Nightscope observation of the harbor porpoises suggested that they could detect the presence of the net and initially avoided it. However, when they became accustomed to the net, they became careless and some became entangled. Although many of the observations are anecdotal and each observation means little by itself, taken together they tend to support the notion that gillnets are detectable by echolocating dolphins.

Since this analysis and field observations indicate that echolocating dolphins should be able to detect gillnets at sufficient ranges to avoid them, why then do they still become entangled? This question is a puzzling one and has been addressed by other investigators (Awbrey *et al.*, 1979; Dawson, 1994; Goodson *et al.*, 1994). I would like to suggest a number of possibilities.

(1) Pelagic dolphins may not echolocate while transiting a body of water. In the open ocean, there seems to be little need for dolphins to echolocate except to detect prey and possibly to avoid predators. However, little is known about how odontocetes utilize their sonar in the wild.

(2) The problem may be in the difference between detecting and perceiving an obstacle. Although the nets are detectable, the echoes will be relatively weak, and a dolphin may not perceive the net as an obstacle but as a penetrable entity. Dolphins probably encounter sources of volume reverberation that are penetrable, such as the deep scattering layer, and may not perceive gillnets as harmful obstacles. In the open ocean, the concept of a barrier is probably foreign to a dolphin. Attaching more acoustically reflective items such as poly rope or light switch chains on a net may help to make a net seem more impenetrable. However, Hembree and Harwood (1987) have experimented with the use of metallic bead chain on gillnets and found them ineffective in reducing the incidental take of *Tursiops truncatus* and *Stenella longirostris* in Australian waters. The results in Fig. 7 (the light switch chain was similar but not identical to those used by Hembree and Harwood, 1987) indicated that *Tursiops* should be able to detect the metallic bead chains at tens of metres.

(3) In some circumstances dolphins may be feeding on prey that inhabit the same general location where fishermen typically set driftnets (Ellis, 1989) and may be too distracted by prey to notice the presence of gillnets or may not be able to distinguish between the sonar reflections from prey and gillnets (Awbrey *et al.*, 1979; Evans *et al.*, 1988). Cockcroft (1990) indicated that *Tursiops* that are caught in shark gillnets used to protect swimmers in South Africa, seem to be aware of the presence of these nets, judging from their normal swimming patterns around them. Nevertheless, when they forage for food, they seem to become oblivious to the nets and are sometimes caught. An analysis of stomach contents indicated that most of the captured dolphins had almost full stomachs, implying that capture occurred either during or subsequent to feeding.

(4) The presence of entangled fish and aggregations of free swimming fish in the immediate vicinity of a gillnet may prevent dolphins from acoustically sensing the presence of the net. The sonar returns from free swimming and entangled fish may mask the presence of gillnets, since the echoes from the nets will be much smaller than echoes from the fishes. For example, from the expression of fish target strength given by Love (1971), a 40cm long salmon will have a target strength (frequency of 120kHz) between –26 and –33dB, considerably greater than the target strength of a gillnet.

(5) The disturbances caused by entangled, struggling fish may actually attract dolphins to a net. As dolphins approach a net to investigate the cause of the commotion, the entangled fish may also distract them from sensing the presence of the gillnet.

In searching for viable solutions to the incidental gillnet capture problem, we should perhaps concentrate in areas other than the animal's sonar detection capabilities. Although only thoughtful speculations on why dolphins seem not to detect gillnets are presented here, some of these speculations should be seriously considered in future research. There is a need to obtain better understanding of the dynamics involved with the incidental catch problem. Why do dolphins swim close to gillnets? How do they typically get entangled? What percentage of dolphins swimming toward a gillnet actually become entangled? What is the role of fish and other marine life already entangled or entrapped by gillnets in attracting porpoises to the nets? Part of the entanglement problem may involve the presence of large quantities of entangled marine life which may attract dolphins to gillnets. Therefore, it may be difficult to discourage dolphins and porpoises from approaching these nets.

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SC/O90/G13

The Potential for Reducing Entanglement of Dolphins and Porpoises with Acoustic Modifications to Gillnets

Stephen M. Dawson

Department of Marine Science, University of Otago, P.O. Box 56, Dunedin, New Zealand

ABSTRACT

To reduce incidental catch of cetaceans in gillnets, two forms of acoustic modifications are reviewed here; one to make gillnets more reflective to cetacean sonar, and another using active sound emitters in nets to alert cetaceans to the presence of nets. A review of the literature shows that neither strategy has proven indisputably effective. Air-tube nets and multifilament nets used in the North Pacific Japanese driftnet fishery for salmon have caught fewer Dall's porpoises than equivalent standard gillnets. However, results were not consistently significant over several years, and have not been confirmed by a thorough study of modified gillnets in another driftnet fishery. Studies examining effects of adding sound emitters to gillnets have also proven inconclusive. Further, there appear to be serious problems with the logical basis for acoustic net modification strategies. I argue that such strategies are not likely to achieve the reductions in cetacean bycatch that are required to conserve several dolphin and porpoise species and propose alternative methods which are likely to be more effective.

KEYWORDS: INCIDENTAL CAPTURE; NORTH PACIFIC; FISHERIES; DALL'S PORPOISE; HARBOUR PORPOISE; BOTTLENOSE DOLPHINS; HECTOR'S DOLPHIN; ACOUSTICS; BEHAVIOUR

INTRODUCTION

'In marked contrast to the improving prospects for the great whales, the status of many smaller cetaceans has continued to deteriorate over the last two decades' (Brownell *et al.*, 1989, p.5; and see Perrin, 1988). In part this is due to their incidental capture in gillnet fisheries (for a recent compilation of estimated catches, see IWC, 1994). Incidental catch of cetaceans in gillnets appears to be a generic problem inherent in all forms of gillnetting. Oceanic driftnet fisheries kill many thousands of cetaceans annually (e.g. Jones, 1984; Harwood *et al.*, 1984; Harwood and Hembree, 1987). Large incidental catches also occur in coastal gillnet fisheries for groundfish (e.g. Pilleri, 1971; Harrison *et al.*, 1981; Gaskin, 1984; Peltier *et al.*, 1993; Read and Gaskin, 1988; Dawson, 1991a; Brownell *et al.*, 1989). Such coastal fisheries may have a greater impact than oceanic fisheries because they kill coastal cetaceans which often have more restricted distributions than their oceanic relatives (Dawson, 1991b). The Gulf of California harbour porpoise, *Phocoena sinus*, ostensibly the rarest marine cetacean, appears threatened with imminent extinction by entanglement in gillnets (Barlow, 1986; Silber, 1988; Brownell *et al.*, 1989; Vidal, 1995).

There have been many proposals to reduce incidental catch of cetaceans by modifying gillnets. Several of these are based on the concept of modifying gillnets acoustically, so that dolphins and porpoises can detect them and hence avoid entanglement. In this paper I will briefly review the results of experiments testing these modifications, discuss some of the difficulties with the concepts and make some specific recommendations for the management of cetacean bycatch problems. Statistical tests used here are tests of proportion (Neter *et al.*, 1988) or G tests with Williams' correction (Sokal and Rohlf, 1981).

CONSTRAINTS ON POTENTIAL MODIFICATIONS

Modifications must be practical to be adopted in commercial gillnet fisheries. The conditions described below must be met.

(1) *The modifications must have reasonable longevity under commercial fishing conditions.* For acoustic reasons, air-containing structures (as long as they are of reasonable size; Pence, 1986) are ideal to increase the reflectivity of nets to sonar. As they have a very different density to the surrounding water, they reflect sonar pulses better than any solid object of similar size. However, because they lack internal support, air-containing structures are usually less robust than solid ones and hence are more easily damaged. Also, unless rigid they are likely to crush at depth, becoming less effective as reflectors. Air-filled plastic tubing (8mm) in gillnets did not function as intended because it filled with water after compression by the net hauler (Hembree and Harwood, 1987). Similarly, panels of plasticised aluminium foil incorporated into the net matrix were found unsuitable as sound reflectors because seawater dissolved the aluminium layer when the plastic layer was damaged (Peddemors *et al.*, 1991).

(2) *The modified gillnets must be safe to handle.* Peddemors *et al.* (1991) found that netting braid incorporating a double strand of 0.16mm diameter stainless steel braid became too brittle to handle safely. This is likely to occur in any method involving the addition into nets of wire filaments which are large enough to be detectable by cetaceans (Busnel and Dziedzic, 1966).

(3) *To avoid compromising the economic efficiency of gillnetting, the net modifications must be reasonably lightweight and inexpensive.*

(4) *Net modifications must not decrease catch rates of target species below an economic level.* For example, Hembree and Harwood (1987) found that nets set 4.5m below the surface caught significantly fewer cetaceans than standard nets, but that the modified nets also caught about 25% fewer fish. The gillnetting industry is unlikely to accept these costs willingly.

EXPERIMENTS TESTING ACOUSTIC MODIFICATIONS TO GILLNETS

Modifying gillnets by increasing their target strength

Most gillnets are made from nylon monofilament. This material is almost the same density as seawater and gives a poor sonar echo (i.e. has low target strength; Pence, 1986). Prompted by this observation, many authors have assumed or suggested that entanglement occurs because the animals' sonar *cannot* detect the net (Ohsumi, 1975; Awbrey *et al.*, 1979; Hatakeyama, 1986a; Hembree and Harwood, 1987).

On the assumption that increasing the target strength of gillnets will decrease incidental catches, Japanese workers have experimented with two types of passive modifications to gillnets. In the first (AT-1), three air-tube threads were intertwined into the central band in an otherwise standard gillnet (Snow *et al.*, 1988). These hollow threads were 0.5mm in diameter with a 0.25mm internal air space. Between 1981–6, mean incidental catch rates in these air-tube nets were about 21% lower (range = 6 to 48%; Ogiwara, 1986) than catches in standard nets. This reduction seems surprising, considering that the air-tube nets have a target strength only 3–4dB higher than standard monofilament (Hatakeyama, 1986a). The AT-1 nets showed significantly lower catch rates in four of the six seasons tested. This inconsistency is possibly explicable by the marginal nature of the increase in target strength. Neither increasing the number of air-tubes to five (AT-2) nor concentrating the air-tubes in the top third of the upper portion of the net (AT-3) resulted in lower catch rates than in AT-1 nets (Ogiwara, 1986).

A second type of modification has been tested since 1986. In these nets (MT-1), three multifilament threads were intertwined into a central band of an otherwise standard gillnet. Although Snow *et al.* (1988) do not give the plane in which target strength was measured, they state that multifilament thread had a target strength about 10dB higher than standard monofilament. In both the 1986 and 1987 trials, multifilament nets had marginally lower catch rates than air-tube nets, but the difference was not significant in either season ($z[1986] = 0.6$; $p = 0.27$: $z[1987] = 1.06$; $p = 0.14$: test of proportions; data from Ogiwara, 1986; Snow *et al.*, 1988). Data from adjacent sets provide a stronger test, but were available only from the two month study of 1987. A paired-sample t test comparing 88 pairs of adjacent air-tube and multifilament nets showed that multifilament nets caught significantly fewer (28%) porpoises ($p < 0.01$; Snow *et al.*, 1988). Catch rates of the two net types were significantly different in June ($z = 3.7$; $p < 0.001$), but not in July ($z = 0.96$; $p = 0.17$).

If multifilament threads are easier for porpoises to detect than air-tube threads, one would predict fewer entanglements in the modified portions of multifilament nets than in corresponding portions of air-tube nets. Only the 1987 data were available to test this idea. The vertical distribution of entanglements was significantly different between the two net types ($G = 16.3$; $p < 0.001$; 2*3 G test); paradoxically, the multifilament nets caught more porpoises in their central portions than did the air-tube nets (Hatakeyama, 1988; Snow *et al.*, 1988).

In summary, the Japanese AT-1 air-tube nets appeared to reduce entanglement by about 21% over standard nets. However, the reduction was variable among years and not consistently significant. Multifilament nets also produced inconsistent results, but appeared to have lower catch rates than air-tube nets. However, more porpoises were caught in the modified portions of MT-1 nets than in corresponding sections of air-tube net, suggesting that the benefit of multifilament is yet to be established clearly.

After finding that captive, blindfolded, bottlenose dolphins (*Tursiops truncatus*) reacted strongly to 4mm chrome-plated nickel bead chain, Hembree and Harwood (1987) used this material to modify nets used in the Taiwanese drift gillnet fishery in northern Australian waters. In their 1984 trials, alternating half and full-length pieces of bead chain were woven vertically into the net every 8m. During the next season bead chain was woven into the mesh as nine 3m diagonals per 15 x 15m net panel. In neither season did the net modifications significantly reduce the number of dolphins caught. The 1985 trials produced the unexpected result that the modified nets caught more dolphins than the control nets (Hembree and Harwood, 1987).

The Japanese results, and those of Hembree and Harwood (1987) are somewhat in conflict. Bead chain has a much higher target strength than air-tube thread or multifilament thread (Au and Jones, 1991), and yet the bead chain did not reduce entanglement while the air-tube threads did (at least in four of six seasons). There are three reasonable interpretations of this result. (1) Increasing the target strength of gillnets is less effective in reducing entanglement than the Japanese studies suggest. (2) Target strength increases quoted above may represent the best case, measured with a sound source perpendicular to the modification material. An echolocating animal approaching from other angles is likely to perceive a lesser target strength. Hence, the modifications above, from an acoustic point of view, have not been ideal (Goodson *et al.*, 1994) and this may have contributed to the inconsistency of effectiveness. (3) There is something radically different between the sonar capabilities of bottlenose and spinner dolphins, *Stenella longirostris* (the major catch off Northern Australia) and Dall's porpoise, *Phocoenoides dalli*.

There are some valuable lessons to be learned from the approach of Hembree and Harwood (1987). Their 1985 trials are the only passive net modification trials which have used a balanced design with equal numbers of control and experimental net panels. This balance was achieved by using nets with alternating 1km long modified and unmodified sections. Balanced design helps strengthen the power of statistical comparison. Also, Hembree and Harwood's (1987) study was conducted on a scale which was large enough to be useful. Several smaller-scale studies have involved too few entanglements to allow statistical comparison of modified and unmodified nets (Hasegawa *et al.*, 1987; Peddemors *et al.*, 1991). This is unavoidable where the entanglement problem is localised and the total number of animals involved small (Peddemors *et al.*, 1991). However, in the North Pacific driftnet fishery for salmon the total number of porpoises caught is large and despite the extra expense, studies of adequate design and scale could have been conducted. For example, the goal of Hasegawa *et al.* (1987) was to assess the catch rate of four types of modified net against a control, unmodified net. However, they studied only 13 setting operations in which the amount set of each net type was unbalanced (195–260 tans for experimental nets; 845 tans for standard net (1 tan = 50m)). It is not surprising that the total number of porpoises caught was small (5) and that there was no significant difference between between catches in modified nets (3) and those in unmodified nets (2). Studies like this can do little to clarify the value of gillnet modifications.

Unfortunately, this is not an isolated case in tests of the effectiveness of net modifications (Silber *et al.*, 1994) or sound emitters (Hatakeyama, 1986b; Hatakeyama, 1987) in reducing incidental catch.

The influence of active sound emitters in gillnets

Sound emitters appear to be of marginal benefit, if any. When sound emitters were added to AT-1 nets, there was no significant decrease in catch rates in any of the years tested (Ogiwara, 1986; Hatakeyama, 1988; Snow *et al.*, 1988).

If sound emitters reduce incidental catch, one would expect fewer entanglements in regions of the net near emitters than in regions further away. As indicated above, attempts to make such comparisons have been frustrated by small sample sizes and unbalanced designs. Data are available for only 13 entanglements from 1985 (Hatakeyama, 1986b) 8 from 1986 (Hatakeyama, 1987) and 12 from 1987 (Hatakeyama, 1988; Snow *et al.*, 1988). The 1985 and 1986 data suggested that the emitters may have an effect, but in 1987 the entanglement rate in sections of the net near emitters (<55 tan) was not significantly different from that in sections further away.

Even if sound emitters reduced catches of dolphins and porpoises it is extremely unlikely that it would be practical in the foreseeable future to place them in all gillnets. Devices currently available are large, heavy (Hatakeyama, 1986a), relatively expensive (Ogiwara, 1986) and require regular recharging (Hatakeyama, 1988). As Peddemors *et al.* (1991) point out, metal devices, whether electronic or not, are vulnerable to corrosion. Further, as high-frequency sounds attenuate quickly in water, there would need to be many emitters spaced along the net (Awbrey *et al.*, 1979). Their comment that 'The cost and complications of active devices would preclude their proper use and maintenance.' (1979, p. 36) is still accurate today. This applies not only to set-up and operating costs, but also to costs of enforcement, as an observer scheme would be necessary to ensure that fishers use the devices as intended (Gaskin, 1984).

LOGICAL PROBLEMS WITH ACOUSTIC MODIFICATIONS TO GILLNETS

Increasing the target strength of gillnets

I. The assumption that nets are difficult to detect

The strategy of increasing target strength to reduce entanglement is largely based on the assumption that the sonar systems of dolphins and porpoises are incapable of detecting unmodified nets, or at least have difficulty in doing so (Ohsumi, 1975; Awbrey *et al.*, 1979; Gaskin, 1984; Hatakeyama, 1986a; Hembree and Harwood, 1987). At face value this assumption seems fair, but data on the sonar capability of dolphins and porpoises and observations of their behaviour near nets suggest that entanglement does *not* result from an inability of the sonar system to detect nets (Au and Jones, 1991; Dawson, 1991b; Au, 1994). Similar phenomena are observed in insectivorous bats, which despite their remarkable sonar ability are routinely caught in mist nets for study and marking by researchers.

Dubrovskiy reported that the harbour porpoise, *Phocoena phocoena*, can detect nylon filaments of 0.1mm diameter (Dubrovskiy, pers. comm. in Evans *et al.*, 1988). Even so, harbour porpoises are routinely entangled in gillnets made of nylon several times that diameter (0.8mm; Gaskin, pers. comm.). Au (1994) has shown that bottlenose dolphins should be able to detect gillnet webbing made of 0.49mm diameter monofilament at long enough ranges to avoid entanglement. However, that species is occasionally entangled in shark nets of coarse 3mm multifilament braid (Peddemors *et al.*, 1991), which would be much easier to detect. A net's detectability is enhanced by the knots between the meshes (Pence, 1986). Furthermore, the floats along the top of a groundfish gillnet should be easily detected by even a crude sonar system (Awbrey *et al.*, 1979; Pence, 1986; Ogiwara, 1986). If cetaceans can detect the nets which entangle them, entanglements are most likely to result from one or more of three factors: (a) the animal is not making sonar pulses at the time of entanglement and hence is not aware of the net's presence; (b) the animal is aware of the net but fails to perceive it as something to avoid; or (c) the animal is aware of the net and the danger it poses, but simply makes a (fatal) mistake.

II. How much of the time do cetaceans use their sonar?

Increasing the target strength of a gillnet is irrelevant if the animals are not making sonar pulses when they encounter nets. If cetaceans only echolocate when they need to, i.e. when feeding or trying to localise objects, they are likely to be silent most of the time. Species which remain in relatively small areas for extended periods (such as Hector's dolphin, *Cephalorhynchus hectori*; Slooten and Dawson, 1988) would seem to have no need to constantly interrogate their environment with sonar as they would be thoroughly familiar with it. Neither would oceanic species cruising in open areas where they do not expect an obstacle. No study has yet quantified what proportion of time free-ranging dolphins and porpoises spend echolocating. This would be a difficult task because of the narrow emission field of these animals (Au *et al.*, 1978; 1986; 1987) and the inherent directionality of high-frequency sounds[1]. During my recordings of free-ranging Hector's dolphins (Dawson, 1988; Dawson and Thorpe, 1990; Thorpe and Dawson, 1991) sounds were not recorded every time a nearby dolphin was oriented at the hydrophone, suggesting that they were not always vocalising.

III. Perceptual problems

When using sonar, cetaceans probably have a 'search image' of what they expect to encounter. It is possible that sonar reflections from airfilled net modifications might mimic a fish's swimbladder, and attract cetaceans to nets. In other cases, foraging dolphins may disregard echoes from a net as being from non-prey, and hence become entangled (Awbrey *et al.*, 1979; Evans *et al.*, 1988). Observations of insectivorous bats confirm that echolocating animals are not always able to detect obstacles when chasing prey. Evans *et al.* (1988) described these bats as having a detection system which is open for prey detection but closed for obstacle avoidance.

[1] Quantification of the time dolphins spend silent could be possible using small event recorders which store the time of occurrence of each of a free-ranging dolphin's high frequency sonar pulses. In a study such as the long-term study of bottlenose dolphins in Sarasota Bay (e.g. Wells *et al.*, 1987) in which dolphins are routinely caught, examined and released, an event recorder could be attached to a dolphin's melon with a suction cup and recovered when it detaches for downloading of its data.

The rate at which clicks are repeated is probably a significant factor in gillnet detection by dolphins. Dolphins normally space their clicks apart so that the previous pulse's echo returns before the next pulse is emitted (Au *et al.*, 1982; for review see Turl and Penner, 1989). When searching for a target they 'range-gate' using a click repetition rate suited to detecting a target within an expected range (Au *et al.*, 1974; Turl *et al.*, 1987; Goodson *et al.*, 1994). Once a target is detected, echolocating animals typically increase their click rate as they approach the target (Watkins, 1980: i.e. range and click rate are matched). In both the searching and target-locked phases, objects outside the (expected) range of the target are unlikely to be easily perceived. This suggests that dolphins, like bats, may not perceive obstacles (gillnets) while chasing prey.

Echolocating dolphins and porpoises may not interpret echoes from gillnets (modified or not) as representing an impassible obstacle. Cetaceans, especially oceanic species, live in an environment in which barriers are rare. Also, they routinely encounter sources of volume reverberation which are passable (e.g. the deep scattering layer), and may interpret the reflections from gillnets similarly (Au, 1994). Further, even if they perceive gillnets as dangerous obstacles, some entanglements will occur because cetaceans make mistakes. Human car accidents are analogous in that although drivers know the dangers, accidents still happen at a high rate.

Active sound emitters

To be effective in reducing entanglement rates, sound emitters could work if (a), (b), or (c) (below) were true.

(a) *The sound is sufficiently aversive to scare cetaceans away from nets.* It seems likely that any low frequency sound sufficiently aversive to scare cetaceans away from nets would also decrease fish catches. That 'tuna bombs' are used to herd dolphins shows that high-level explosive sounds are aversive to dolphins. However, such sounds are rich in low frequencies which are readily perceived by fish. Sounds of sufficiently high frequency to be inaudible to fish are unlikely to be perceived by dolphins as inherently aversive.

(b) *The sound is effective at both attracting the attention of nearby cetaceans and encouraging them to use their sonar to carefully examine their environment.* Implicit in this idea is the assumption that cetaceans might investigate the source of sound and discover the gillnet in the process. It would seem paradoxical to attempt to reduce entanglement by encouraging cetaceans to investigate the source of the danger.

(c) *The sound is effective as a warning which cetaceans associate with the danger of gillnets.* However, 'warnings' involve learned behaviours which, in the absence of sophisticated communication between individuals, will only be apparent to those who experience both the danger and the warning sound, and survive to associate the two. According to Awbrey *et al.* (1979, p.2) the 'low incidence of net damage unrelated to porpoise deaths would be evidence that encounters are usually fatal'. In addition, if the danger is not clearly perceived and associated with the sounds, cetaceans might be expected to quickly habituate to the emitters' sounds (Gaskin, 1984). Randomising the sounds used (Hatakeyama, 1986b) might prevent habituation, but it may also prevent association of any particular sound with the danger of gillnets.

Habituation to the sounds is a general problem in each of these hypotheses, and even if the emitters are successful in making cetaceans aware of the presence of gillnets, cetaceans may not perceive gillnets as an impassable barrier (see III above).

Additionally, there are cases in which marine mammals appear to feed directly on fish caught in gillnets, or on the scavengers of gillnetted fish. In Canadian waters, harbour porpoises appear to be attracted to gillnets to feed on hagfish, which are scavengers of gillnet-caught fish (Gaskin, pers. comm.). In this situation, attaching sound emitters to nets could have the effect of 'ringing the dinner bell'.

CONCLUSIONS

To maintain current dolphin and porpoise populations, acoustic modifications to gillnets need to be shown to result in unequivocal and large reductions in cetacean bycatch. It must be stressed that even statistically significant reductions in catch rates may be insufficient to stem population declines. Most dolphins and porpoises have relatively low reproductive rates (Gaskin *et al.*, 1984; Perrin and Reilly, 1984; Reilly and Barlow, 1986; Slooten and Lad, 1991) and some stocks or species appear to have suffered population declines as a result of gillnet entanglement (Gaskin, 1984; Read and Gaskin, 1988; Dawson and Slooten, 1993). Potential gillnet modifications have now been tested for over ten years. No study has demonstrated that they achieve unequivocal, large reductions in catch rate of cetaceans. This fact must surely argue against the continuation of gillnetting in areas where entanglement rates remain high.

Obvious differences exist among the sonar signals of different odontocete species (Au, 1994), yet no species common in intensively gillnetted areas appears able to avoid entanglement completely. The generality of the problem across many different gillnet fisheries suggests that the answer does not lie in detailed investigations of the interactions present in each. I suggest that the problems discussed above and elsewhere (Awbrey *et al.*, 1979; Au, 1994; Au and Jones, 1991; Dawson, 1991b) are likely to apply in most, if not all, situations in which odontocetes are incidentally caught in gillnets.

Management action required

As a top priority it is essential that the status and reproductive rates of incidentally caught species be assessed as soon as possible. Such data could be used to determine acceptable catch levels for gillnet fisheries. Decisions about whether to continue the fishery should be based on the need to prevent further declines of cetacean stocks or species rather than on the economic needs of gillnet fisheries.

From these arguments, I believe there are two reasonable courses of action.

(1) Abandon acoustic gillnet modification experiments because of their poor prospects for success and in their place initiate time/area and/or gear restrictions to achieve the necessary reductions in incidental catch.
(2) If, despite the arguments above, it is believed that acoustic gillnet modifications still hold promise (Goodson *et al.*, 1994), conduct one more set of experiments for a limited time, perhaps over three seasons. These experiments should test only the modification which is most promising (by acoustical and practical criteria; Goodson *et al.*, 1994). The experiments should be of balanced design, preferably

using alternate modified and unmodified panels (Hembree and Harwood, 1987). Power analysis, based on the reduction in catch necessary to avoid population decline, should be used to determine an appropriate scale for the experiments (Fairweather, 1991). If the experiments fail to demonstrate an unequivocal reduction in catch rate to, or beyond, the required level, acoustic gillnet modifications should be either abandoned or used only in conjunction with time/area and/or gear restrictions.

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Response of Free-Ranging Harbour Porpoises to Potential Gillnet Modifications

Gregory K. Silber

Institute of Marine Science, University of California, Santa Cruz, CA 95060, USA[1]

Kelly A. Waples

255 Via San Andreas, San Clemente, CA 92672, USA[2]

and

Peter A. Nelson

Institute of Marine Science, University of California, Santa Cruz, CA 95060, USA[3]

ABSTRACT

Thousands of porpoises die annually in monofilament gillnets. Simple net modifications may alleviate the problem. In June through August 1988, we quantified harbour porpoise (*Phocoena phocoena*) reactions to weighted vertical lines suspended from corklines. If effective in deterring porpoises, vertical lines might be threaded into gillnets to reduce entanglement rates. No structure deflected all porpoise groups, but strands consisting of small metallic spheres and surgical tubing turned a greater proportion of porpoises than did polypropylene line verticals. Although the structures may not be useful in reducing cetacean mortality in gillnets, the experiment may have merit in identifying areas for continued research in attempts to reduce cetacean entanglement in gillnets.

KEYWORDS: INCIDENTAL CAPTURE; HARBOUR PORPOISE; BEHAVIOUR; ACOUSTICS; VISION; FISHERIES

INTRODUCTION

Porpoises (family Phocoenidae) are vulnerable to entanglement in monofilament gillnets because their distributions overlap those of commercial fisheries. Thousands of porpoises die annually due to entanglement in set and drift gillnet fisheries. For example, throughout the 1980s, an average of 2,300 Dall's porpoises (*Phocoenoides dalli*) died each year in drift gillnets (Jones *et al.*, 1986), although incidental catches of this species have declined in recent years (Hobbs and Jones, 1993). Harbour porpoise (*Phocoena phocoena*) annual mortality on the California coast was estimated to be between 200–400 individuals from 1983–1986 (Hanan *et al.*, 1987), and Read and Gaskin (1988) concluded that incidental mortality in gillnets may seriously threaten the harbour porpoise population on the Atlantic coast of North America. Gillnet entanglement most affects coastal species and populations that are small or have limited distribution. For example, the vaquita (*Phocoena sinus*), one of the rarest cetaceans, continues to die in gillnets in unknown numbers (Silber, 1988; Vidal, 1995).

There have been few published accounts of experiments aimed at reducing cetacean entanglement through net modifications. Air-filled nylon tubing has been incorporated into gillnets in an attempt to reduce the incidental catch of Dall's porpoises in North Pacific salmon fisheries (Snow *et al.*, 1988), but these efforts were ineffective in reducing incidental entanglement (Jones, 1984). Hembree and Harwood (1987) performed open ocean trials of modified nets and examined changes in dolphin mortality rates and fish catch rates. The two materials used, air-filled tubing and metallic bead chain, both yielded inconclusive results with respect to cetacean entanglement rates. The bead chain, although promising in one trial, yielded no significant difference in dolphin mortality in a second trial.

Our objective was to study porpoise reactions to vertical lines in the water column and to identify economical and readily accessible materials that, when incorporated into gillnets, might deter porpoises. The study was based on the findings of Norris and Dohl (1980) who determined that spinner dolphins (*Stenella longirostris*) did not swim between vertical 30m lengths of 6.35mm diameter polypropylene line suspended from the surface. This apparatus was called a 'hukilau'. When the distance between verticals was increased incrementally from 1 to 6m, spinner dolphins continued to avoid swimming through the hukilau.

We theorised that harbour porpoises, like spinner dolphins, might avoid swimming through hukilaus. If effective in deterring porpoises, vertical lines could be threaded into gillnets without a concomitant reduction in target species catch levels. This paper reports on our initial testing of porpoise responses to hukilaus of various materials and configurations; it quantifies porpoise reaction to hukilaus in Monterey Bay, California in the summer months of 1988.

METHODS

Two corklines 120m in length were constructed with 9.53mm diameter yellow polypropylene line, strung with either 7.0 x 7.5cm styrofoam floats or 5.5 x 9.5cm plastic floats at roughly 10–15cm intervals. Suspended verticals, 10m in length, were attached to the corkline. The lines were held vertical in the water column with 3–4 links of

[1] Present address: *Marine Mammal Commission, 1825 Connecticut Ave NW, Room 512, Washington, D.C. 20009, USA.*

[2] Present address: *Marine Mammal Research Program, Bioenergetics Laboratory, Texas A&M University, 4700 Avenue U, Bldg. 303, Galveston, TX 77551, USA.*

[3] Present address: *Department of Biological Sciences, Northern Arizona University, Flagstaff, AZ 86011, USA.*

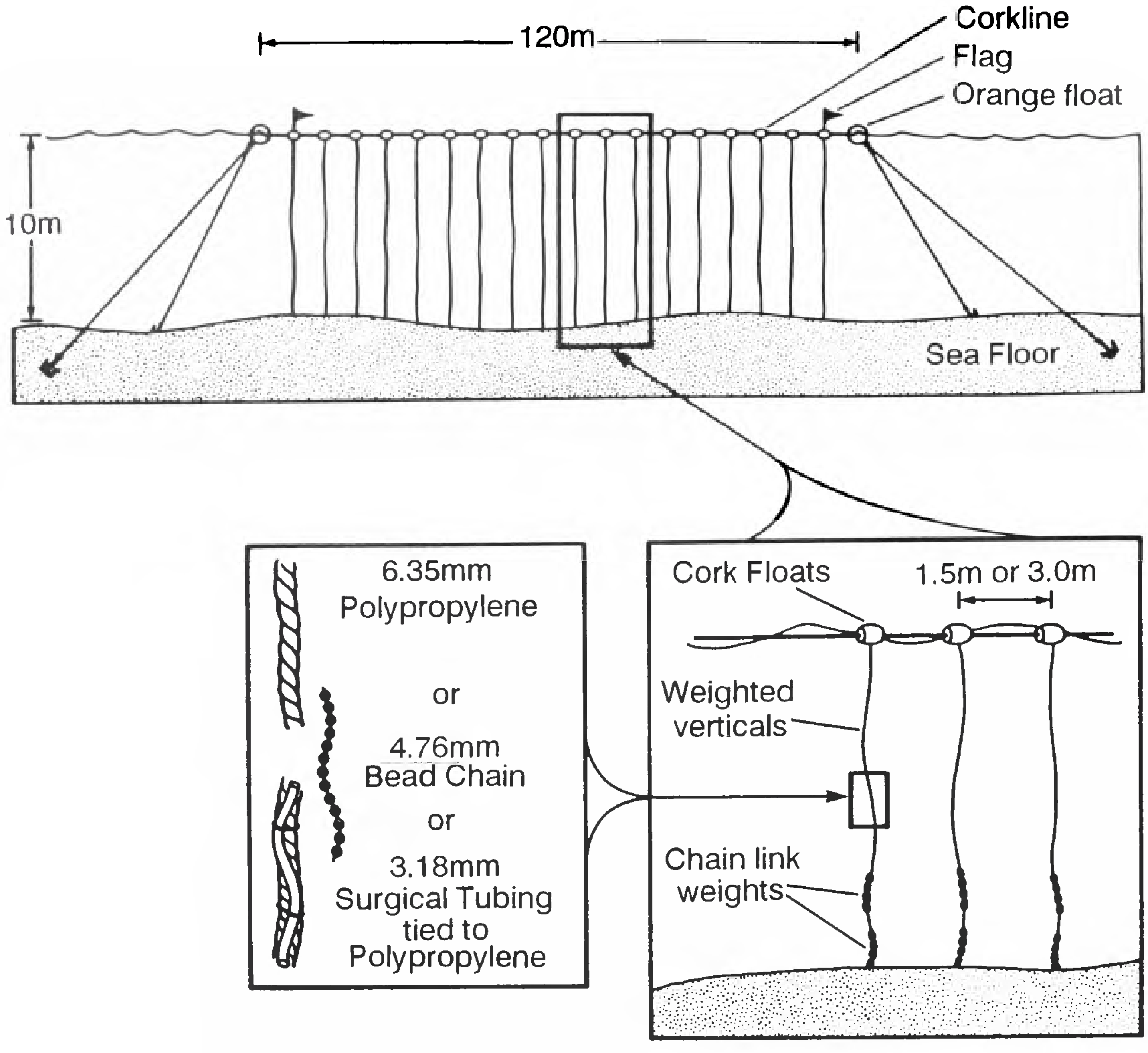

Fig. 1. Schematic representation of experimental apparatus. Weighted vertical lines that consisted of three types of material were suspended from corklines to the sea floor.

6.35mm chain at the bottom and roughly 1.5m from the bottom (Fig. 1).

Five variations on this structure were used: (1) a corkline with nothing attached; (2) a corkline with 6.35mm polypropylene line verticals spaced 1.5m apart; (3) a corkline with 6.35mm polypropylene line verticals 3.0m apart; (4) a corkline with 10m verticals of surgical tubing tied to rope 3.0m apart; and (5) a corkline with 10m verticals of 4.76mm diameter bead chain (strands of metallic spheres) 3.0m apart.

Surgical tubing (interior diameter of 3.18mm and 0.79mm walls) was used in an attempt to utilise air trapped in water, to reflect underwater sound. The tubing was knotted at the ends and at roughly 1–2m intervals to hold air when submerged. However, parts of the tubing collapsed and fused following extended exposure to salt water, sunlight and water pressure, and it probably did not hold air for the duration of the study period. Bead chain was selected based on the gillnet trials by Hembree and Harwood (1987). It was suspended without polypropylene line and without weights because it was sufficiently dense to hang straight in the water column.

Corklines and hukilaus were placed roughly perpendicular to the shoreline at two observation sites in water 8–10m deep. They were held in place by 5–22lb Danforth anchors; two anchors at each end on 12.7mm diameter nylon or polypropylene line (Fig. 1). To render the structures more visible to boat traffic, 45.72cm diameter orange polyvinyl floats were secured at each end of the corkline. A red flag extending 0.75m above the water's surface was also attached to the corkline.

Observations of porpoises were conducted from bluffs overlooking Monterey Bay (Fig. 2). The sites, located at Sunset and Manresa State Beaches were 67.5 and 22.4m above mean sea level respectively. They were operated (simultaneously on 24 days) from 25 June to 26 August 1988. Each configuration remained in the water from 13–37 days and a minimum of 25 hours of observations was conducted per variable (Table 1). Porpoise movements were plotted with two theodolites: a *Leitz* DT20E and *Pentax* TH-10WA.

Wind speed and direction, sea state (Beaufort scale), cloud cover and visibility were estimated at the outset of observations, and when changes occurred in conditions. All observations were conducted when sea state was ≤3, 96.6% were conducted when the sea state was ≤2 and the mode was sea state 1.

Porpoises were usually abundant within the study area which allowed us to concentrate on those in the vicinity of experimental apparatus. From computer-generated plots of theodolite data, we assessed porpoise behavioural response to the experimental gear. In 52 cases, porpoises clearly responded by swimming through (Fig. 3a) or by avoiding (Fig. 3b) hukilaus. However, in some cases (n=30) it was not possible to definitively ascertain porpoise reaction to the structures. In analysis, we used only those cases for which we were certain about the porpoise's reaction to the gear. The 'closest observed approach' to the gear was measured as the closest surfacing to the gear, even though we were unable to quantify the possibility that they may have proceeded closer to the gear by travelling underwater.

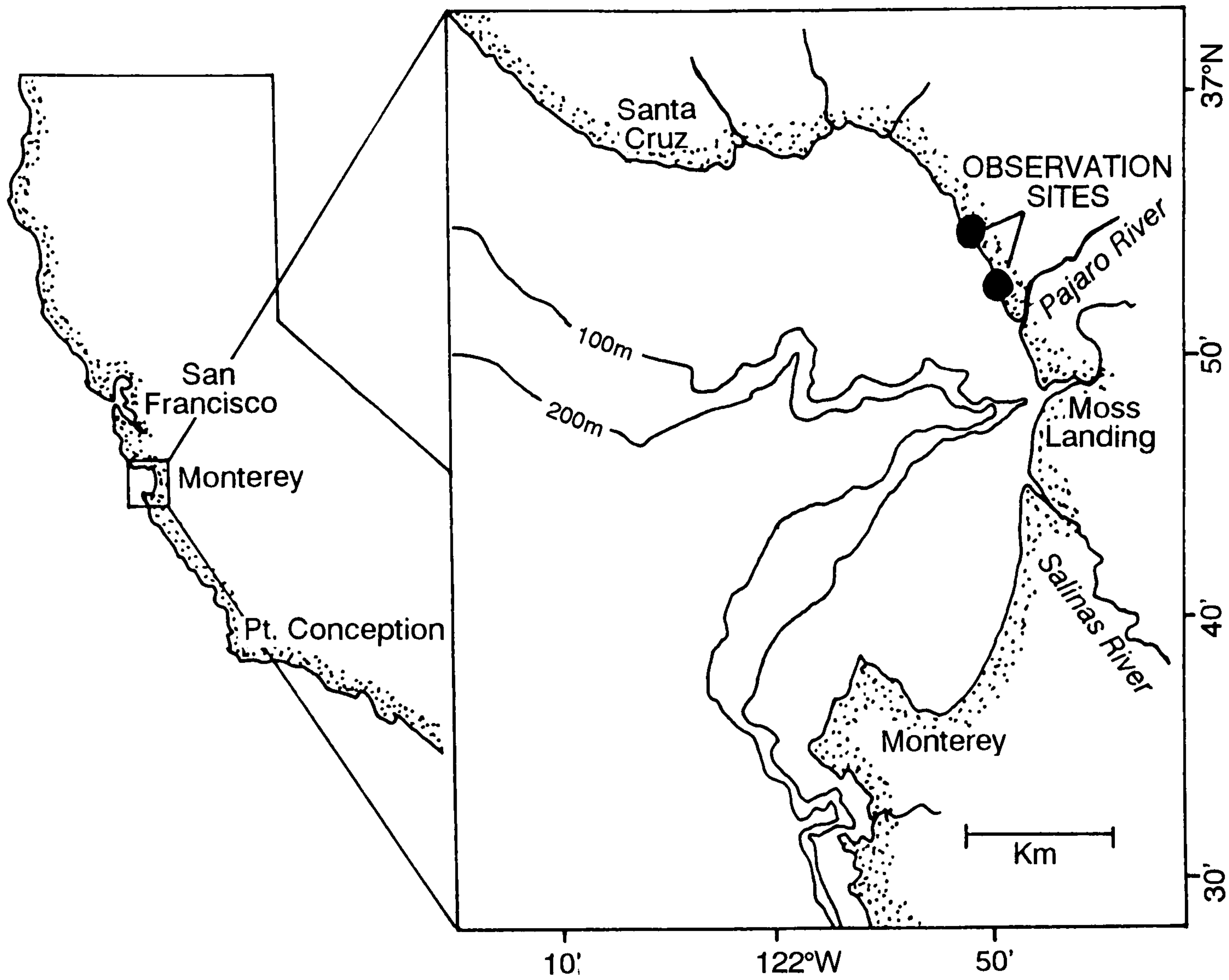

Fig. 2. Study area where harbour porpoise observations were conducted in Monterey Bay, California.

Table 1

Deployment schedule of experimental structures and hours of observation.

Variable	Period	Obs. days	Total obs. hrs.
Cork line	25 Jun - 11 Jul	11	37.5
Polypropylene 3.0m	11 Jul - 23 Jul	9	28.8
Surgical tubing 3.0m	06 Jul - 11 Aug	27	83.7
Polypropylene 1.5m	23 Jul - 11 Aug	10	31.5
Bead chain	11 Aug - 25 Aug	11	25.0
Total:		68	206.5
Mean:		13.6	41.30
SD:		7.54	24.14

A log likelihood ratio test (and Yates continuity correction statistic where appropriate) was used to determine if the number of porpoise groups that altered course differed between configurations. An analysis of variance (ANOVA) was used to determine if differences existed in the distances that porpoises turned from each experimental configuration. A Student's t-test was used to determine if differences existed in the size of groups swimming through versus those swimming around the gear, and the size of groups that swam within 50m of the gear relative to those whose closest approach exceeded 50m.

RESULTS

Although the number of porpoise groups that encountered the experimental gear was relatively small, the proportion that responded by turning differed with each configuration. All of the structures turned some porpoise

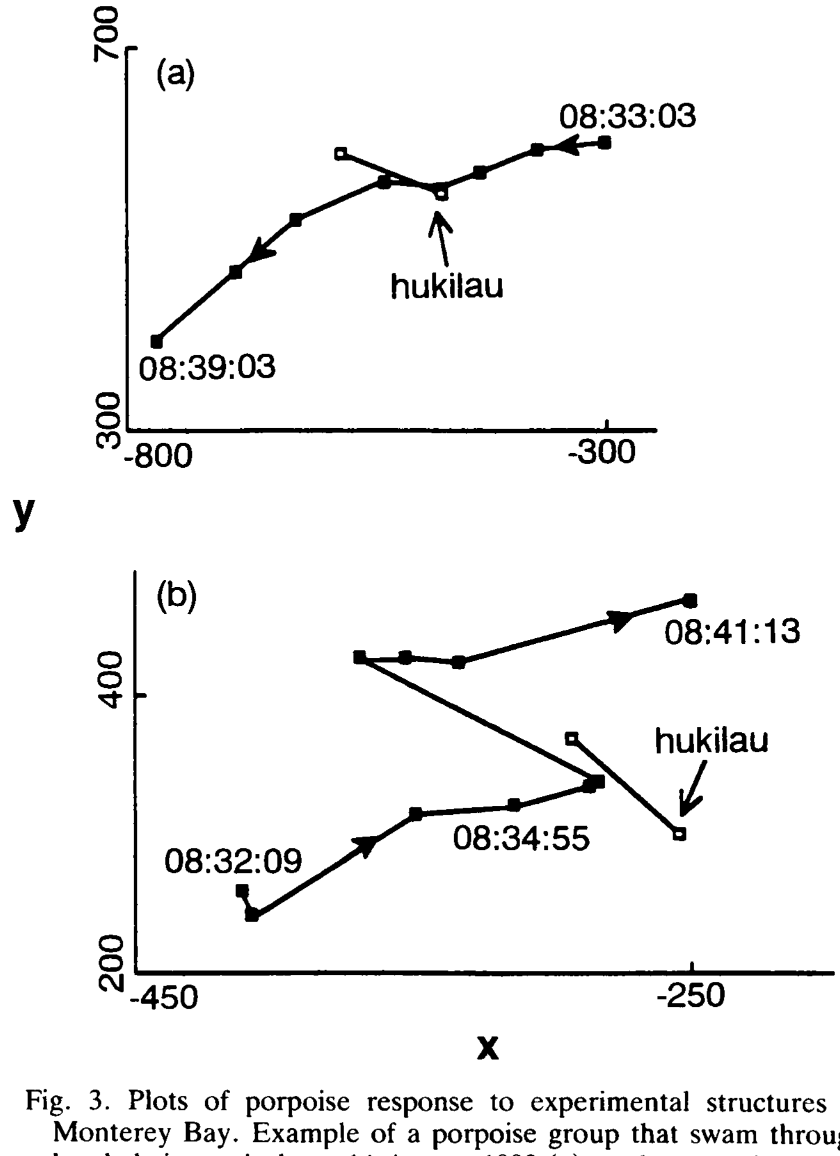

Fig. 3. Plots of porpoise response to experimental structures in Monterey Bay. Example of a porpoise group that swam through bead chain verticals on 14 August 1988 (a), and a porpoise group that altered course relative to surgical tubing verticals on 13 July 1988 (b).

groups, but no structure deflected all groups (Fig. 4, Table 2). There was a significant difference (G=33.86, 4 df, p < 0.001) in the proportion of porpoise groups that swam through the five structures. Although some groups were turned by polypropylene hukilaus (vertical lines at 1.5 and 3.0m intervals), porpoises swam through them 68.2% (n=22) of the time (Table 2). The number of groups that altered course in response to polypropylene line did not differ significantly (G=0.0217, 1 df, 0.75 < p < 0.90) from the number of groups that responded in a similar manner to the corkline alone. There was no significant difference (G=0.113, 1 df, 0.50 < p < 0.75) between the proportion of groups that turned from bead chain versus surgical tubing hukilaus. Only 25.0% (n=3) of the groups that encountered bead chain and surgical tubing hukilaus swam through them, and there was a significant difference (G = 6.102, 1 df, 0.005 < p < 0.01) between the number of groups that turned away from these hukilaus relative to all other hukilaus. On two occasions (both were polypropylene hukilaus) porpoises initially turned from the hukilau and subsequently swam through it. Several groups milled near the corkline and two groups swam under it repeatedly.

Although dive times and respiration intervals were not quantified, groups which swam close to the experimental gear (<30m) appeared to dive for longer periods or interrupted patterned surfacing sequences relative to those which did not encounter the structures. This may have been a period in which they explored the apparatus. The mean closest observed approach was greatest for bead chain, least for surgical tubing, and intermediate for corkline and polypropylene hukilaus (Fig. 5), however these data were not significantly different (F=1.178, 4 df, p=0.3576).

Table 2

Harbour porpoise reaction to experimental structures in Monterey Bay, June through August 1988.

Variable	n	Swam through	Altered course	Response uncertain
Cork line	26	11	7	8
Hukilaus				
Polypropylene				
1.5m	22	10	4	8
3.0m	13	5	3	5
Bead chain	6	1	4	1
Surgical tubing	15	2	5	8

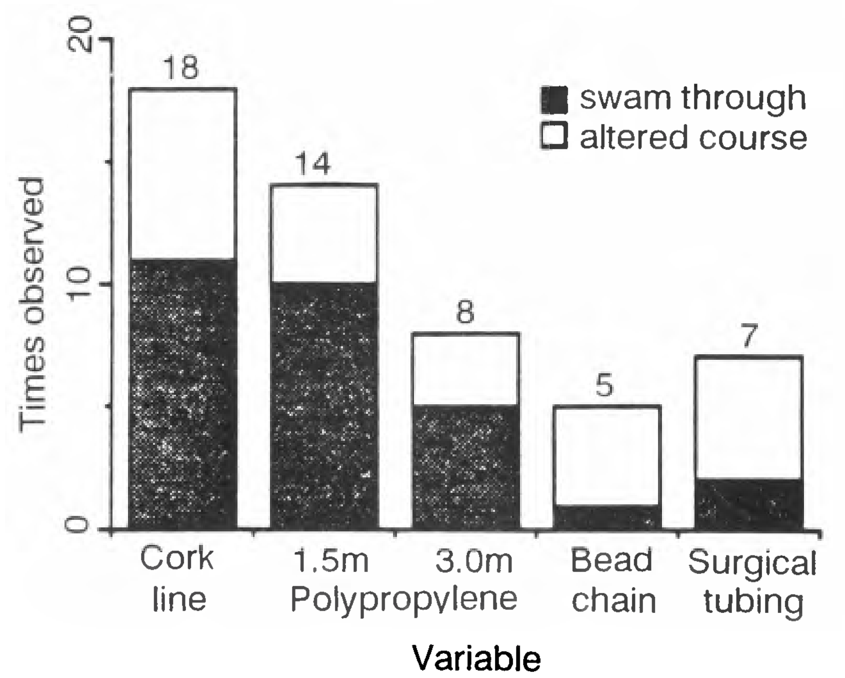

Fig. 4. Number of porpoise groups that swam through or altered course relative to each experimental variable.

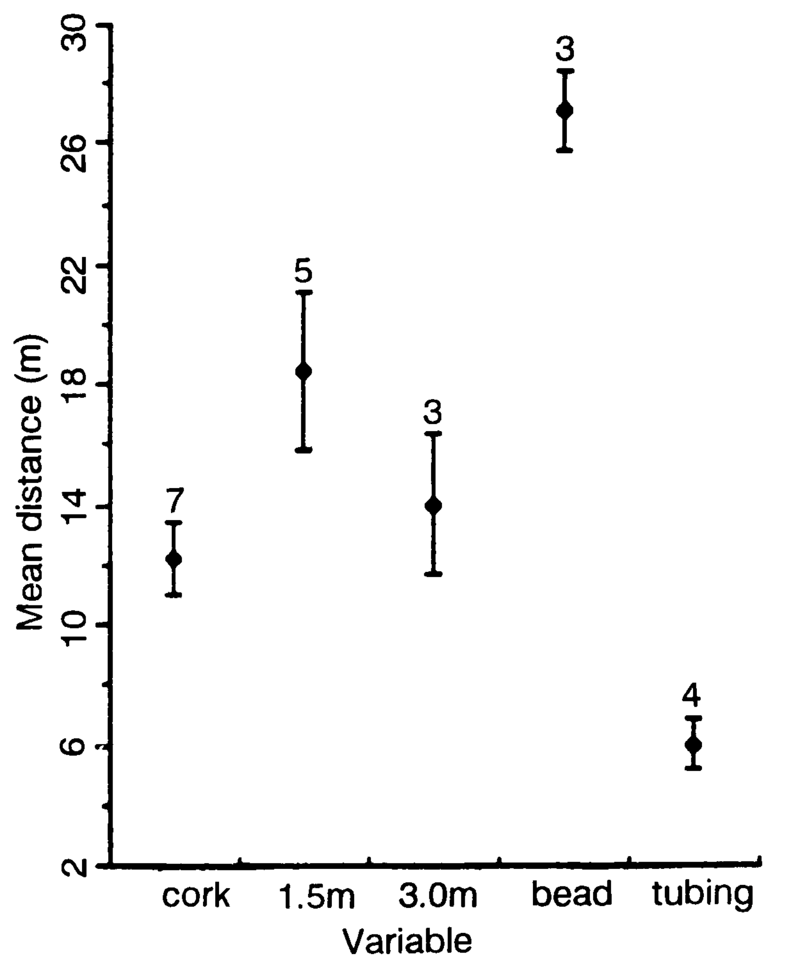

Fig. 5. Mean closest observed approach of porpoise groups relative to each experimental variable. One standard error is represented.

Water clarity measurements, using a secchi disc within 20m of the experimental gear, ranged from 2.8 – 7.0m (mean = 4.4 ±1.53 (SD)m, n = 7). The degree of water clarity that we observed near the hukilaus was likely adequate for porpoises to see the structures. Therefore, the porpoises' reaction to the gear (their tendency to avoid or swim through it) probably was not dependent upon their capacity to visually detect the gear.

The mean size of groups that swam through the experimental gear (4.6 ±5.80(SD) individuals, n = 29) did not differ significantly (t = –0.206, 42 df, p = 0.838) from those that altered course or swam around the gear (4.3 ±2.23(SD) individuals, n = 23). However, there was a significant difference (t= –2.382, 77 df, p = 0.020) in mean group size between groups that approached within 50m (4.6 ±4.52, n=44) of hukilaus as compared to those whose closest approach exceeded 50m (6.9 ±3.77(SD), n = 35). It is possible that large porpoise groups possessed greater 'sensory awareness' and the ability to locate the gear was enhanced by cumulative abilities of large groups. Larger groups were more readily seen at greater distances than smaller groups, which may reflect a bias toward large groups being seen more often than smaller groups farther from the experimental structures.

DISCUSSION

Incidental mortality in gillnets poses an actual or potential threat to many cetacean populations worldwide and, in many settings, few alternatives are available to reduce cetacean mortality in gillnets (IWC, 1994). Our work was undertaken to assess porpoise reaction to a particular type of net add-on or modification that might reduce incidental mortality by deterring porpoises from nets. We showed that some porpoises avoided vertical lines in the water column, although the variables that we tested were not completely effective in deterring porpoises.

Polypropylene vertical lines were no more effective in turning porpoises than was the corkline alone. Polypropylene line is a common material in coastal marine environments where humans are present (e.g. anchor lines). Familiarity with polypropylene line may increase the likelihood of porpoises approaching the material and may account for the lack of response to the corkline alone and to the polypropylene verticals. In contrast, those porpoises that avoided polypropylene hukilaus may have been responding merely to the corkline component of the hukilau. Bead chain hukilaus may have turned a higher proportion of porpoises than did other hukilaus because it was a less familiar material than the other hukilaus. In addition, bead chain hukilaus may have possessed acoustic properties which not only caused a greater proportion of porpoises to avoid this material, but also to change direction at slightly greater distances relative to other hukilaus. Because the surgical tubing did not hold air as intended, it probably reflected very little sound, such as porpoise echolocation signals. However, the tubing turned a relatively high proportion of porpoises. The tubing was used in conjunction with polypropylene and it may have represented a more obvious and unfamiliar material than did polypropylene alone.

Unlike harbour porpoises, spinner dolphins would not swim through hukilaus (Norris and Dohl, 1980). However, spinner dolphins are a pelagic species and are likely to respond to obstructions that are uncommon in their habitat. In contrast, harbour porpoises frequent coastal waters where they are likely to encounter structures in the water column such as pier pilings, kelp and anchor lines. In addition, groups of harbour porpoises typically average less than ten individuals, whereas spinner dolphin groups may contain tens or hundreds of individuals; greater distances between vertical lines may be needed to allow spinner dolphin schools to pass than is required for harbour porpoise schools.

The issue of gillnet mortality is biologically and sociologically a complex problem and a debate exists regarding solutions to high cetacean mortality in gillnets (IWC, 1994). Some researchers advocate a total elimination of gillnets (Dawson, 1991), others recommend fishery closures by location or time, while some believe that it is possible to render the nets less destructive through modifications (for example Goodson *et al.*, 1994).

Clearly more work is needed to address this problem and attempts to reduce cetacean entanglement almost certainly lie in a multi-faceted approach in which several avenues are pursued simultaneously. Restricting the use of gillnets by degree (e.g. time and area closures), the use of alternative fishing techniques, net modifications and total bans should all be considered depending upon the region, the fishery and the marine mammal species involved. Reasons for cetacean entanglement may vary with fishery, net type, means and timing of net deployment, mesh size and target species, and the social structure and behaviour of incidentally captured species.

We believe that in many cases, the abolition of gillnets may be the only solution. However, moratoria on gillnets will encounter resistance due to the detrimental economic impact on fishermen. In addition, in many remote locations enforcing bans on gillnet use will be extremely difficult. It is not reasonable to assume that gillnets will be eliminated in all regions in the foreseeable future, and because cetaceans continue to die, alternatives should be explored in the interim.

Further experimentation on gillnet modifications that reduce cetacean mortality should be considered, particularly if moratoria are not possible. However, gear modifications should not be necessarily regarded as solutions, but as potential short-term means of lowering cetacean mortality rates while more far-reaching and effective solutions are sought. Reductions of even small percentages in entanglement rates could benefit affected populations until permanent solutions are found. For example, in the Gulf of California, where vaquita incidental mortality is high relative to the population size, laws banning the use of gillnets have existed since 1975, but the practice continues unchecked due to a lack of resources to adequately enforce the laws (Vidal, 1994). Attempts to implement additional or more stringent laws are not likely to reduce the amount of gillnetting activity. However, by instituting a programme involving simple modifications that lower entanglement levels, it may be possible to mitigate the impact of incidental mortality, while other people work simultaneously toward the elimination of this fishing practice. Net modifications that reduce but do not eliminate porpoise entanglement rates should not be pursued *in lieu* of the possibility of substituting the use of gillnets with safer fishing methods, but they might provide relief to porpoise populations while more permanent solutions are sought.

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Enhancing the Acoustic Detectability of Gillnets

A. David Goodson

Signal Processing Research Group-Bioacoustics & Sonar, Electronic & Electrical Engineering Department, Loughborough University of Technology, Leicestershire, LE11 3TU, UK

Margaret Klinowska

Research Group in Mammalian Ecology and Reproduction, Physiological Laboratory, University of Cambridge, Downing Street, Cambridge, CB2 3EG, UK

Peter R.S. Bloom

The Dolphinarium, Flamingoland, Kirby Misperton, Malton, North Yorkshire, YO17 OUX, UK

ABSTRACT

The entanglement and drowning of large numbers of the smaller cetaceans in gillnets is a matter of international concern and necessitates research to identify techniques which will minimise such incidental catch. In attempting to explain the behaviour of animals immediately prior to net entanglement in modern driftnets we need to understand the ability of the animal to detect and assess the threat. A non-intrusive study of the behaviour of a solitary wild *Tursiops truncatus* (using sonobuoys) has examined several natural behaviour patterns classified respectively as: foraging, travelling and resting. This paper examines some specific acoustic behaviours which were observed to be employed by this free ranging animal. The interpreted behaviour of this dolphin is seen to further complicate the problems of gillnet perception. No simple solution appears to exist, but for those animals which are actively echolocating the authors believe the best chance of net avoidance requires that the net be detectable near the animal's maximum searched range. The target tracking behaviour employed during fish interception suggests that diffuse obstructions, i.e. gillnets, that can only be detected at lesser ranges, are likely to be ignored. Design parameters for passive enhanced echo reflectors which are orientation independent and optimised for dolphin sonar signal characteristics are discussed in detail.

KEYWORDS: INCIDENTAL CAPTURE; BOTTLENOSE DOLPHIN; ACOUSTICS; BEHAVIOUR

INTRODUCTION

The incidental capture of cetaceans in fishing gear is recognised as the major threat to their populations in many parts of the world (IWC, 1994). Attempts to reduce incidental catches have been hindered by a lack of knowledge as to why cetaceans become entangled. This can be oversimplified as a question of 'detection' (they do not know the net is there) or 'classification' (they know it is there but do not recognise it as a threat). Many of the early attempts to modify fishing gear were based on an assumption that the problem was one of detection. Given that dolphins used echolation it was concluded that the solution was to make nets 'louder'. These attempts rarely considered the detection capabilities of dolphins, their behaviour, the acoustic properties of water or the acoustic properties of the gear.

In this paper we examine these factors and use the information to consider ways of enhancing the detectability of gillnets in a manner that takes into account the physiology and behaviour of dolphins.

PHYSIOLOGICAL AND BEHAVIOURAL CONSIDERATIONS

Most studies of the acoustic capabilities of cetaceans have been of captive animals, for obvious reasons. However, while this is of value in providing baseline data, it is important to study the acoustic behaviour of animals in the wild in order to better address problems, such as gillnet entanglement, that face them in their natural environment.

A common difficulty encountered when carrying out acoustic studies of animals in the wild is that of isolating and identifying the individual sound sources within a group. Studies of a single wild animal, which exhibits repeatable patterns of behaviour, greatly simplifies the problems of classifying activity and correlating the associated sound emissions (Goodson *et al.*, 1988; Goodson and Datta, 1992).

The study animal

The solitary bottlenose dolphin (*Tursiops truncatus*) resident close to Warkworth harbour entrance at Amble by the Sea (Northumberland, UK) has been extensively studied since 1989 (Bloom, 1990; 1991). The animal is a mature male of approximately 20 years (this estimate is based on the dolphin's size, condition, visible tooth wear and apparent lack of tongue papillae – Kastelein and Dubbeldam, 1990). Conveniently, the animal normally remains within sight of shore inside a relatively small, well defined home range which is less than 1km square. Brief excursions outside this favoured area do occur, usually while providing an escort to local fishing boats as they approach or depart from Warkworth harbour. Increasing social interaction between the dolphin and humans, especially with divers, occurred after the first year of study but this modified behaviour is ignored here. Night-time foraging patterns of behaviour seem to be consistent, especially when interference due to human activity is absent.

Equipment

Sonobuoys (modified type *SSQ*41a) were employed to monitor the dolphin's acoustic emissions continuously during 24 hour intensive study periods. The available sonobuoy signal bandwidth was extended upwards to 40kHz and the low frequency response below 50Hz restricted for this application. The signal bandwidth in practice was restricted by the use of the original 'bender' hydrophones. Although sensitive, these hydrophones possess a rippled frequency response above a nominal 2kHz resonance and are therefore unsuitable for determining signal power spectra or examining precise pulse wave shape. Precision hydrophones (*B&K* 8104s and *Universal Sonar* D/70s) were occasionally used but their deployment for directly wired wideband recording is limited by the weather and turbulent water conditions close to the pierheads. As a result sonobuoy radio telemetry provided the bulk of the data.

AOR Ltd AR-2002 and *Yaesu* FT9600 communication receivers were used to receive the sonobuoy signals. Simultaneous recordings from each deployed sonobuoy were made on separate channels of a wideband *Racal Store* 4D instrumentation recorder at 19cms^{-1} (37kHz bandwidth). A VHS Camcorder was deployed at the pier and operated by the observers. An additional sonobuoy communication receiver assisted the pierhead observers and supplied underwater sounds to the video camera sound track. Handheld VHF radio transceivers were used to coordinate observers, mobile activity, boat handling and the recording/control vehicle (Base) throughout the 24 hour watch periods. The sonobuoy (with a long-life battery pack) deployed at sea was moored between two small surface floats and kept on station by a double anchor system (to avoid entangling the hydrophone). The inshore sonobuoy was deployed 40m clear of the south pierhead and moored using a rope loop with a pulley at the seaward end attached to an anchored surface float. The inshore end was attached to the pierhead and could be controlled by the observers. This technique provided for sonobuoy recovery and replacement if required and allowed the hydrophone position to be optimised without needing a support boat. Subsequent analysis of the instrumentation recordings was aided by a Loughborough Sound Images (LSI) speech work station.

Summary of the animal's behaviour

During 1989 and 1990, the positions of the animal within its home range were logged, during daylight hours, by local observers. In addition, four intensive 24hr studies were carried out in order to acquire data under both winter and summer conditions. Bloom (1991) reported that typically during these 24hr study periods, the animal exhibited behaviour patterns loosely classified as foraging (53%); resting (22%); play or other behaviour (12%). The animal was out of observation range for 13% of the total period. This summary is based on 96 hours of observation, sampled at 15 minute intervals.

Acoustic behaviour – resting

A navigation buoy marking the outfall of a sewer pipeline some 500m offshore (Fig. 1) appeared to be used by the animal as a reference point during resting. The animal spent significant periods circling near it, exhibiting a regular breathing pattern. Sonobuoys deployed nearby registered no echolocation 'click trains' or 'whistle' sounds while the animal was near. A very occasional 'loud click' was the only sound noted which might possibly be classed as a bio-sonar emission from the dolphin (Goodson *et al.*, 1988).

Echolocation behaviour – travelling

The sonobuoy sensitivity is such that good detection of click train emissions could be obtained at ranges in excess of 500m when the animal was orientated towards the hydrophone. At ranges of <100m, the low directivity of the low frequency spectrum sampled ensured that clicks were detectable even when the animal was swimming away

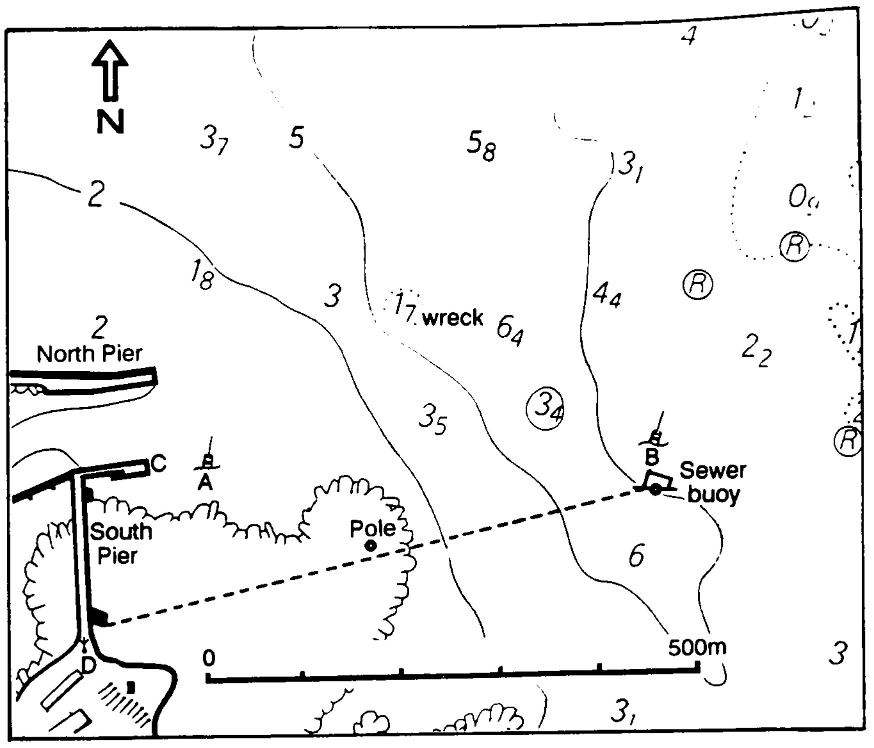

Fig. 1. The Amble dolphin's home range close to Warkworth harbour. A & B – sonobuoy positions; C – south Pierhead observers; D – base station for telemetry reception.

from the hydrophone. The relative amplitude of the clicks and their reverberation components also provided clues to changing orientation.

Sonobuoys were deployed at the sewer outfall and close to the end of the south pier. On a number of occasions the animal was timed travelling underwater quickly (8–10ms^{-1}) and directly between these two sonobuoy locations, which were about 500m apart. Echolocation signals were rarely evident in this fast travel mode. This 'quiet' travel behaviour was typical and noted in a variety of sea states, in both winter and summer, and in conditions of poor water visibility and fading evening or dawn light. No evidence was found to support the view that the dolphin employs its active sonar as a navigational aid within this home range.

The preferred foraging zone

The river at Amble passes into the sea between two parallel (concrete and stone) breakwater piers, some 68m apart, which define the harbour entrance. The area immediately outside and between the breakwater arms appears to be a prime foraging area. Sonobuoy deployment 40m seaward of the end of the south pier permitted continuous monitoring of the dolphin's sonar emissions. Observers based on the south pier head were well placed to monitor the dolphin's fishing activity, much of which occurred within 100m of their position. Even in total darkness, the animal's blow could usually be heard at this range while the radio receiver relayed underwater sounds from much greater ranges.

Fish entering or leaving the river must pass between the two piers of the harbour breakwater. Severe tidal scouring effects exist close to the north pier which has been undermined. A sand 'bar' causing a small step discontinuity in the seabed exists between the seaward ends of the piers. The average tidal range is 4.5m and the minimum water depth, measured at the bar, is less than 1m at spring low tides.

Echolocation – search patterns

The animal's search pattern was dominated by a slow, relatively loud click emission typically transmitted at a rate varying between 12 and 16Hz. In rough sea conditions or when the animal chose to fish between the pier heads, the click rate was noticeably faster, up to 25Hz. In contrast, in calm quiet conditions when the animal was swimming clear of both piers, the slowest repetitive emission rate recorded was 8Hz. These slow repetition clicks were employed over long periods (hours) at a time. They were initiated at the start of a dive and were the emission pattern to which the animal returned after interruptions by other acoustic activity. These pulse trains exhibit a characteristic slightly irregular interval with each sequence settling to, and varying about, the nominal rate (Fig. 3a). The presence of this type of sonar emission has been used to classify 'foraging' behaviour. Foraging activity could occur during any tidal state, although the ebb tide appeared to be favoured. It was rare for the dolphin to fish close to the harbour mouth at low water. Extended periods of fishing activity frequently occurred at night.

There was a short pause after taking breath before these slow sonar transmissions resumed, suggesting that the animal dived to a preferred depth and levelled out parallel to the bottom before initiating a long range search transmission. During this activity, the animal frequently resurfaced in the same position and on the same heading as the preceding dive. The underwater search strategy would seem to be the repetition of a particular underwater manoeuvre.

Changes in the peak received signal intensity were minimised by the sonobuoy's reverberation gain control (RCG) circuitry, but cyclic variations in the relative strength of the inter-click reverberation components suggest that the animal may have been circling slowly on or near the bottom, presumably sweep-searching a large sector. Alternatives to this normal circling pattern included patrolling a path across the harbour mouth some 10 to 20m outside the pier heads and a 'figure of eight' pattern executed between the harbour pier walls. These patterns have been reported independently by divers near these locations.

Interaction with fish

The sudden cessation of the slow 'foraging' clicks and the initiation of a rising pitch 'mewing' sound (Goodson *et al.*, 1988) appears to characterise detection of a target fish and initiation of a chase sequence. After such sounds the animal was occasionally observed to surface holding a relatively large fish in its mouth. On several occasions the dolphin has also been seen to play with a fish, either 'herding' it along the surface or by throwing it into the air (Fig. 2). Salmon, sea-trout, herring, mackerel, cod, coalfish, flatfish (dabs or plaice) and dogfish are among species that have been tentatively identified as prey by both pierhead observers and divers.

Although the transition from the 'foraging' clicks to 'mewing' sounds may occur as a progressive increase in click frequency, it is more common for the foraging click sequence to terminate abruptly and after a brief silent period (some 200 millisecs) for 'mewing' to commence. The perceived pitch of this signal rises and may vary before terminating, either in silence or in an immediate resumption of the slow loud clicks.

Echolocation signals – interpretation

The inter-click period is presumed to define the maximum range being actively searched, as the next transmitted pulse must tend to desensitise the receiver and thus effectively terminate detection of weak echoes returning from greater ranges. If strong long range echoes originating from an earlier transmission are detected then the target range perceived will be ambiguous. The maximum range searched by this animal in ideal conditions is therefore believed to be less than 94m (from the occasional 8Hz repetition rate noted in calm conditions). The slow click repetition rates normally employed suggest that this dolphin was rarely interested in searching for prey much beyond about 60 to 70m, coincidentally the width of the Warkworth harbour entrance. This is also close to the maximum range achieved by trained animals searching for a –35dB target close to the seabed (Murcheson, 1980).

'Mewing' comprises a rapid sequence of discrete clicks emitted in a regular and precisely timed sequence (e.g. Fig. 3b). These rapid clicks appear to be repeated at intervals closely related to the two way sound propagation time between the animal and the target of interest and can be seen to represent the maximum rate at which echo data from the target can be acquired. By concentrating directly on the target range, this technique will effectively mask multipath secondary echoes of the target and also reject much of the echo clutter returned from greater ranges than that of the fish. The consistent range/time interval relationship appears to break down at very short ranges (<1m) but this may well be due to physiological factors controlling the maximum rate of click generation. *T. truncatus* is rarely observed to click at rates much above 1kHz.

Published studies of range locked behaviour (Au *et al.*, 1974; 1982; Turl *et al.*, 1987) are confined to constrained or stationary animals. It is worth considering whether the unrestrained forward motion of a wild animal during target interception should be considered as a parameter affecting the acoustic behaviour and, in particular, the reported variations in latency.

Fig. 2. Throwing a fish (salmonid) into the air.

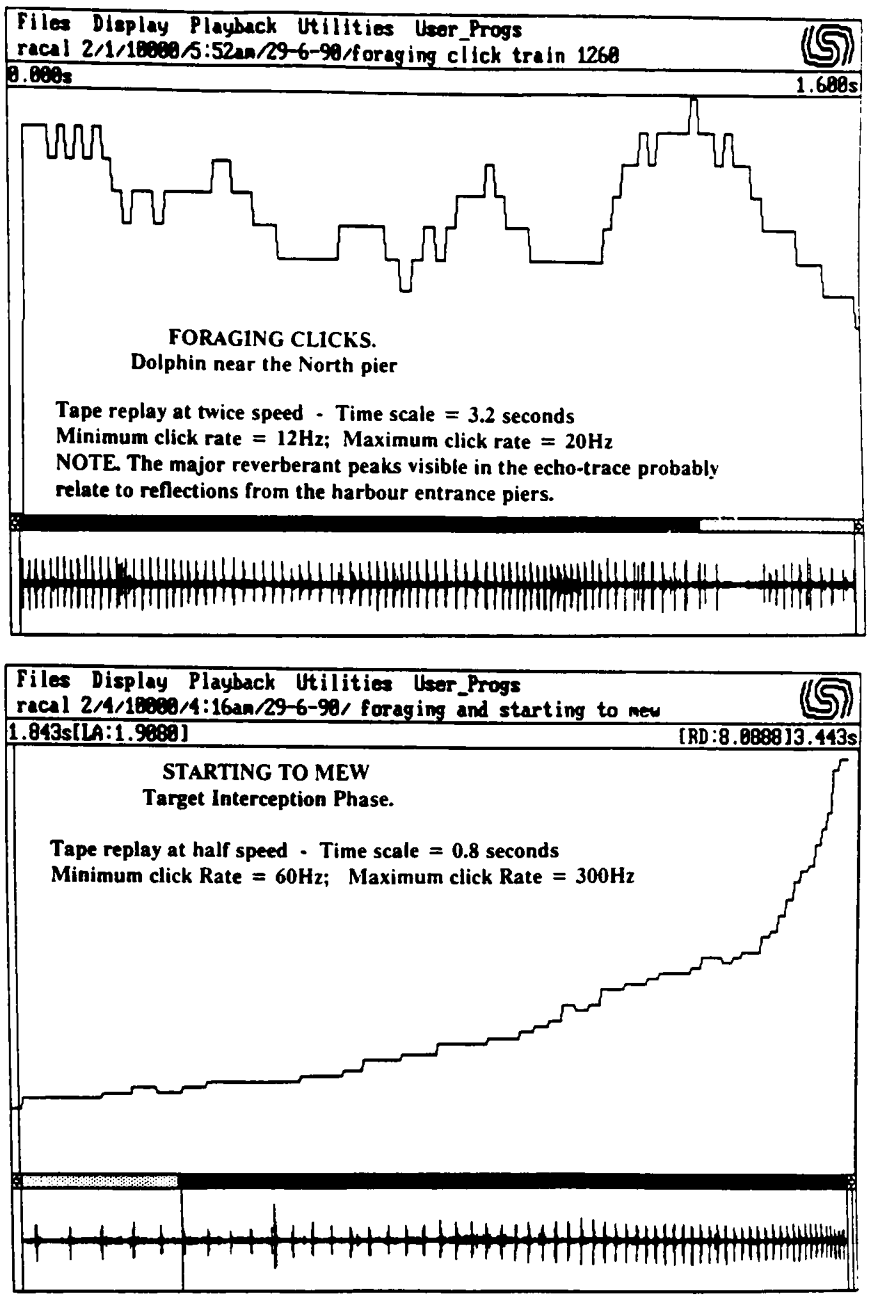

Fig. 3. Inter-click period (instantaneous frequency) plotted against time. (a) Foraging clicks 'unlocked' variable 12 to 20Hz. (b) Target interception phase, starting to 'mew'.

During a typical fish chase sequence, the pitch of the 'mew' increases as the dolphin rapidly shortens the range during interception. Short periods of almost constant pitch are occasionally observed which could suggest that, having achieved a close range, the animal may be content to tire its prey (fish muscle exhaustion tends to occur suddenly, leaving the fish helpless in the path of the dolphin). Alternatively, it seems probable that when intercepting a large target fish with a swimbladder, the increasing click rate employed as the range shortens will match and stimulate a resonant response in the swimbladder. The peak click rate then employed may thus reflect target size rather than range parameters. The subsequent reaction of the targeted fish is unknown but repetitive stimulation of the Mouthner escape reflex through swimbladder transduction is unlikely to aid the fish's ability to escape (Canfield and Eaton, 1990).

Unsuccessful chase sequences or target rejection are assumed to have occurred if 'mewing' stops and foraging clicks are abruptly resumed. The frequency of the 'mew' occasionally fell slightly before terminating. There is of course no reason why the ingestion of very small fish should necessarily interrupt the sonar transmissions. In chase sequences known to be successful, i.e. where a fish was brought to the surface within sight of observers, the sonar transmissions appeared to terminate at capture, the abrupt cessation of the 'mew' occurring at the highest frequency.

Long range 'foraging' clicks exhibit relatively loose timings and the instantaneous rate often seems varied cyclically about a nominal range (Fig. 3a). In contrast, 'mewing' comprises click sequences with precisely timed click intervals. Plots of inter-click period/time profiles (Fig. 3b) can be used to identify segments of acceleration, deceleration or constant swimming velocity relative to a target.

Selecting segments of constant gradient as indicative of a constant velocity allows the relative dolphin/fish velocity to be estimated; the Amble dolphin's swimming speeds during target interception were typically $5ms^{-1}$ terminating in a brief burst at higher speed (up to $8ms^{-1}$).

In some of the data analysed, the dolphin appeared to employ an intercept behaviour built up from segments of nominally constant swimming velocity. If this 'stepped velocity' behaviour is non-accidental, it may be a technique employed to simplify the moving target interception problem.

Echolocation behaviour – implications

The detection and active tracking of a target by a dolphin is characterised by a range locked transmission, i.e. as the echo from the target is detected, the next click transmission occurs. The interclick period normally reflects accurately the range to the target at any instant and the increasing frequency as the dolphin closes with a target gives the observer a reliable indication of distance until the target is very close to the animal. At ranges less than 2.5m the range/frequency relationship ceases to be linear and it is unusual to observe click rates which peak at much above 1kHz, so the effort or usefulness of this information rate is assumed to be rarely needed.

One important benefit of a range locked transmission rate is the effective suppression of over-range target information and multipath 'echo clutter'. The transmission of the succeeding click immediately on receipt of an echo ensures that the echo-receptor is desensitised. A latency period will follow in which the receptor recovers. The perception of any over-range target during an active fish chase would appear to necessitate a very strong echo from the secondary target.

Dolphin sensory perception during fishing activity

The two senses which are usually assumed to predominate during fish hunting activity are hearing (sonar) and vision, with the former clearly the more important. Other senses such as chemoreception, may play a part in long range detection but are not believed to offer more than 'present/absent' clues, although it is not inconceivable that fish or shoals of fish might be tracked by taste. As noted above, at ranges greater than about 100m, the presence of gillnets will provide no warning clues to an animal swimming on a collision course. Underwater vision, even in ideal conditions, will not be able to detect netting until significantly closer than 20m. At night or in 'normal' sea conditions, animals will probably not see a net until collision is imminent. Sound detected in the passive sense may provide coarse hydrographic orientation and position clues to a travelling animal, especially in shallow coastal waters. However, gillnet 'self noise' (i.e. noise generated by the drifting netting due to sea state disturbance) will be at low levels and will probably be masked in most conditions by the background ambient seastate noise; it would be interesting to compare statistics of incidental catch in relation to sea state. The assumption must be then that few clues to a drifting gillnet position will be given to a passively listening animal. The sense most likely to detect the presence of a net as an obstruction is therefore the active sonar 'echolocation' mode employed by the animals, especially when foraging.

Dolphin sonar – resolution

Bottlenose dolphins project their broadband transient clicks from the melon (Wood, 1964; Norris and Harvey, 1974; Romanenko, 1974). This anatomical feature functions as an acoustic lens of limited aperture and as a result the projected signal is spectrally dispersed in both azimuth and elevation. The energy distribution within a *T. truncatus* high source level transmitted pulse has been shown by Au (1980) to peak spectrally near 120kHz within a tight (10°) conical beam. The dispersive effect of the melon's limited acoustic aperture means that lower frequency components progressively dominate as the observation point is moved off axis (Au, 1980; Watkins, 1980). The projected acoustic 'directivity' pattern can be pictured spatially as a graded series of concentric conical beams of increasing included angle but dominated by progressively lower frequency and lower amplitude spectral components. If the dolphin's angular perception is based solely on the transmitted signal beamwidth, then the animal should have difficulty resolving target position in azimuth or elevation to better than 10° (unless the dolphin ignores the human convention of half-power beamwidth and successfully discriminates echo intensity variations significantly smaller than -3dB). However, trained animals have consistently displayed an ability to discriminate angular position in both azimuth and elevation to better than 1° (Renaud and Popper, 1975; Floyd, 1988). The receptor mechanism by which this angular resolution is achieved is unclear and not explained by the traditional hypothesis based solely on the cochlea response to a fatty tissue sound conduction pathway along the lower jaw. An alternative echo receptor hypothesis, optimised for high frequency echo-reception within the near field, is modelled in Goodson and Klinowska (1990).

It is evident from physical acoustic principles that, regardless of the receptor mechanism employed, the animals angular discrimination of very small objects must utilise the high frequency spectral components contained within its transmission. This perception can therefore only function within the very narrow 'spotlight' beam projected forward along the swim axis. Searching behaviour in dolphinarium experiments supports this, as head swinging actions are employed while swimming towards and discriminating between spatially separated target positions. Once the required decision has been made, the animal points its beak accurately towards the selected target for the final approach phase. For an optically masked target (TS=-41dB) the data acquired during the early learning phase of using three captive bottlenose dolphins an experiment suggested that they left their final discrimination decisions to about 2.5m range (Goodson, unpub. data).

The limiting factors affecting detection of very small sonar targets relate to the target's physical size, geometry and the insonifying wavelength. Progressively reducing the target's dimensions to below 1 wavelength of the incident sound, results in the back scattered echo energy returned towards the source becoming very small (Fig. 4). For very small targets the animal's perception will therefore be limited to the centre line of the transmit axis. Larger targets may be perceived in off-axis positions as the outer conical zones of the transmitted beam are defined by lower frequency and lower power components. If a recording of a sequence of clicks made by the animal as it scans its sonar transmissions across a hydrophone, is slowed down by a large factor (16:1), then the human ear can perceive a significant shift in the apparent pitch of the individual dolphin click. This azimuthal shift in pitch may well provide the initial centring clues during target acquisition. At short ranges, the perception of a phase difference between the echo received by the left and right receptors must explain the ability of an echolocating dolphin to track an elusive fish target down to the capture point in total darkness. The lack of head scanning movements when a dolphin is in the final 'locked on' (mewing) phase of a fish chase and the animal's apparent ability to react to the target's sudden direction changes without employing head scanning actions, would seem to support this (Goodson, unpub. data).

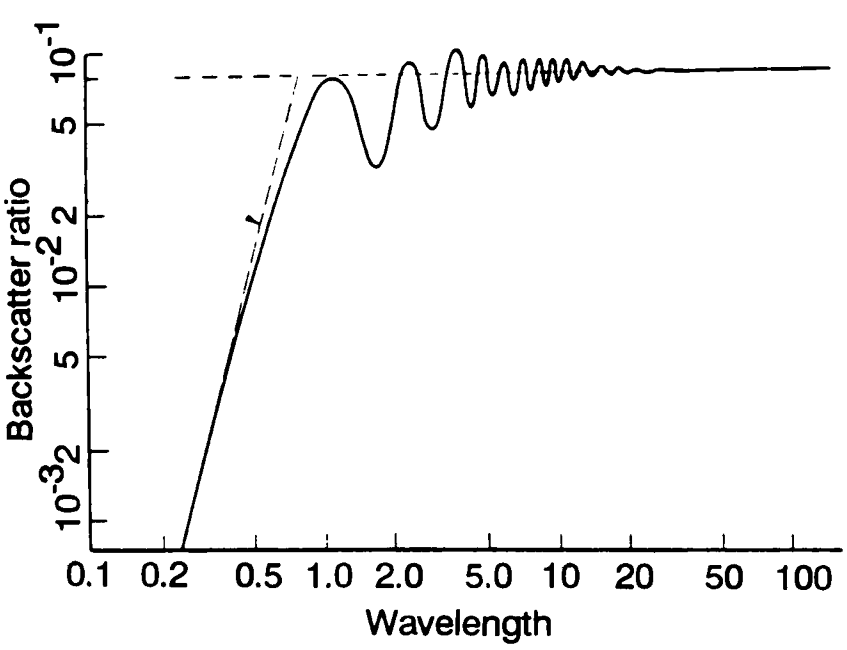

Fig. 4. Acoustic backscatter from a rigid sphere, as a function of the insonifying wavelength (after Clay and Medwin, 1977).

THE PROPERTIES OF GILLNETS

The deployment of gillnetting made from modern polymer materials is an efficient method of fish capture which, although intended to discriminate its target species by choice of mesh size, also indiscriminately captures much larger species through entanglement. Gillnets can be exploited by a wide range of fisheries, from relatively small scale inshore artisanal to large scale off-shore operations. The technique has proliferated throughout the world during recent years and is rapidly replacing traditional fishing methods. The nets are frequently deployed at night in order to capture fish which approach the surface nocturnally. Before the UN ban on large-scale pelagic driftnetting came into force in 1992, vessels in the Tasman Sea albacore tuna fishery each deployed long lengths of gillnet, typically 39km per boat, which hung below the surface in a curtain some 10–15m deep (Coffey and Grace, 1990). Alternatively, in shallow water much smaller nets may be permitted to sink close to the seabed (Karlsen and Bjarnason, 1987). A wide variety of cetacean species are taken as incidental catches and those that escape may only do so after causing significant damage to the nets (IWC, 1994). It seems probable that many of these animals are captured during their own foraging. In a large number of cases the netted animal is unable to break away and once entangled, suffocates. From the fisherman's perspective, the damage to expensive netting and the associated down time is significant (Lien *et al.*, 1988) and an economic incentive exists to employ methods which minimise the problem.

The Target Strength of gillnet webbing

The Target Strength (TS) of various gillnet materials* have been assessed by Au (1994), by Hatakeyama *et al.* (1994), by Pence (1986) and for tuna purse seine nets by Leatherwood *et al.* (1977). The quoted results differ depending on methodology and materials and the highest values assessed result from insonification normal to the plane of the deployed webbing. Insonification at other angles results in reduced echostrengths and for an azimuth change of 15°, Au (1994) determined a reduction in the perceived TS of 3.8dB. Although he did not examine the worst approach angle scenario, his measurements imply that the peak TS value should be reduced by some 7.6dB in order to allow for a dolphin/net interception along combined azimuth and elevation angles exceeding 15° from the normal. For monofilament gillnet webbing, Au (1994) measured a peak TS value of –58dB. For net detection estimates, the use of the peak value is likely to mislead and a worst case TS value (-66dB) needs to be considered as the general case. Hatakeyama and Soeda (1990) refer to directivity data (provided by Pence) which indicates that small changes in azimuth angle (3–4°) at frequencies of 150kHz and 170kHz should result in a reduction in the perceived TS by 10dB. Thus the 'worst case' TS estimate of –66dB (for a monofilament salmon gillnet with animals intercepting the plane of a net at angles other than 90° in both azimuth and elevation) may still be an overestimate.

In this context it may be argued that foraging animals must spend a significant proportion of each dive projecting their echolocation signal for maximum range in the horizontal plane. However, the actual angle of incidence of a horizontally projected signal at the gillnet interface may not be normal in the elevation plane, as strong thermal gradients near the surface will modify the incident angle at the net by refraction. This effect is likely to be pronounced in tropical waters and may result in a diurnal changes in the bycatch. In addition (for moored nets), tidal displacement will deflect the plane of the net from the vertical.

THE NET DETECTION PROBLEM

Given that the acoustic reflection characteristic of the unmodified gillnet webbing is inadequate for long range detection, an estimate of the increase in TS theoretically needed to alert dolphins can be made from the foraging behaviour and targeted prey of the animals at risk. From observations of the (Amble) dolphin's sonar behaviour and from consideration of the size of the larger fish observed caught by this animal, we can deduce that swimbladdered fish, with a TS in the order of –35dB (re a 2m radius sphere; Foote, 1980) are frequently sought, and are believed to be detectable at ranges between 60 and 70m.

Using the basic sonar equations (Urick, 1983; Au, 1994) to predict the spreading and attenuation losses due to range for a monostatic sonar functioning at 120kHz, we can demonstrate that the equivalent detection range of an unmodified gillnet (TS= –66dB) when compared with a targeted large fish (35–40cm salmon nominal TS=-35dB) at 70m range will be less than 12m.

Knowledge of the actual source level employed and of the animals detection threshold in noise is not essential for this comparison, given that the ability to detect fish of this TS at the stated range has been observed.

Since the prior detection of a fish and the initiation of interception sonar behaviour is believed to exclude the detection of over-range targets, even assuming the simplest scenario the problem of dolphin/net detection cannot be solved unless the net position is always perceived before the fish is detected! That this assumption may be simplistic is witnessed by the (unique) South African shark net bycatch problem (Cockcroft and Ross, 1991; Peddemors *et al.*, 1991), where prior knowledge of the net position could be presumed. However, it may be argued that for the (Amble) dolphin at least, any enhancement of the gillnet TS to a value that is less than about –35dB will be ineffective in the presence of fish. For other animals at risk, the maximum size of fish prey regularly taken can be used to establish a minimum TS value that must be matched or exceeded by the gillnetting if its position is to be detected before that of a fish.

Of course, detectability alone is not enough to ensure that animals avoid entanglement. The echoes from the net obstruction once detected must also be classified as an impenetrable barrier to be avoided. The characteristic distributed echo returns from a curtain of gillnet webbing will appear diffuse and may easily be classified by the animal as penetrable volume reverberation, as would similarly distributed echo returns from seaweed, algae blooms or even the bubble wakes left from passing boats.

Although the addition of reflecting objects to a gillnet to achieve the 'minimum' TS criteria described is possible, net handling imposes serious operational constraints. The physical size of these additional devices, their spacing, shape and buoyancy all need to be considered (Goodson *et al.*, 1994).

Some assumptions about dolphin behaviour and net perception

(1) Dolphins in a resting mode appear to swim relatively slowly (0.5 to 1.5ms^{-1}) and seem to only maintain minimal active monitoring of their immediate environment. Although the evidence is slight, our observations suggest that the occasional loud click thought to be emitted by the dolphin may be intended to maintain a position check. 'Dozing' dolphins sometimes appear slow in reacting to rapidly approaching boats on a collision course.

(2) When travelling fast (5 to 8 ms^{-1}) in known territory, the dolphin does not appear to employ its active sonar; our evidence suggests that active sonar is only used when foraging. Human fishing activity (an occasional bottom set cod net) within the Amble dolphins home range did not result in any reported interactions. The animal was aware of the deployment of the net and presumably treated it as part of its 'normal' environment. Seal/net conflicts in the same general area are a regular complaint of the local fishermen.

(3) While foraging actively for food, the sonar range examined is probably defined by the anticipated prey behaviour and the balance of effort required to intercept, *versus* the size of the reward. The slow click rates employed by our study animal suggest a 60–70m

* When measuring Target Strength (TS) the target dimensions need to be fully ensonified by the sonar beam. If the target's dimensions exceed the beam width, as in a fishing net, the echostrength becomes range dependent. Unless the measurements conditions are fully specified the TS values, conventionally assumed to be in dB re a 2m radius sphere, are not comparable.

maximum search range. Although acoustic searches beyond this range for large targets may well be possible in good acoustic signal/noise conditions, the effort involved in capturing large fish targets detected at extreme ranges is probably uneconomic.

(4) Observed behaviour patterns suggest that the dolphin is searching a large volume of water by swimming slowly in a circular pattern while clicking at these slow repetition rates. From the estimated sizes of the largest fish seen to be caught, the probability of *T. truncatus* detecting a large (TS= -35dB) fish at the maximum range in mid-water is quite high. Target detection frequently occurs at ranges less than the search range maxima, suggesting that the animal is turning onto the bearing of a fish at closer range.

(5) The final attack phase is usually fast (some chase sequences last less than 4 seconds) with maximum speeds estimated at about $8ms^{-1}$. Much longer sequences can occur with inter-click intervals which suggest quite short dolphin/target ranges. These seem to indicate that the target fish may be detectable but less accessible due to the seabed topography. Initial target detection commonly occurs at ranges well under the search maxima.

(6) The dolphin's echo-perception, exploiting its own high frequency signal components, does not appear to be degraded by high levels of low frequency noise. Off-line spectrographic analysis of the recorded signals demonstrated that the dolphin's fishing activity frequently continued while a fishing boat, entering or leaving harbour, passed at very close range, as the presence of foraging click signals is clearly discernible extending well above the relatively low frequency ship noise spectrum (Mitson, 1989).

IMPLICATIONS FOR PASSIVE ACOUSTIC NET MARKERS

Sonar perception of a fish target is not believed to be impaired in the presence of a competing (or cooperating) dolphin sonar. The lack of *a priori* knowledge of the echo/source timing precludes other animals acquiring range information from such echoes. The sharp directivity of the transmission and the apparent focussing of attention to the precise target range during a chase/interception 'mew' can be seen to be an excellent technique to reject such interference. Gillnet detection as a byproduct of a second animal's signal echoes is thus not likely.

Attempts to enhance a gillnet's TS by the addition of simple sound scattering mechanisms such as ropes or 'bead chain' (e.g. Hembree and Harwood, 1987; Dawson, 1994) have not been very effective. However, the mechanisms employed so far are ostensibly inefficient as most of the incident echolocation energy is dispersed omni-directionally. Strong specular echo returns can only be produced from target dimensions which exceed several wavelengths of the incident sound. The very high TS's measured by Au (1994) for 'light switch chain' (-36dB) and for 'poly rope' (-33dB) are the peak values which are specific to vertical deployment with horizontal insonification at one (2.4m) range. At all other angles of incidence the proportion of energy reflected back towards the source from a line reflector (long thin cylinder) is much lower (Urick, 1983; Hatakeyama *et al.*, 1994). The TS is also dependent on range as the length of target insonified by the transmitted beamwidth changes. These factors may partially explain the disappointing second year results noted by Hembree and Harwood (1987) when their 'bead chain' was deployed diagonally within the net structure.

Clearly if a significant proportion of the intercepted acoustic energy is reflected back directly towards the source, independently of the approach angle, then the perceived echostrength will remain consistently high. However, most simple shapes, large enough to return specular reflections, involve flat reflecting facets which are highly orientation and wavelength sensitive and these will rarely be positioned to reflect echoes back directly towards the approaching animal.

Reflecting shapes which return the intercepted radiation back along a reciprocal bearing can be constructed, e.g. the radar 'diamond' commonly found on navigation buoys and small boats effectively increases the TS detected by a ship's radar. However, the acoustic equivalent of an idealised 'corner reflector' has several design parameters which need to be taken into account if the result is to be efficient.

Target Strength – directivity

The strength of echo returned by a target depends on several factors, the most important being the shape and size of the target, the material of its construction and the intensity of insonification and its angle of incidence. The smaller the target, the less the returned energy. However, as the target's size in cross-section becomes $<1\lambda$ of the incident sound, the echo strength returned decreases quickly (λ = the acoustic wavelength in the medium). Small gas bubbles can exhibit resonant peaks in some circumstances and may be an exception to this generalisation. Since λ for sound in seawater at the peak frequency of 120kHz is 12.5mm, this represents a minimum target dimension for *T. truncatus* below which the intercepted energy will be scattered rather than reflected.

The reflecting target's dimensions must be evaluated in terms of the wavelength (λ) of the incident acoustic wave (see description in Clay and Medwin, 1977; Urick, 1983). As a simple guide, if the re-radiating target cross-section equates to a flat disk of single λ diameter, the reflected energy will be re-shaped as a spreading cone some 60° wide together with lower intensity side lobes (note that when the echoes are perceived by a monostatic sonar, this angle appears to be 30°!) For smaller target dimensions, the reflected energy is scattered over wider angles and tends towards an omnidirectional distribution. For larger apertures, the width of the reflected cone of sound will be progressively narrowed and hence more intense (for a 2λ diameter aperture the cone becomes 30° etc.) Conventional acoustic engineering utilises 'wave numbers' ($k=2\pi/\lambda$) to simplify the problems of estimating TS variation with size in a given medium. When the wave number defined by the surface dimensions (radius=a) and $ka>5$, then the object is assumed to reflect 'geometrically'. When $ka<5$, 'Rayleigh' scattering effects dominate. Diffraction effects result in a rippled amplitude response as the dimensions approach $ka=1$ and these less predictable sizes are normally to be avoided (Fig. 4).

The most predictable reflecting shape, which has frequency independent characteristics and a consistent TS independent of the incident angle, is a large sphere, but attempting to obtain large TS's by increasing size will rapidly lead to net deployment problems. However, some non-spherical target shapes can offer significant size advantages.

Cylinders of significant length (with a diameter where $ka>1$) will only return strongly directional echoes towards the source if the incident wave approach angle is normal to the straight cylindrical surface. However, the energy is spread omnidirectionally in the other plane by the circular cross-section. To be effective this shape would require accurate vertical deployment within the net structure and even so, unless the animal approached horizontally, the perceived returns would be minimal.

Thin cylinders ($ka<1$), i.e. ropes or bead chains, are much less effective, as the sub-wavelength cylindrical crossection is a Rayleigh scatterer and the specular return due to the length insonified is sharply directional.

Flat disks deployed in the plane of the vertical net wall suffer the same disadvantage, in that the maximum return only occurs for incident signals normal to the surface. Although these reflections are relatively intense, in a practical deployment they cannot be assumed to occur towards the approaching animal (there is a special case where $ka=1$ which, although inefficient, may be considered a useful economic option).

It should be clear from these examples that the angle of incidence to a reflecting surface is critical.

Acoustic impedance

The target material affects the percentage of energy reflected *versus* that transmitted. Most animal and fish tissues are relatively transparent to sound, and more incident energy passes through the target than is reflected. The best sound reflection will occur from materials with a ρc value very different to water, e.g. a gas bubble reflects incident energy well (ρc is an expression of acoustic impedance and is the product of ρ, the density and c, the sound velocity for the material.)

Synthetic net materials, especially the monofilament varieties, are relatively transparent to sound. Traditional net materials, twisted from natural fibres, tend to trap significant quantities of air which are retained for quite long periods of immersion and hence exhibit much higher TS's. Fish TS in the swim bladder species is dominated by the bladder gas bubble (Foote, 1985). For species without a swim bladder, the bone skeleton may reflect sound better than the flesh, but as the proportion of bone is small, the overall TS of such fish is significantly lower. Molluscs such as squid and octopus are predicted to have low TS's relative to body size.

Efficient sound reflecting materials must exhibit a significant mismatch in acoustic impedance when compared to water; both very dense materials and very low density materials can be good reflectors.

Dense materials such as rock or metal with high ρc values reflect echoes which are in-phase with the insonifying signal. In contrast, gas-filled objects (including foamed plastics) are classed as 'pressure release' and produce echoes characterised by a phase reversal between the incident sound and its echo, a perceptual detail that a dolphin may be capable of exploiting when classifying targets as potential food. Evidence that a dolphin can detect the difference between an initial 'rarefaction' and a 'compression' pulse is reported by Ridgway *et al.* (1981). The possibility that echoes from gas bubble filled objects could be perceived as 'food like' and therefore act as 'attractors' must be considered.

A further disadvantage of gas-filled objects is the difficulty of ensuring accurate shape retention with increasing water pressure. Thin-walled plastic tubes, balls etc., all tend to collapse or deform badly with hydrostatic pressure and predictable reflection characteristics cannot be assumed.

Any material selected for deployment at sea must be examined for its longevity in saltwater corrosive conditions. Most metals are very susceptible to electrolytic corrosion and connections made with dissimilar conductive materials can result in very rapid dissolution.

Deployment – reflector distribution

The distribution pattern of any deployed reflectors must also be considered. It is desirable that the dolphin perceives the enhanced net as a continuous barrier rather that a series of minor obstructions. Experiments with spinner dolphins, using net crowding techniques, have shown that escape apertures less than 1m x 1m in size seriously deterred the animal from attempting to pass through (Perrin and Hunter, 1972). If this factor can be transposed to distributed point reflectors, then an equivalent distribution density of $1m^{-2}$ provides a useful starting point for experimental evaluations.

The TS of reflectors must to be as high as possible in order that the barrier created can be perceived in the presence of fish targets. However, physical size, shape and total mass must be compatible with net handling. Specifically the shape chosen must pass through net handling gear without damaging the net to which it is attached. Similarly the attached device must be retained on the net efficiently without creating entanglement problems in storage. The total mass of the reflectors must not seriously alter the net buoyancy or behaviour when the net is set. The distributed pattern of reflectors must not impair the primary function of the net which is to catch fish. Finally, the extra cost of net modification must be seen to balance the significant down time losses currently incurred through net damage.

Preferred echo-enhancing shapes (Fig. 5)

One practical option is to create a disk reflector surface as a segment taken from a larger sphere i.e. a bi-convex lens shape. The surface curvature must be selected to return the echo into a suitably restricted range of approaching angles. The device must be mounted in the plane of the net and will then generate quite large TS's without excessive physical dimensions. This reflector will be least effective at grazing angles of approach to the net.

A corner reflector 'diamond' shape, with included 90° facets is probably the most efficient relatively simple shape. Almost all the incident energy is double reflected back into the approaching dolphin's path. However, the angular shape may be incompatible with net handling operations, although it could be deployed in fixed gear and in beach protection 'shark nets'.

Reshaping a sphere into a faceted polygon can offer some enhancement if the size is carefully optimised: if the facet size is small ($ka<1$) there is no advantage, as the object behaves as a sphere of the same overall size; if very large, then the echo return pattern will possess deep nulls between peaks.

A cast metal 'icosahedron', with the faceted sides replaced with corner reflecting recesses, is an effective and compact target. However, in this context, the shape complexity may make mass production uneconomic.

A simpler shape with few of the perceived disadvantages of the previous examples, is the 'bi-conic' or 'diabolo'. This in effect is a cylindrical corner reflector constructed from two conical 90° sections mounted point to point.

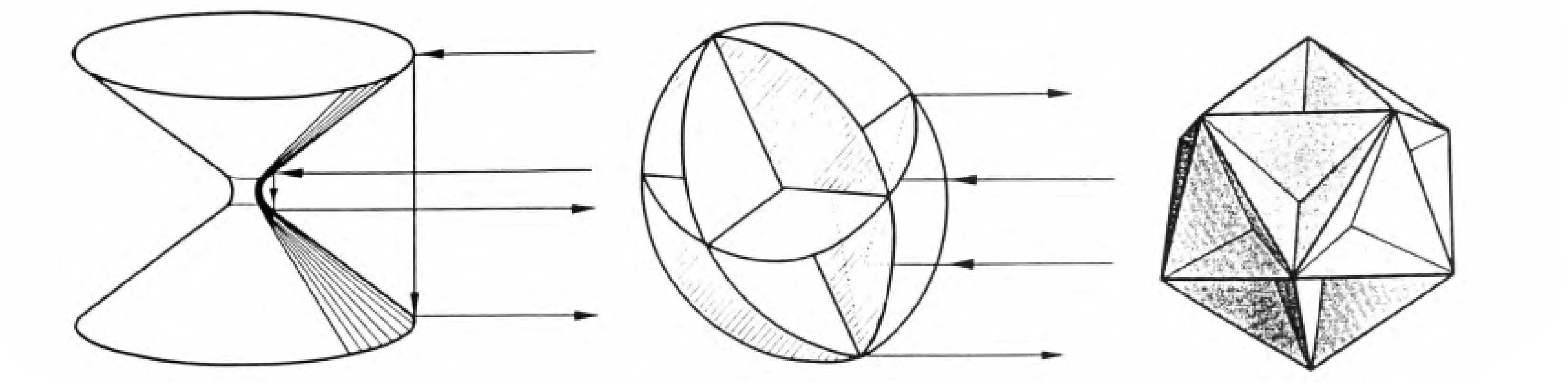

Fig. 5. Strong echo forming target shapes which return significant energy directly back towards the source.

Reflections are returned towards the source by double reflection as from a line reflector, energy in the other plane being spread cylindrically. These shapes may be made compatible with net handling and a variety of mass production techniques appear possible and requires more detailed study.

An additional reflection mechanism offering a high TS for a given size is the 'focussing sphere' (Folds, 1971). This device comprises a thin wall spherical metal shell containing a high density liquid filling (SG 1.8 – 1.9) with a high sound propagating velocity. The sphere size and the liquid filling are selected to bring the incident (planar) wave front to a focus on the back wall of the sphere where total reflection occurs. The liquid lens then refocuses the returning echo back along the incident path. For a given size, this device can offer the strongest echo return towards the source, but the TS is frequency dependent. The concept of liquid filled spheres as net markers does not lend itself to practical deployment in a fishing industry context and in any case the liquid fillings, some based on CCl_4, could involve handling problems.

Target dimensions

The dolphin 'click' signal comprises a relatively wide band transient pulse with a duration of less than 1ms. When this transmission is sampled on-axis, its energy spectrum is observed to peak near 120kHz, within a 10° (-3dB) beamwidth, (Au, 1980). If the signal is sampled outside this angle, the spectral peak is observed to fall as a direct result of the limited acoustic aperture of the melon. Measured at 60kHz, the projected beamwidth will be approximately 20° wide. Since an animal's acoustic sensitivity is best between 60 and 80kHz and still excellent at 120kHz (Johnson, 1966; Seeley *et al.*, 1966), it would seem a desirable compromise that echo-reflecting net markers should provide enhanced echo returns at all these frequencies.

Fig. 6 compares the computed maximum TS's predicted for a range of dimensions, with a 60kHz insonification, for some of the shapes discussed. These were based on formulae listed by Urick (1983) and from J. C. Cook (pers. comm).

For a nominal TS of –35dB at 60kHz, the computed size for each shape will be:

Sphere = 7.1cm diameter	(ka>5)
Corner reflector = 2.3cm sides (4.6cm dia.)	(ka>2)
Diabolo= 5.6cm diameter	(ka>5)

Clearly other target shapes can be considered, especially as the conventional design requirement of a constant TS with angle can be relaxed in this application. However, a successful net marking reflector must meet not only the acoustic but also mechanical and economic criteria to be acceptable to the fishing industry.

This above discussion has concentrated on passive reflectors with dimensions optimised for detection at the maximum foraging ranges searched by the smaller delphinoids. The concept is unlikely to be as effective for the larger echolocating animals as their echo-perception is assumed to exploit much lower spectral components. To be effective for these, the passive reflectors would need scaling in size but this is likely to exceed the mechanical limitations imposed by commercial net handling.

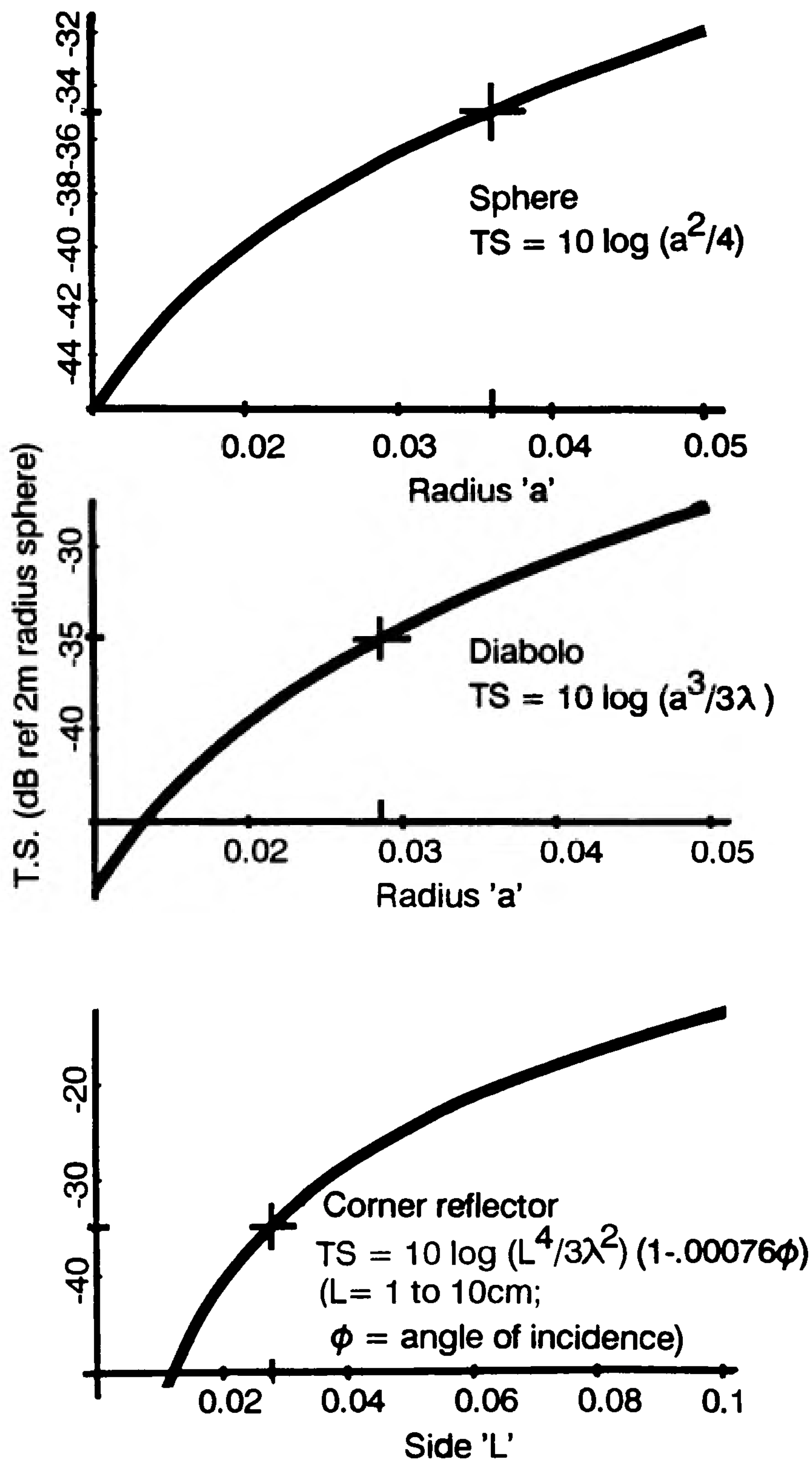

Fig. 6. Computed TS for a range of sizes, a=1cm to 5cm at an ensonifying frequency of 60kHz.

CONCLUSIONS

The sense most likely to perceive a fishing net obstacle is the dolphin's active sonar but this is only likely to be in operation when the animal is foraging for food. At other times, active sonar cannot be assumed to be a factor. If a dolphin is fishing and has already detected and locked its sonar repetition frequency onto the range of a target fish, then echoes from greater ranges are suppressed and perception of a fishing net prior to entanglement is unlikely unless the TS of the net is enhanced very significantly. Advance warnings from echoes generated by other dolphins in close proximity are unlikely to provide any interpretable information about the obstacle's presence.

Increasing the gillnet TS by the addition of wires, ropes or thin 'bead chain' will be ineffective if these devices are intercepted at incident angles other than normal. True vertical deployment of these acoustically 'thin cylinders' is essential if the technique is to be of benefit. Enhanced echo reflector shapes can be designed to return strong specular echoes directly towards the approaching animal and such devices are more likely to be perceived independently of the azimuth/elevation angles of approach. The distribution of reflecting devices along the net may need to approach a $1m^2$ pitch spacing if the echo structure is to be classified as an impassable barrier by the animal.

In order that an animal can perceive the net position before locating a fish, the gillnet TS needs to be increased to be at least as detectable as the maximum size fish prey normally taken. The stomach contents of autopsied bycatch victims should be examined in an attempt to obtain this information for all vulnerable animal groups.

If the reflecting surface of the TS enhancer is manufactured from a pressure release material, single surface reflections may be perceived as 'food-like' and could act as attractants. The same effect may occur with time as the captured target species accumulate in the net. The mass, buoyancy and shape of the added reflectors need considering carefully as these parameters will affect the deployed behaviour of the gillnet and its handling during deployment and recovery.

The passive reflector target shapes which seem worthy of practical evaluation should include the 'diabolo', 'diamond' corner reflector and derivatives of these. In practice, however, any design which demonstrates a measurable reduction in cetacean bycatch must also satisfy additional mechanical and economic parameters imposed by the commercial gillnet fishery if it is to be accepted without legislation.

Additional economic and ecological incentives in favour of significantly increasing the fishing net TS can be found in the context of lost netting. Lost fishing gear, particularly bottom set nets, continue to fish for long periods as 'ghost' nets, the recovery of such gear is likely to be simplified if the nets can be more easily located by a ship's echosounder.

Goodson *et al.* (1994) describe how the principles described in this paper were put into practice in the development of a prototype modified net and in initial field trials.

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Field Testing Passive Acoustic Devices Designed to Reduce the Entanglement of Small Cetaceans in Fishing Gear

A.D. Goodson

Signal Processing Research Group – Bioacoustics & Sonar, Electronic and Electrical Engineering Department, Loughborough University of Technology, Loughborough LE11 3TU, UK

R.H. Mayo

Department of Civil Engineering, Loughborough University of Technology, Loughborough LE11 3TU, UK

M. Klinowska

Research Group in Mammalian Ecology and Reproduction, Physiological Laboratory, University of Cambridge, Downing Street, Cambridge CB2 3EG, UK

P.R.S. Bloom

The Dolphin Centre, Flamingo Land, Kirby Misperton, Nr Malton, North Yorkshire YO17 0UX, UK

ABSTRACT

Field trials to examine the behaviour of wild bottlenose dolphins in the presence of passive acoustic deterrents supported in a surface set gillnet configuration were carried out in September 1991 and 1992 in the Moray Firth, Scotland. Leading animals were tracked using electronic theodolites as they interacted with these barriers which were placed across their regular travel paths. Underwater acoustic behaviour was recorded from hydrophones via radio telemetry. Avoidance behaviour was consistently initiated at ranges greater than 50m and occasionally greater than this. On only two occasions behaviour that might have resulted in entanglement was observed. In addition a sea trial using commercial tuna gillnet gear was undertaken in which a sidescan sonar was used to evaluate the acoustic detectability of both modified and unmodified components. The potential of passive acoustic deterrents for the reduction of cetacean bycatches in commercial fisheries is discussed.

KEYWORDS: INCIDENTAL CAPTURE; FISHERIES; NORTH ATLANTIC; BOTTLENOSE DOLPHIN; ACOUSTICS

INTRODUCTION

The problem of incidental catches of marine mammals (and indeed other non-target species) in fishing gear is well known (IWC, 1994). As discussed in Goodson *et al.* (1994), one approach to the problem has been to investigate ways of making nets more apparent to the animals. Although a number of attempts to increase the acoustic detectability of fishing nets have been made, the methods employed have been largely ineffective in achieving a reduction in cetacean bycatch (see review by Dawson, 1991). In general, the techniques employed did not consider the wavelength-dependent resolving power of dolphin sonar signals, the directivity of the reflectors or the behaviour-related restrictions imposed by the animal. Furthermore, the problem is now seen to include target classification, i.e. it is not simply a problem of detection (Au and Jones, 1991; Au, 1994). In other words, it may be difficult for dolphins to interpret weak diffused echoes from nets as a life-threatening hazard, when experience has taught them that similar volume scattered echoes, returned by algae or by entrained air bubbles, are penetrable zones to be ignored, especially when a discrete fish target can be detected on the far side (Goodson, 1992; 1993).

As described in Goodson *et al.* (1994), our approach differs significantly from these earlier attempts in that we seek to enhance the detectability of the fishing net under all conditions to a level at least equivalent to that of the larger prey sought by the foraging animal. This objective cannot be achieved by simply altering the dimensions, material or other base characteristics of the gillnet mesh, as the reflectance of the webbing structure is primarily limited by its geometry (assessed in wavelength terms). Even if the webbing were to be constructed from a perfectly reflecting fibre material, the overall Target Strength (TS) enhancement that could be achieved is unlikely to exceed 10dB above that of unmodified monofilament nylon. Goodson *et al.* (1994) estimated that enhancements greater than 25dB may well be required. To achieve such improvements, the devices added need to be efficient acoustic reflectors returning echoes directly back towards the source (analogous to 'cat's eyes' road markers which reflect car headlights back to the driver). Some limitations of dolphin sonar in the context of net-like targets and parameters to be considered when attempting to apply acoustic engineering techniques to the design of efficient passive acoustic reflectors have been discussed elsewhere (Goodson, 1990; Goodson *et al.*, 1991; 1994; Goodson and Datta, 1992).

Whilst an efficient reflector design must be optimised to suit the characteristics of the individual odontocete sonar, a consideration of the wavelengths involved suggests that a common solution for the delphinid species similar to the bottlenose dolphin (*Tursiops truncatus*) and for the smaller phocoenids seems to be practical. In summary then, to at least have the possibility of success in addressing the bycatch problem, the following acoustic characteristics would be required of a sonar reflector:

(1) echoes from the approaching animal's sonar must be reflected directly back towards the animal, regardless of its approach direction in either azimuth or elevation;
(2) the device must be large enough (in acoustic terms) to intercept and return a specular echo with sufficient energy to become a more detectable target than the

largest fish normally foraged for – the individual devices should be detectable at the maximum search range of the animal;

(3) the reflecting devices must not generate echoes which can be incorrectly classified as 'food-like' or the devices may function as attractors;

(4) the distribution of the devices across the face of the net must be perceived (at close range) as an impenetrable barrier.

These minimum parameters have been quantified, largely through detailed studies of wild bottlenose dolphin foraging behaviour, and several physically small prototype reflectors have been engineered which appear to meet these requirements (Goodson *et al.*, 1994). For a bottlenose dolphin foraging in relatively shallow water, a reflector with a TS of approximately –35dB (reference a 2m radius sphere) appears to be optimum.

This approach has been used to identify a commercially available device which possesses acoustic and mechanical characteristics that meet many, but not all, of the parameters needed by an optimised reflector. The present paper describes a series of experiments that have been devised in which the distribution of these devices, supported within a simulated surface gillnet configuration, could be closely studied in interactions with wild bottlenose dolphins. These experiments are similar in concept to those described by Silber (1994). However, our approach also includes the monitoring of cetacean echolocation signals underwater in the vicinity of the barriers, video recordings and a high order of achievable precision in the electronic theodolite tracking technology (Mayo and Twigg, 1993). The preliminary results presented here confirm that the devices tested function effectively to deter echolocating bottlenosed dolphins at ranges in excess of 50m and occasionally from as far away as 170m. These initial experiments allow interaction data to be obtained at a faster rate than can be achieved in a commercial fishery and without placing the animals at risk of entanglement. At this stage the experiments were not designed as statistical tests of efficiency but were rather qualitative studies to determine the value of continuing the current line of research.

The practical problems that fishing nets modified with this reflector technique may cause to commercial fishermen have also been examined in a short sea trial off Cornwall, in which an experimental net was shot and hauled and examined with a side scan sonar for its acoustic detectability.

MATERIALS AND METHODS

Wild dolphin interaction trials held in the Moray Firth

The site chosen for the first field test carried out in September 1991 was the Moray Firth, NE Scotland. This was chosen for a number of reasons. The bottlenose dolphins in the area are already being studied and a catalogue of approximately 150 photo-identified individuals has been compiled (Wilson *et al.*, 1992). Although not used in the trials described here, the potential to identify individual animals may be important for future work. Animals are regularly sighted within 200–600m of shore near the entrance to the Cromarty Firth, where there is good visibility from adjacent 50m cliffs and the seabed in the zone of interest is flat (hard sand) with a minimum water depth of 7m. A larger scale experiment was carried out in the same area in September 1992.

Equipment and procedures

As shown in Figs 1 and 2, in 1991 a single barrier, consisting of a buoyant head-rope from which thin rope tails were attached, was deployed perpendicular to the shore, across the predicted path of the dolphins. The acoustic reflectors were attached at 2m intervals to the rope tails, which were spaced 2m apart. The head-rope was 200m long, half unchanged and half supporting a grid of reflectors, comprising an obstruction 100m x 7m deep.

In September 1992, a larger scale experiment was carried out using two 200m long barriers of reflectors distributed on a 2m x 2m spacing. On the last two days of the two week study concluded with one barrier reconfigured with a reduced numbers of reflectors (6m x 2m spacing).

Details of the differences between the 1991 and 1992 trials are illustrated in Fig. 1 and Table 1.

A detailed list of equipment for both years is given in Table 1. The experiment extended that described by Silber (1994), with the dolphins being tracked by their surfacing positions using an electronic theodolite (with data logger), and underwater acoustic activity monitored with sonobuoys. The theodolite employed was also capable of working as a distance measuring device and in this mode the instrument could be used to accurately measure its own height above sea level. Subsequent measurement of horizontal and vertical angles enabled the Northings and Eastings of each surfacing position and of the head rope barrier, to be calculated and plotted. The precise times of these readings were also recorded. As only one theodolite of this type was available it was usually not possible to track more than the leading animal(s) from each passing main group, even when several distinct sub-groups were present. To back up the theodolite readings, two video cameras and voice-logging recorders were used. The underwater sounds, received from the sonobuoy hydrophone by radio telemetry, were recorded on a four-track instrumentation machine, together with timecode and a voice log. A second receiver simultaneously fed the telemetry to an R-DAT digital recorder. In general, observations could be maintained only between dawn and dusk, as the team was too small to provide full 24-hour cover.

Initial handling trials at sea

A short sea trial took place in Cornwall in June 1992, where both modified and unmodified panels of gillnet were shot and hauled in order to evaluate handling problems. Additionally the acoustic detectability of echo-enhanced net panels was compared with equivalent un-modified sections at different ranges and angles using a 100kHz sidescan sonar.

Equipment and procedure

A short sea trial to discover any practical problems associated with using modified nets was arranged with the support of the Sea Fish Industry Authority on board a UK gillnet fishing vessel, the 15.25m (overall length) *Britannia V* (FH 121). A test net, based on a commercial tuna net, was prepared (Table 2, Fig. 3). The reflectors had been prepared, by a commercial twine manufacturer, within a mixed fibre flat braid. This technique was chosen with a view to ease of handling and reducing the likelihood of 'buttoning', which would cause adjacent layers of netting to catch together. Braiding also avoids the torque effects that occur in a conventional rope when under tension.

Table 1

Equipment for Moray Firth 1991/92 Trials.

Equipment	1991	1992
Radio		
Telemetry from hydrophones	Wide band sonobuoy; Type UEL 30059 modified for extended life	SSQ904 sonobuoys modified for wide band operation
Telemetry receivers	*Yaesu* FT9600 (2); *Icom* R1; *AR* 2002	*Yaesu* FT9600 (2); *Icom* R1; *AR* 2002
Communications	Hand-held radios (4)	Hand-held radios (4)
Recording equipment	*Racal* Store 4 DS - high speed instrumentation recorder; *Aiwa* HD-S1 R-DAT recorder; *Nagra* IV SJ reel to reel	*Racal* Store 4 DS - high speed instrumentation recorder; *Aiwa* HD-S1 R-DAT recorder; *Nagra* IV SJ reel to reel
Timecode	*Yam* EBU timecode generator and reader	*Yam* EBU timecode generator and reader
Video equipment	*Sony* Broadcast Hi-8; *VHS* camcorder; *JVC* portable recorder	*Sony* Hi-8 V5000; *VHS* camcorder; *JVC* portable recorder
Theodolite	*Sokkia* Set 5, EDM prism and data logger	*Sokkia* Set 5 total station, EDM prism and data logger, *Sokkia* DT4 theodolite
Computer	*Walters* 386 notebook	*Walters* 386 notebook, *Apple-Mac* power book, Husky Hunter
Vehicles	*Ford* camper (base); *Shogun* 4 x 4 (all-terrain transport)	*Ford* camper (base); *Shogun* 4 x 4 (all-terrain transport)
Boats	7m hard chine double hull motor boat *Zodiac* inflatable with outboard motor	Orca - Ex Air/Sea Rescue launch Osprey - rigid inflatable
Test barrier	1 x 200m headline, half rigged to support a 2 x 2m grid of reflectors (see Fig.1); made to the same specifications as the headline of the Eastern Atlantic tuna gillnets	2 x 220m headlines rigged with reflectors initially at 2 x 2m spacings with leadlines (see Fig.1)

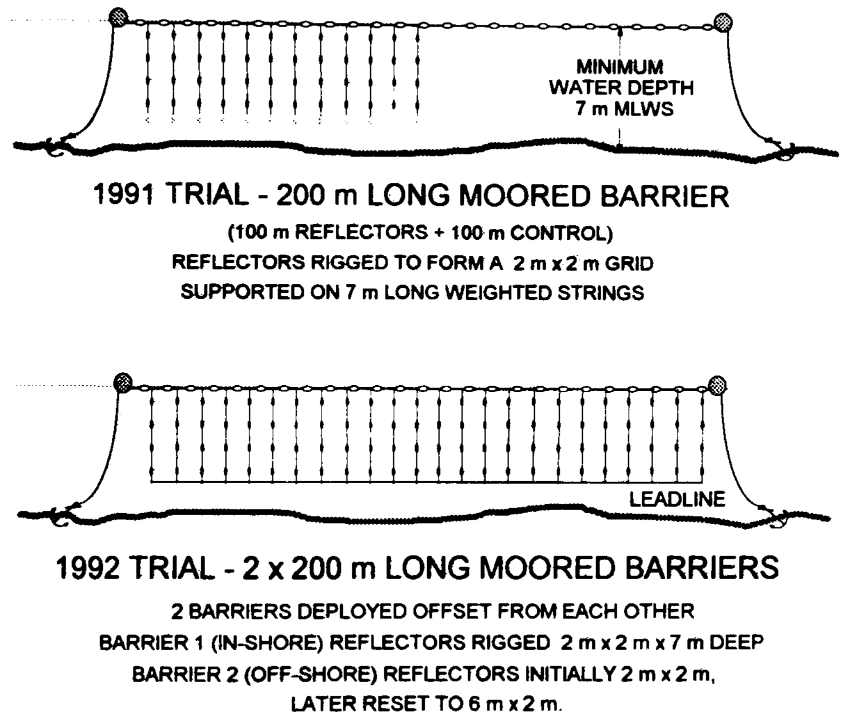

Fig. 1. Headline and reflector configurations.

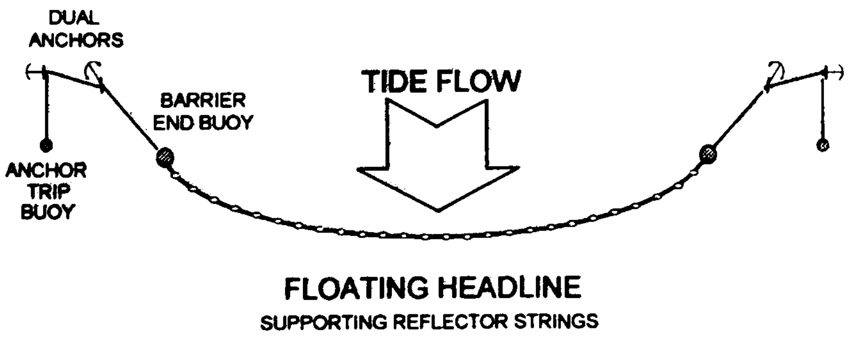

Fig. 2. Diagram of deployment plan for each headline barrier.

Table 2

Net specification for 1992 sea trial.

Mesh
Twine size: 210/18 (420 tex)[1] red nylon multifilament
Mesh size: 168mm stretched (6.625 inches)

Panel
Mesh long: 588
Mesh deep: 125.5
Stretched panel length: 100m

Rigging
Ranging ratio (E) 0.55
Staple settings: 2 full meshes onto the staple length
Staple length: 197mm (7.375 inches)
Set depth: 17.8m
Set length: 55m
Flotation: one polyurethane 350g buoyant float every 1.1m (44 inches)
Leadline: No. 4 reinforced, runnage 11kg/100m

Prototype Acoustic Reflectors
Target strength: nominal -35dB (ref. 2m radius sphere) rigged in a 2 x 3m grid across the face of the net
Reflectors: plastic, elliptical, air-filled, 20g weight in air, 20g lift in seawater (nominal); length 67mm, maximum diameter 33.5mm, axial hole 10mm internal diameter
Attachment sheath; braided polyethylene/polypropylene/worsted twine composition; runnage 35.3g/m
Reflector vertical spacings (from headrope downwards): 3m, 6m, 9m, 12m, 15m
Reflector string horizontal spacings: every 2m along the net.

[1] 210/18 is a Denier notation for twines.

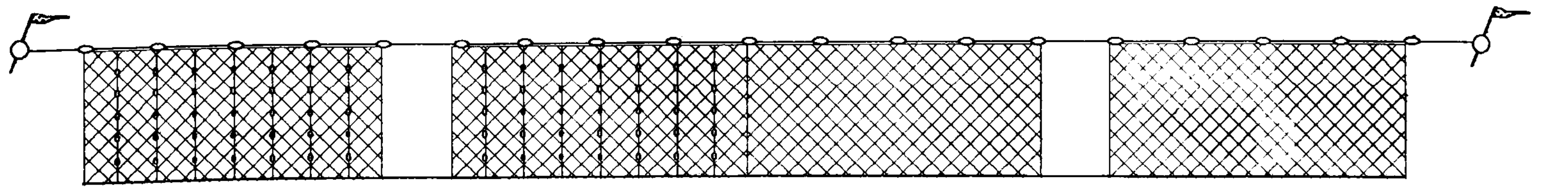

Fig. 3. Configuration of experimental gillnet for the 1992 sea trials, total length = 240m. Four off panels (each 55m long by 18m deep) and 2 modified panels with reflectors + 2 unmodified + 2 gaps (10m wide).

The prototype devices employed (small ellipsoid shaped pressure release reflectors) were applied to two of four panels of an experimental 240m long 'tuna' drift net and were distributed in a 2 x 3m grid pattern across the face of the net (see below). The study included the use of a *Waverley* 3000 towed sidescan sonar to examine the effectiveness of the modified net as an acoustic barrier. The sidescan sonar equipment operated at 100kHz, i.e. with a wavelength λ of 15mm in seawater. At this frequency the sonar has a broadly similar resolution to that of the bottlenose dolphin. The animal's resolution is limited by the highest frequency response in its audiogram, i.e. for the bottlenose dolphin around 120kHz to 130kHz, (Johnson, 1966) and by the presence of these frequencies as spectral components within its sonar transmissions, (Au, 1980). The sidescan sonar operated at a Source Level of 227dB reference 1 μPa which is very close to the maximum reported for a bottlenose dolphin (Au, 1980). However, it is important to appreciate that the dolphin's sonar functions as a forward looking (10°) spotlight system whereas the sidescan generates two very narrow vertical 'fan' beams (1.5° x 50°) which are projected at 90° to each side of its track. The sidescan image is built up on a paper record from successive transmissions as the tow fish, several metres below the surface, follows its parent vessel's course (Fig. 4).

Fig. 3 illustrates the net configuration employed in the gillnet trial. The first pair of 55m long panels were modified with a grid of acoustic reflectors spaced apart 2m horizontally and 3m vertically. A 10m wide gap was deliberately inserted as a potential 'passing place' between these. The remaining pair of panels were also separated by a 10m gap and the two 120m sections butted together. The reflectors in braided tubes formed vertical 'strings' attached to both headline and leadline. The complete net assembly, with marker dahn buoys attached by short bridle ropes to each end, was shot in very calm conditions in 50m water depth where it drifted throughout the period of study. The sidescan sonar was deployed 50m behind the vessel and a series of runs made with the tow-fish deployed between 15 and 20m depth at different ranges and angles to the experimental net.

RESULTS

Moray Firth

September 1991

Control sightings and recordings, made before the barrier was deployed (e.g. Fig. 5), confirmed that dolphins passing in small groups, and in loose associations of up to about 30 animals, did swim parallel to the cliff, in both directions, at a predictable distance offshore (2½ days of observation, an average of about 30 animals per day). The presence of a moored sonobuoy close to this track line had no discernible effect of the passing animals' behaviour (which was usually travelling). As the barrier was first deployed on the afternoon of 27 September, a group of dolphins approached. There was considerable acoustic activity and all the animals diverted to avoid the barrier, taking an inshore passage very close to the edge of the kelp (Fig. 6). Late the following morning the inshore anchor of the barrier dragged, but for the first afternoon and most of the next morning animals were observed passing, in both directions, between the inner end of the barrier and the shore in a narrow zone of very shallow water. After some difficulty in obtaining stable moorings closer to shore, the barrier was finally repositioned during the morning of 29 September to obstruct the inshore passage.

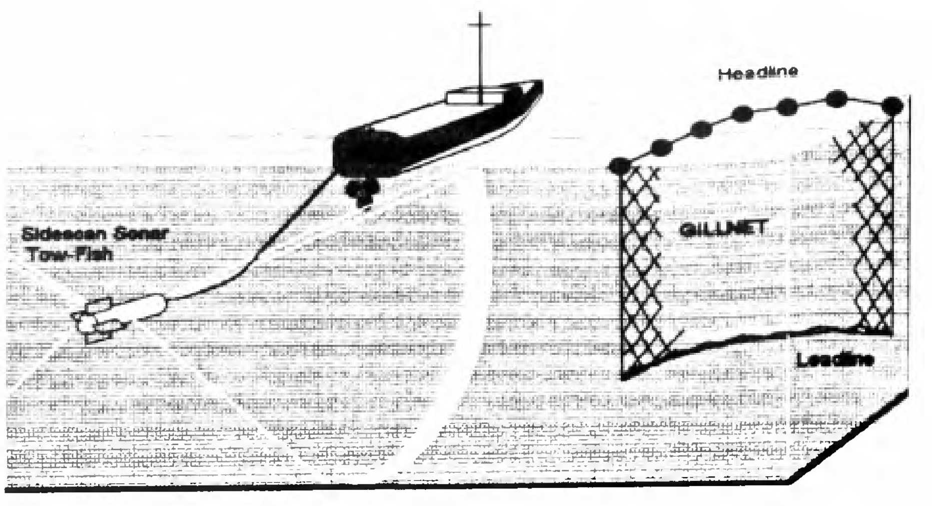

Fig. 4. Diagram of sidescan sonar examining net.

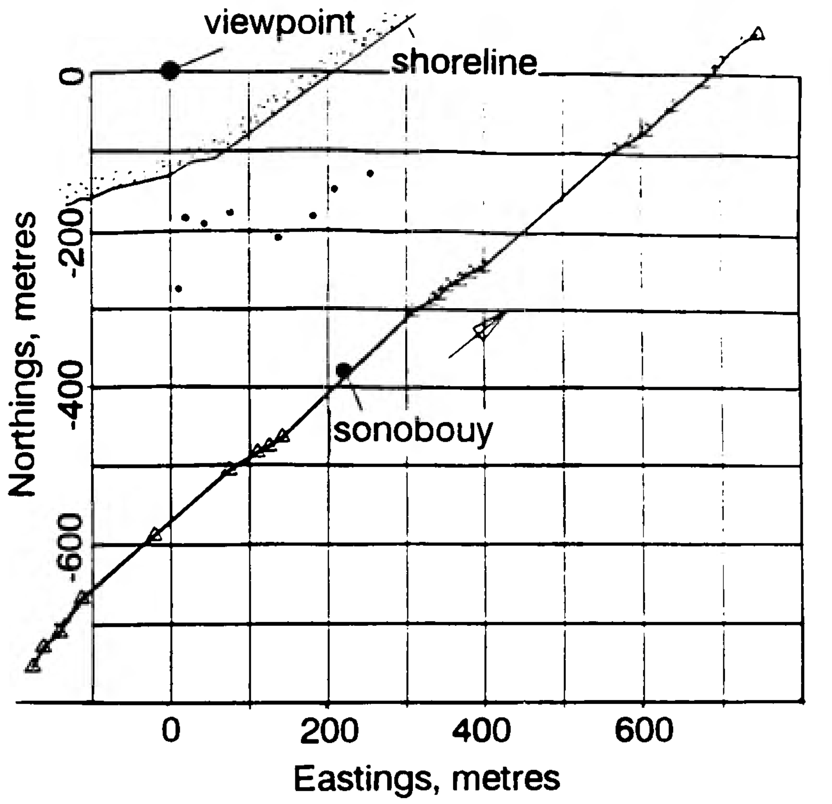

Fig. 5. The passage of the leading animal (direction shown by arrow, surfacings by triangles, the line represents minimum distance between surfacings) of a group of five bottlenose dolphins (including one accompanied by a calf) before deployment of the headline barrier. Deployment of the sonobuoy is clearly not associated with any deviation in the line of travel. The solid dots show the positions of buoys marking crab pots.

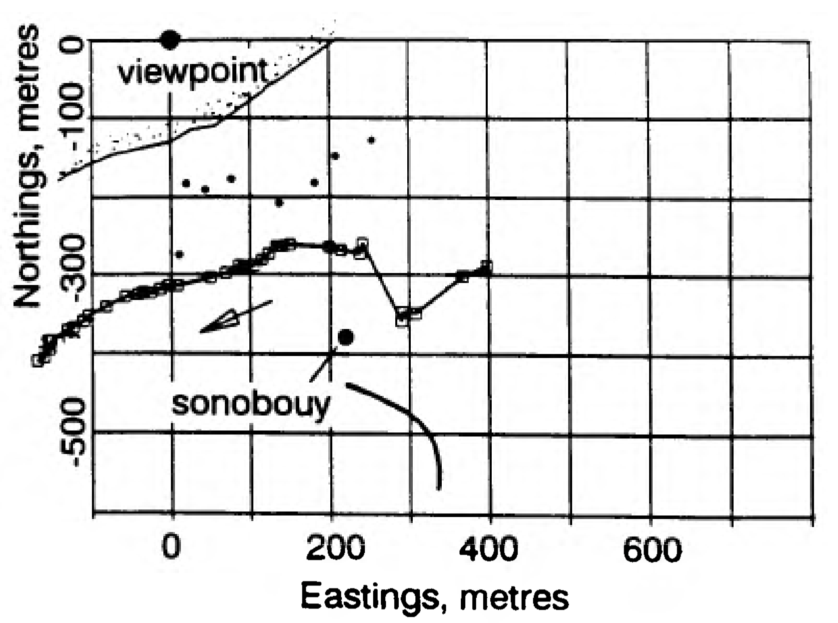

Fig. 6. The passage of the leading animal of a group of 8–10 (including 2 juveniles) after deployment of the headline barrier; Squares indicate surfacings. Although the initial approach is exactly on the line shown in Fig. 5, there is a clear deviation inshore to avoid the barrier.

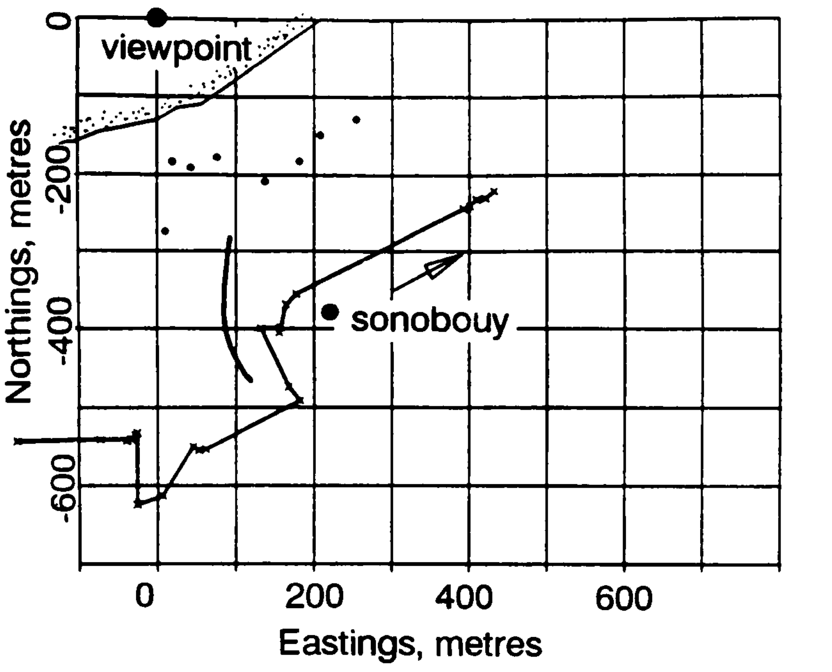

Fig. 7. The passage of a pair of animals leading the first sub-group of the second main group on 30 September 1992, after final deployment of the headline barrier closer inshore. (For further explanation, see Fig. 5. Surfacing positions shown here by crosses.)

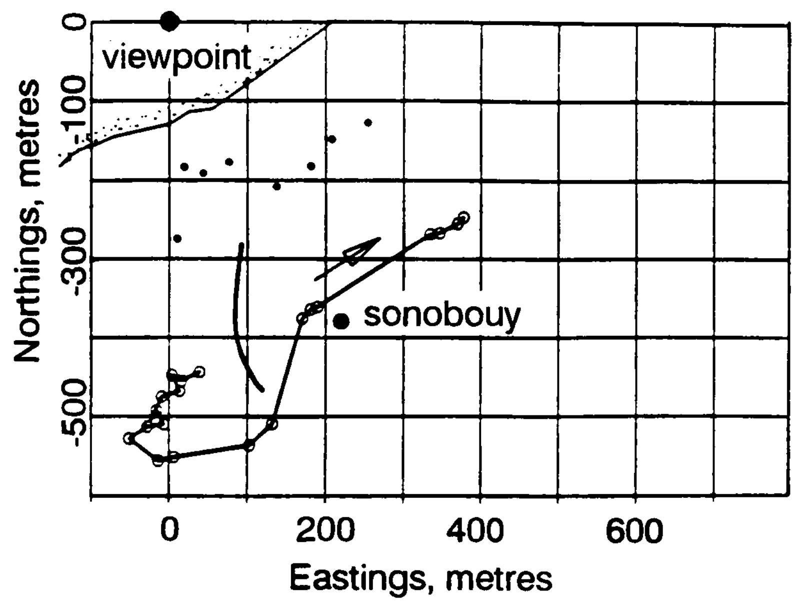

Fig. 8. Passage of a single animal, a trailing member of the second main group on 30 September 1992, first sighted 55 m from the headline barrier. Note that in this figure the arrow only indicates the general travel direction. (See text, Fig. 5, Fig. 9 and Table 3 for further explanation.)

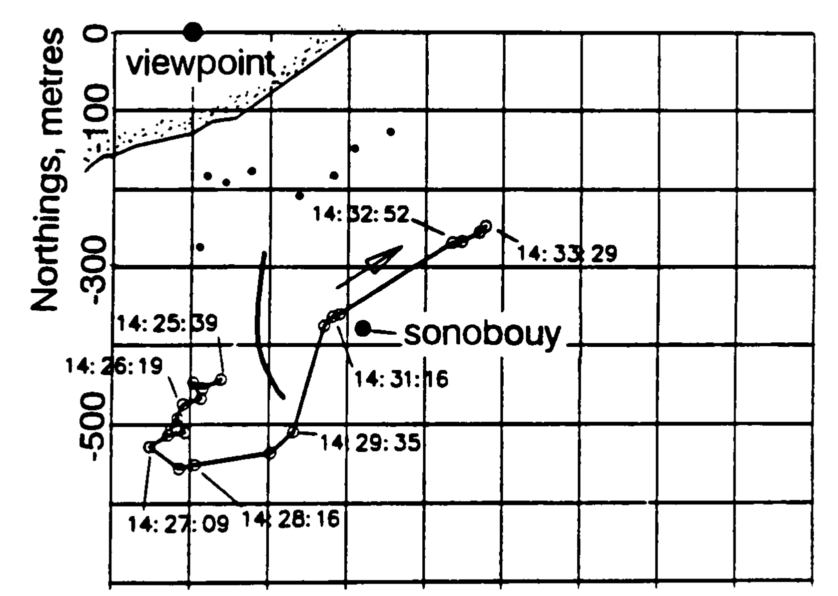

Fig. 9. Time between surfacings of the animal from Fig. 8. Surfacing positions, minimum calculated speeds and times between surfacings are tabulated in Table 3.

In the early afternoon of the final working day (30 September), two distinct main groups of about 30 animals, each with several sub-groups, were observed sequentially passing the outer end of the barrier over about an hour. The track of a pair of animals leading the first sub-group of the second main group is shown in Fig. 7. After tracking this pair through the test zone and while other sub-groups were still passing, a single animal was seen to surface some 55m from the centre of the barrier. The subsequent track of this animal is plotted in Figs 8 and 9. It retreated, initially at a speed of about 3–4ms^{-1}, to a distance of 170m. This apparent retreat from the barrier was interrupted several times, with the animal backtracking briefly while swimming at much slower speed (Table 3). It finally altered course to join the track of the rest of the group and, closely following this, swam past the outer end of the barrier. Then, as had been observed for the previous passing groups, the single animal appeared to investigate the back of the barrier before leaving the area, continuing along the usual line of passage. The similarity between these two main tracks can be seen by comparing Figs 7 and 8. It has not been possible to establish from the photographic evidence whether the same or different animals passed during the days of the experiment. It is possible that some individual identification information may be obtained from analysis of 'signature' whistles. However, from the experience of the photoidentification team (Wilson, pers. comm.), it seems likely that the groups were different.

Subsequent analysis of the recorded underwater sounds demonstrated no obvious echolocation activity which can be assigned to the approaching single dolphin until seven seconds before the first surface plot made as it retreated.

Table 3

Surfacing times, positions and minimum swim speeds from Fig. 6 (land referenced).

Dolphin Tracking Project - Conversion of Readings

Tracking Reference No: DT30-3 (Dolphin Track 3 on 30/09/91)
Theodolite Height: 55.20m (Corrected to Sea Level at track time)
Station Point 1: OmN OmE,

X-Y m	Northing m	Easting m	Time (H:M:S)	Distance m	ΔTime (Secs)	L. Speed (ms^{-1})
447.0	-445.3	38.7	14:25:39			
456.8	-456.5	15.7	14:25:46	25.62	7	3.66
448.9	-448.9	3.6	14:26:02	14.31	16	0.89
469.2	-469.0	13.4	14:26:11	22.36	9	2.48
476.4	-476.3	-9.6	14:26:19	24.11	8	3.01
507.3	-506.7	-24.3	14:26:28	33.82	9	3.76
493.7	-493.4	-16.2	14:26:39	15.56	11	1.41
511.4	-511.4	-6.6	14:26:47	20.39	8	2.55
514.8	-514.1	-27.8	14:26:55	21.40	8	2.68
531.4	-528.9	-51.5	14:27:09	27.94	14	2.00
557.0	-556.8	-13.7	14:28:06	46.95	57	0.82
552.1	-552.0	6.2	14:28:16	20.44	10	2.04
547.2	-537.5	102.6	14:29:05	97.55	49	1.99
527.0	-510.3	131.6	14:29:35	39.76	30	1.33
413.2	-376.5	170.1	14:21:02	139.18	87	1.60
407.2	-364.8	180.9	14:31:16	15.97	14	1.14
408.3	-361.6	189.5	14:31:25	9.10	9	1.01
429.1	-269.4	334.0	14:32:52	171.46	87	1.97
438.2	-268.2	346.5	14:33:07	12.57	15	0.84
449.6	-256.3	369.4	14:33:18	25.81	11	2.35
451.5	-248.4	377.0	14:33:29	10.95	11	1.00

At that time a burst of clicks at a repetition rate indicative of target detection at 20m range is apparent. Slow motion replay of the video record shows that at the first surfacing position the animal is swimming rapidly away from the barrier. This is the single recorded close approach to the barrier made during the study period, although a large number of animals (50 or more during daylight hours) passed the site each day.

September 1992

Pre-trial observations were carried out for several days prior to barrier deployment but poor weather resulted in few dolphins being seen (less than two per day on average). For the seven days the barrier was in place, on a typical day, two large (12–20 animals) groups and several smaller groups (<6 animals) would be seen. As in 1991, the reflectors appeared to be detectable to the dolphins at ranges in excess of 50m and were consistently avoided (Fig. 10). Figs 11 and 12 demonstrate composites of tracks taken by the lead animals and by close knit groups. The avoidance behaviour is clear. It is worth noting that a single animal was observed and tracked as it 'crashed' the barrier at slack water whilst apparently travelling on an intercept course towards a group which had safely passed around the end of the barrier a few minutes before – the animal in question was not echolocating and emerged from the barrier at high speed (6 ms^{-1}). The risk of entanglement therefore appears to remain high for a few non-echolocating 'stragglers' especially when these appear to be travelling in a low state of alertness. For the last two days of this trial the outer barrier had two out of three reflector string supports removed and the low density 6m x 2m distribution that resulted continued to generate avoidance behaviour although it seemed that detection/avoidance behaviours around this modified structure were initiated at shorter ranges. This spacing factor was examined in more detail in the 1993 trial (see Goodson and Mayo, In press).

Handling trials

Irrespective of their success or otherwise in reducing incidental catches of marine mammals in gear, the application of acoustic devices to commercial fishing nets may create practical problems for fishermen e.g.

(1) the increase in the volume of the modified net may overfill a standard net storage bin;
(2) the handling of the net during deployment, recovery and during transfer between net pounds on board ship may be impaired;
(3) the change in buoyancy caused by the reflectors may affect the deployment of the net in the water.

In fact during the field trials, the method of attachment of the reflectors functioned reasonably well during shooting and recovery although a potential for snagging may exist. The braided tubing was chosen to support the reflectors as this does not twist under tension and was intended to smoothly guide the devices while shooting to reducing the likelihood of the reflectors catching into adjacent net layers. However, the wetted braid tube trapped air bubbles which were slow to disperse and the consequent additional buoyancy hindered the net from quickly achieving its correct fishing geometry. The presence of trapped air in the braided tubes also appeared to temporarily enhance the acoustic TS. The most significant handling problems occurred while transferring the wet net after recovery between the net storage 'pounds' preparatory to re-shooting the net. Some improvement in the attachment method will be necessary before this technique can be applied in a large scale commercial test but the mounting problem can be reduced with a minor design change incorporated in the device moulding.

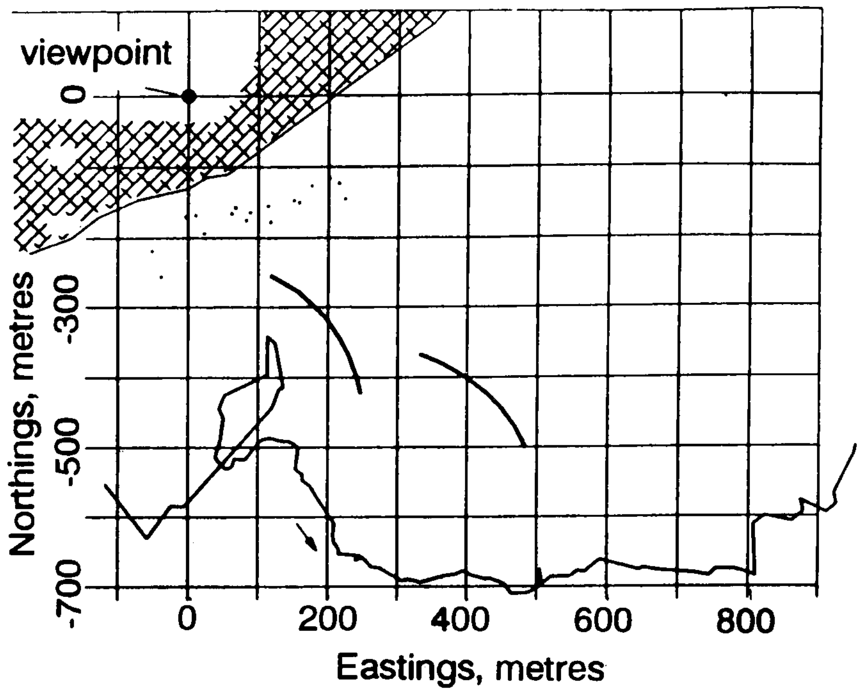

Fig. 10. Detection and avoidance behaviour, 1992 (see text).

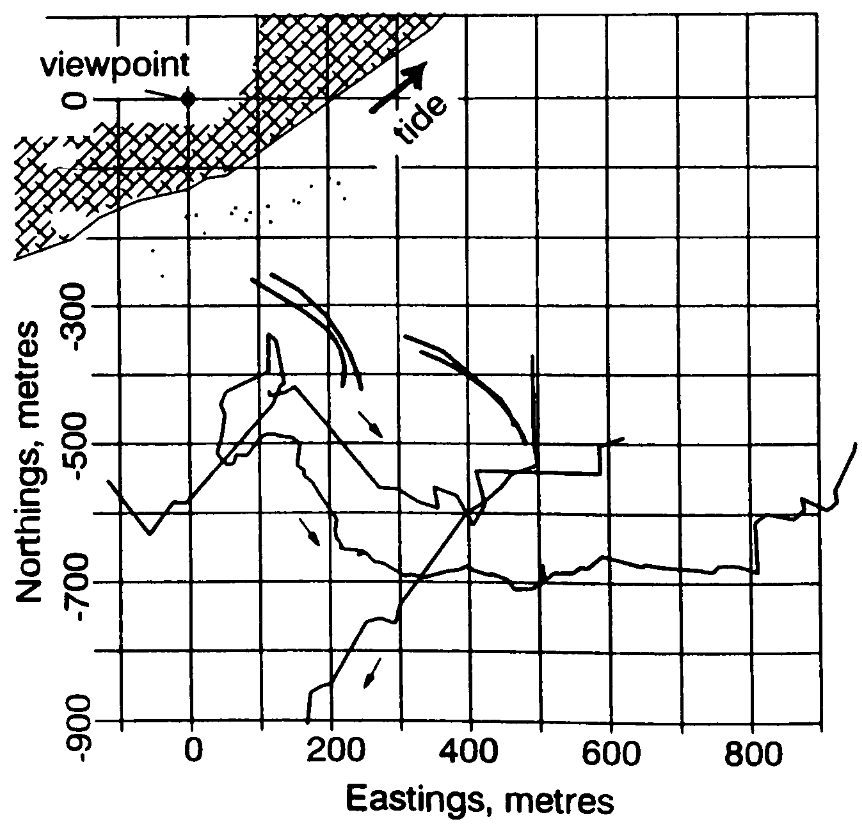

Fig. 11. Composite 1992 tracks – Ebb tide.

Sidescan sonar images

The (unusually) flat calm trial conditions were favourable for the sonar study and in these conditions the side scan images revealed considerable detail. The sonar images all clearly resolved the acoustically modified panels even though one of these panels remained incorrectly deployed (folded) for much of the study period. Fig. 13 shows a typical sidescan sonar image and the annotations indicate a number of interesting features.

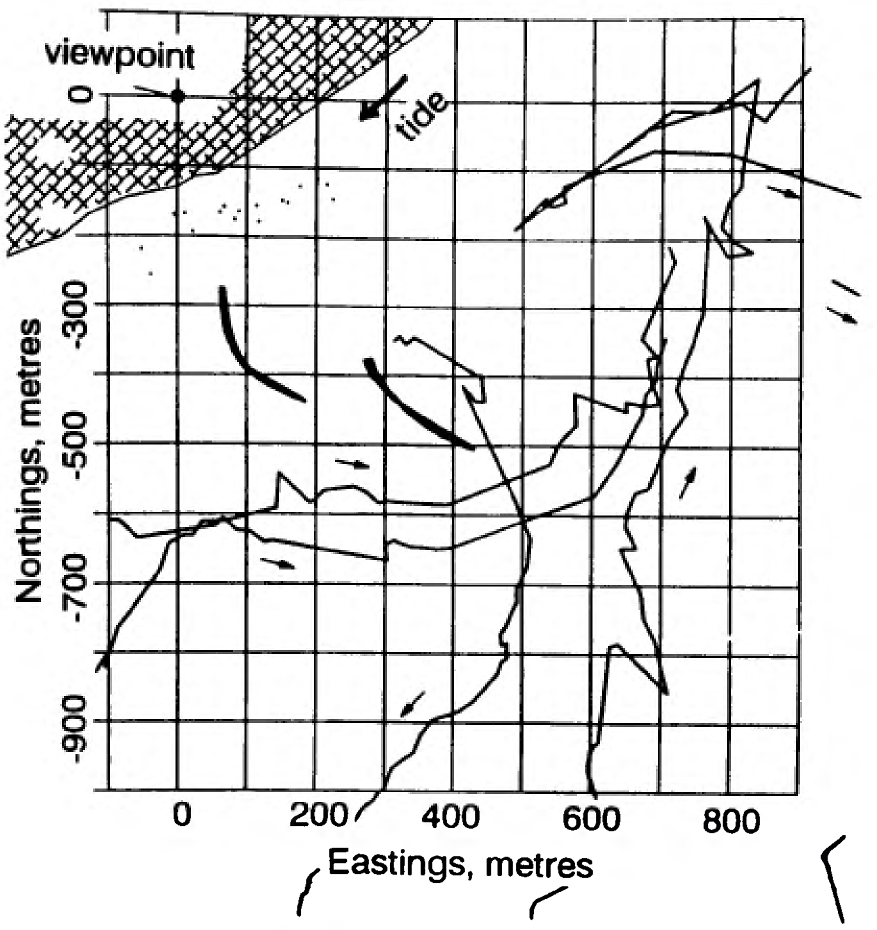

Fig. 12. Composite 1992 tracks – Flood tide.

The headline was the most detectable component in these very calm test conditions. However, in rougher seas, wave troughs will form which will mask the headline and its echoes from a horizontal (dolphin) sonar operating near the surface.

When viewed at 30m range, i.e. by a sonar towed parallel to the net, the echo component of the leadline/footrope is easily detected. However, the leadline constitutes a long 'thin cylinder' target structure and this strong echo (produced by the ensonified length dimension) is very directional. At all other angles, the detectability of the leadline component falls rapidly as the reflections are then directed elsewhere!

Very fine bubbles, created by the vessel's propeller, are driven several metres deep producing an acoustically opaque cloud which persists for quite long periods. An identical effect spread throughout the water column occurs when high sea states start to entrain air at the breaking wave crests. Such an acoustic 'fog' can severely impair the detection range of a small odontocete's sonar.

The reflector enhanced panels generate very detectable echoes and in-fill the vertical plane of the net between headline and leadline. By contrast the unmodified net segments appear completely transparent, even at short range, with no detectable echoes returning from this 18m deep net curtain.

The 10m wide passing places (net 'ends') are defined by the 4mm polypropylene vertical cords.

DISCUSSION

Moray Firth trials

The tracks reconstructed seem to indicate that whilst most animals approaching on a potential collision course detected the barrier and changed course at ranges greater than 50m, a few leading animals became aware of the barrier position at a maximum range of 150 to 170m – a much greater range than predicted. Two factors may help to explain this.

(1) The dolphins were approaching in a direction normal to the plane of the barrier. At a range of 170m a 10° beamwidth will excite nearly simultaneous echoes from the reflectors spread along approximately 30m of the barrier, which effectively increases the TS. This would not be the case if the animals approached from a more oblique angle, as the multiple echoes then arrive sequentially.

(2) The quiet sea (Sea State 2 or less) provided excellent acoustic conditions and the flat sandy seabed contributed little confusing reverberation.

The single animal discussed for 1991 may have been travelling in a low-awareness or resting state. Whether its behaviour was triggered by the acoustic activity of other animals beyond the barrier, or by one of the random loud clicks that have been occasionally noted from other resting animals, has not yet been established. However, if a real gillnet without reflectors had been in the position of the test barrier, this individual seems a likely candidate for entanglement. The single animal that 'crashed' the barrier in 1992 would either have become entangled or broken through the net. Supplementary methods of attracting such animals' attention would still be needed if mortalities are to approach zero, even if the overall approach ultimately proves successful.

One potential problem we had anticipated was that as the simple ellipsoid (air filled) reflectors under test produce 'soft' pressure release echoes, they might have appeared food-like and attracted dolphins. No such attraction phenomena was observed in either year and it is clear that the animals were able to classify these target echoes as 'alien' and took early avoiding action.

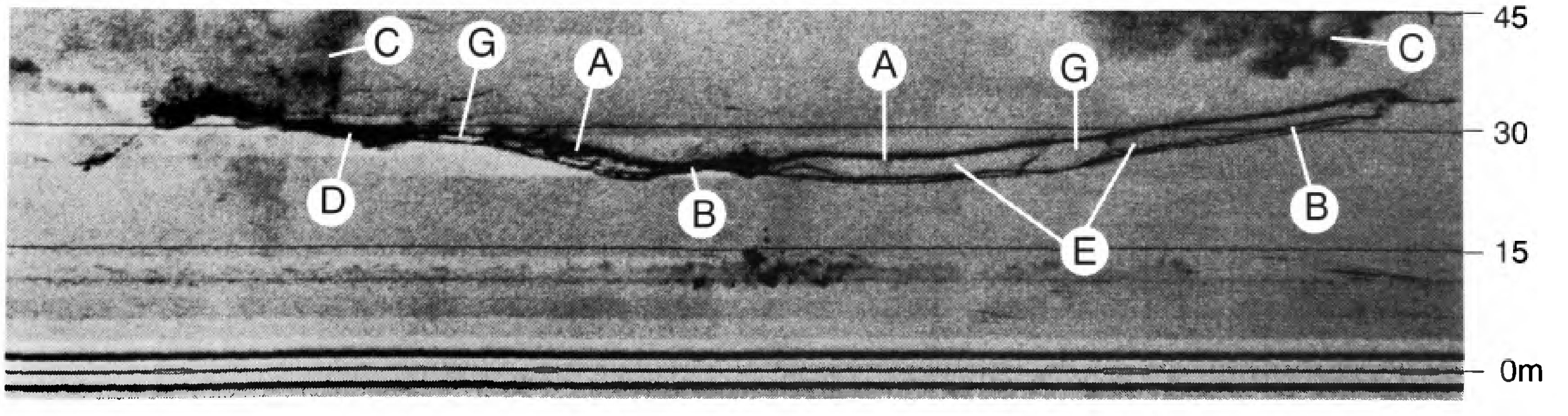

Fig. 13. Sidescan sonar images of the acoustic enhanced net (left) and the unmodified net (right). A=headline, B=leadline/footrope, C=aeration, D=enhanced panels, E=unmodified panels and G=gaps.

We recognise that the data obtained in these first field tests have limitations. Clearly the sample size is as yet rather small. In both years, at least one animal may have become entangled had 'real' modified nets been used. The concept of a 'control' needs refining and improved experimental design is required if one is to be able to prove that the observed 'capture' rate with a modified net is significantly lower than one would have expected from an unmodified net. Similarly, the behaviour of the animals was generally 'travelling' rather than 'foraging', which may also affect capture rates. Further trials are needed to investigate these aspects. In addition of course, particular problems (e.g. with respect to species and area) may require particular solutions: no single method is likely to solve every bycatch problem. Eventually, the only true test is application in a real fishery.

However, having said this, these were intended to be preliminary studies and the results appear promising and exceeded our expectations. Although the protocol employed needs further refinement, it is clear that the technique generates detailed interaction data at rates far faster than in conventional fishery monitoring and without any risk to animals.

Sea handling trials

The sonar images obtained, typified in the examples given in Fig. 13, demonstrate that the difference in acoustic detectability between the modified and un-modified panels is very marked and that the reflector modification effectively infills the 18m deep 'gap' between the headline and leadline.

It should also be noted that an approaching dolphin can only resolve small objects within the 10° wide 'spotlit' zone directly ahead of its path. During its approach it cannot acquire a comprehensive picture of the whole structure, as provided by these sidescan images, each of which took several minutes to scan at this resolution. At any instant the dolphin can only resolve targets that are contained in range by the time interval between its 'clicks' and in angle by the very narrow ensonified cone (beam) projected ahead. Only the highest frequency part of the dolphin's transmission spectrum (the very short wavelength signal components) are capable of resolving the acoustic dimensions of the larger supporting component parts of a fishing net and in most sea state conditions and from most approach directions even these may be missed.

CONCLUSIONS

The trials in the Moray Firth during 1991 and 1992 have demonstrated that the passive acoustic marking technique has the potential to deter small echolocating odontocetes from passive gillnets. The test on a Cornish commercial fishing boat demonstrated that when the devices are attached to a fishing net they function to effectively infill the relatively transparent zone between headline and leadline. The mechanical method of attachment to the nets needs improvement and alternative more efficient reflector designs will need to incorporate a safe/simple method of fastening them directly to the net mesh. For evaluation at sea, especially in an offshore fishery, accurate underwater tracking techniques are required (Woodward *et al.*, 1993) in order to localise positions and plot the underwater tracks of approaching cetaceans in relation to the fishing net. Behaviour changes induced by potential deterrent modifications need rapid evaluation (in relatively small scale comparative tests) if the current reliance on gross 'body count' bycatch statistics is to be avoided in the short term.

ACKNOWLEDGEMENTS

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Postscript

Developments on Issues Relating to the Incidental Catches of Cetaceans Since 1992 and the UNCED Conference

G.P. Donovan

International Whaling Commission, The Red House, 135 Station Road, Cambridge, CB4 4NP

ABSTRACT

Developments on issues relating to cetaceans and gillnets since 1992 are summarised. The most significant is the successful ban on pelagic driftnetting. Incidental catches by European Union vessels using driftnets are discussed. More effective enforcement of the EU ban on nets over 2.5km is required in both the eastern North Atlantic and the Mediterranean. The situation in the Mediterranean is serious and warrants immediate action. Some progress has been made in addressing issues related to the harbour porpoises in the North Atlantic. The situation of the vaquita remains extremely serious. New information on bycatch levels and/or new fisheries where cetacean bycatches have been identified is summarised. In general, the situation remains much as it did in 1992 – in almost no fishery can the impact of bycatches be assessed. Ways in which this may be remedied are discussed. In particular, the need to provide financial and practical support to developing countries is stressed.

KEYWORDS: INCIDENTAL CAPTURE; SMALL CETACEANS-GENERAL; LARGE WHALES-GENERAL; REVIEW; HARBOUR PORPOISE; VAQUITA; STRIPED DOLPHIN; MEDITERRANEAN; NORTH ATLANTIC; SOUTH PACIFIC; SOUTH ATLANTIC; NORTH PACIFIC; FISHERIES.

INTRODUCTION

The two Reports included at the beginning of this volume were accepted by the member governments of the International Whaling Commission (IWC) and submitted as part of the IWC's contribution to the United Nations Conference on Environment and Development held in Rio de Janeiro in 1992. The purpose of this short paper is to summarise developments concerning the issue of cetaceans and gillnets since those reports were written. Much of the information here is taken from the papers published in this volume.

PELAGIC DRIFTNET FISHING

Perhaps the most significant progress since the Workshop concerns high seas driftnet fishing, which was identified as a serious threat to cetaceans (e.g. Hobbs and Jones, 1993; IWC, 1994c). In 1990, the IWC endorsed Resolution 44/225 of the UN General Assembly, which among other things called for a review of the best available scientific data on the impact of large-scale pelagic fishing, noting the contribution that the Scientific Committee Workshop would make to this review (IWC, 1991a). Partly as a result of the Workshop, the UN adopted Resolution 46/215 on 20 December 1991. The active parts of this Resolution called for nations to ensure that:

(1) pelagic driftnet fishing effort should be reduced by half by 30 June 1992;
(2) driftnet fisheries should not expand into new areas;
(3) a moratorium on pelagic driftnet fishing should be implemented by 31 December 1992.

As reported by Nagao (1994), Japan ceased driftnet fishing in summer 1990 for all areas outside the Pacific and on 1 January 1993 for the Pacific. This was accompanied by enforcement and compensation measures. The Republic of Korea suspended such fishing from 30 November 1992 and China, Taiwan ordered vessels to surrender their driftnets by 1 January 1993. Both countries encouraged compliance with the ban by assisting with refitting fishing vessels as well as using patrol vessels to enforce it.

Despite occasional breaches (3 Chinese vessels were prosecuted by the Chinese authorities and one Honduran flagged vessel was seen but not apprehended), the moratorium appears to be holding (Anon., 1994).

DRIFTNET FISHING BY COUNTRIES OF THE EUROPEAN UNION (EU)

Eastern North Atlantic

In accordance with the UN Resolutions noted above, the EU adopted measures to phase out pelagic driftnetting. Initially, it was intended to limit driftnets to a maximum of 2.5km both within and outside EU waters but a request from France resulted in the eastern North Atlantic French albacore fishery being allowed to use nets of up to 5km in length until 31 December 1993, subject to the results of a scientific evaluation of the ecological impact of the fishery.

Although French vessels dominate this fishery (46 vessels in 1992 and 64 in 1993 – Goujon *et al.*, 1993), Irish vessels (about 5 in 1991 and 1992, about 18 in 1993 and 1994 – S. Berrow, pers. comm.) and British vessels (6 in 1993) also operate in the same area.

In response to the EU decision, France carried out a study to examine the impact of the tuna fishery on common dolphins, *Delphinus delphis* and striped dolphins, *Stenella coeruleoalba* (Goujon *et al.*, 1993). In the area surveyed, Goujon *et al.* estimated an annual fishing mortality of around 0.7% for common dolphins and 1.6% for striped dolphins.

Irish vessels carried observers to monitor the fishery in 1991 and 1993, and the Irish South and West Fishermens' Organisation has funded a pilot study to examine the ecological risk in the tuna fishery; preliminary analyses suggest that the Irish fishery has a much lower catch rate per km than the French (Berrow, pers. comm.).

The results of the French study are difficult to interpret, particularly for the striped dolphins. Whether the populations are thought to be able to sustain incidental catch levels depends on what assumptions are made about dolphin population dynamics (see below), the geographical range of the population and, in particular in this case, the vital rates of striped dolphins (Goujon *et al.*, 1993). The EU has decided not to renew the French exemption and now no EU registered vessel may carry more than 2.5km of gillnet (Article 9a, No. L42/18).

This regulation has led to a number of claims and counter claims about vessels from various EU countries using illegal nets in 1994. It is clear that monitoring and enforcement methods require strengthening.

Mediterranean

Despite the controversy over 'illegal' use of driftnets in the eastern North Atlantic, it is the situation in the Mediterranean that gives greater cause for concern.

Large numbers of cetaceans are known to be taken in driftnet fisheries in the Mediterranean, particularly in the fishery for swordfish and albacore. IWC (1994c) commended Italy for banning this fishery from 30 July 1990 and encouraged other Mediterranean states to do the same. However, since then the situation has become complex and confusing, with a number of 'relaxations' and 'rebannings' by both the Government and Administration Courts (Aguilar and Silvani, 1994; Di Natale and Notarbartolo-di-Sciara, 1994). It should be remembered that irrespective of national legislation, EU states should not be using nets >2.5km but nets of 10–12km are still being used. In fact the situation in the Mediterranean may even be worse now than in 1990; over 800 vessels from Italy (600+) and Morocco (200+) in particular are still operating. Although no good estimates of bycatches exist, prior to 1990 the Italian bycatch alone was thought to number several thousand animals (Di Natale and Notarbartolo-di-Sciara, 1994). In view of this, the Scientific Committee has again repeated its concern about the situation in the Mediterranean, particularly for the striped dolphin (IWC, 1995).

It is clear that immediate action is required. A first step would be for EU countries to ensure that EU regulations are met. In addition, the Action Plan for Cetaceans established by the 1991 meeting of the Barcelona Convention should be enacted as soon as possible (Di Natale and Notarbartolo-di-Sciara, 1994).

INCIDENTAL CATCHES OF HARBOUR PORPOISES

The harbour porpoise (*Phocoena phocoena*) appears to be one of the most vulnerable species to capture in fishing nets (IWC, 1994c). Indeed, phocoenids in general are often caught (e.g. Corcuera, 1994; Goodall *et al.*, 1994; Lal Mohan, 1994; Jefferson and Curry, 1994; Van Waerebeek and Reyes, 1994a; c) and, as discussed below, the vaquita, *Phocoena sinus*, is probably the world's most endangered cetacean (e.g. Vidal, 1995). There is some speculation that this vulnerability may partly reflect the nature of their echolocatory abilities when compared to delphinids (e.g. IWC, 1994c).

The Scientific Committee drew attention to catches of harbour porpoises on both sides of the North Atlantic at the Workshop and the UNCED review. Since then it has emerged that, for some countries, much larger catches occur than envisioned in 1990 (e.g. Denmark, see Lowry and Teilmann, 1994). Although some nations have increased their efforts to try and estimate bycatch levels in North Atlantic fisheries (e.g. see Berrow *et al.*, 1994; Lowry and Teilmann, 1994; Read, 1994), even where there are schemes, they are inadequate. Few reliable estimates derived from scientifically designed observer programmes exist, despite resolutions accepted by consensus in the IWC (e.g. 1994a) that such work should be given high priority.

There are however, some positive signs that Governments are beginning to recognise that the harbour porpoise/fishing gear problem must be addressed.

In the western North Atlantic, recent information on the harbour porpoise bycatch problem was considered at a Workshop to assess the status of harbour porpoises in those waters (Palka, 1994). Only for the US Gulf of Maine are bycatch estimates and population estimates available (Read, 1994). A series of recommendations for action and research based on the Workshop Report are given in IWC (1995). Recent US legislation requires that annual incidental catches of harbour porpoises must be significantly reduced to 1% or less of the estimated population size in the near future and a workshop to assess the potential of gear modifications to reduce bycatches in the sink gillnet fishery was held in September 1994 (Frady *et al.*, 1994).

In July 1994, a multi-national survey of the North Sea and adjacent waters was undertaken, although the results are not yet available (Anon., 1994). This should provide a useful baseline for any evaluation of the impact of incidental captures on harbour porpoises in the region, particularly the Celtic Shelf (Berrow *et al.*, 1994) and the central North Sea (Lowry and Teilmann, 1994).

In September 1994, the first meeting of ASCOBANS (Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas) took place (ASCOBANS, 1994). The range states agreed to a Resolution that defined a conservation and management plan for the region, including the reduction of direct and indirect interactions with fisheries (estimation of reliable bycatch numbers and research on gear and fishing method modifications are part of this).

VAQUITAS IN THE GULF OF CALIFORNIA

The vaquita has the smallest range of any marine cetacean, being restricted to the Upper Gulf of California (Vidal, 1995), and probably numbers only a few hundred animals (Gerrodette *et al.*, 1995). Despite a number of attempts to protect these animals from incidental catches, mainly in an illegal fishery for the endangered sciaenid fish, the totoaba, incidental catches still occur. On 10 June 1993, the Government of Mexico declared the Biosphere Reserve of the Upper Gulf of California, a move commended by the Scientific Committee (IWC, 1995). However, evidence of continuing incidental catches (D'Agrosa *et al.*, 1995) has led the Committee to recommend that further action to eliminate bycatches be taken urgently, if the extinction of the vaquita is to be avoided.

NEW INFORMATION

The Workshop has served to encourage a number of studies to improve our knowledge of bycatch levels. In many of these cases the work has been carried out in difficult conditions and without government support. For example, a considerable amount of new information is available from Central and South America. In several cases these studies identified new areas/fisheries (e.g. Félix and Samaniego, 1994; Haase and Félix, 1994; Siciliano, 1994; Zavala-González *et al.*, 1994) or improved our knowledge of existing interactions (e.g. Corcuera, 1994; Lescrauwaet and Gibbons, 1994; Van Waerebeek and Reyes, 1994c).

Although almost all the new information refers to smaller cetaceans, two previously unknown areas where large whales are taken in nets have been documented:

minke whales off Peru (Van Waerebeek and Reyes, 1994b); and sperm whales off Ecuador (Haase and Félix, 1994).

DISCUSSION

While there has clearly been some progress in addressing questions related to fishery/cetacean interactions, it is also clear that much work remains to be done.

Assessing the impact of bycatches

Several pieces of information are required if a quantitative assessment of the impact of bycatches on cetacean populations is to be made: reliable estimates of bycatch numbers; knowledge of stock identity and migration; reliable estimates of abundance. All these are difficult (and expensive) to obtain. Together they will provide us with an estimate of bycatch levels as a proportion of current population size. However, the interpretation of this remains problematic for a number of reasons associated with our lack of knowledge of the dynamics of small cetacean populations (e.g. Reilly and Barlow, 1986) i.e. what level of takes might be sustainable. Such knowledge is also required if attempts are to be made to relate current abundance to 'initial' abundance. Finally, this information needs to be considered in the context of other factors affecting the population (e.g. direct catches, habitat loss/degradation).

A number of attempts to obtain more reliable estimates of bycatch numbers have been made since the Workshop. Generally, to have any chance of success they require observers on vessels; if the cetaceans have an economic or subsistence value to the fishermen (i.e. they bring a substantial percentage of the animals to shore), monitoring of ports may be sufficient. It should not be impossible to use observers on either all, or a representative sample of a fleet in commercial fisheries, although this has rarely been done (e.g. Berrow *et al.*, 1994; Lennert *et al.*, 1994; Lowry and Teilmann, 1994). However, it is almost impossible where large numbers of small vessels are involved, for example in the many artisanal fisheries of the developing world. Other methods, such as questionnaires and interviews are difficult to interpret (e.g. Lien *et al.*, 1994) but may give some idea of the problem.

It is important to recognise that for almost all fishery/cetacean interactions we have, and probably will continue to have, only rough (usually minimum) estimates of bycatch levels (IWC, 1994c – Table 1).

The question of stock identity is a persistent problem in cetacean studies (e.g. Donovan, 1991; Perrin and Brownell, 1994) and our knowledge of small cetacean stock structure is poor for almost all areas and species. Despite the progress made in biochemical techniques (e.g. IWC, 1991b) there are no simple unambiguous ways to address this problem. It is important that a suite of techniques are used (Donovan, 1991) and that information on movements is also obtained.

The question of estimating the abundance of cetaceans has been more thoroughly addressed in recent years and guidelines for conducting surveys have been developed (e.g. Hammond, 1986; Hiby and Hammond, 1989; IWC, 1994b). However, such work is expensive. For example, the survey of the North Sea and adjacent waters carried out in July 1994 cost over £1,000,000. At present we have few reliable estimates of abundance for cetaceans affected by fisheries (IWC, 1994c – Table 1), particularly for developing countries.

It is unlikely that funding research on these three subjects will be allocated high priority in developing countries given their economic situation. It is important that Government and non-governmental agencies from the 'developed' world offer financial and logistical support for such studies to be carried out, particularly where the impact of bycatches is suspected to be high. In this regard it should be noted that many of the projects identified in the IUCN Action Plan for Cetaceans (Reeves and Leatherwood, 1994) address research relevant to bycatch problems.

Management actions

It is clear that in almost all cases it is impossible at present to determine reliably the impact of bycatches on cetacean populations; it is equally clear that action to reduce bycatches should not wait until it can be shown with certainty that levels are unsustainable.

Although there are some indications that passive and active acoustic modifications may eventually result in a reduction in bycatches in some fisheries (e.g. Goodson *et al.*, 1994; Lien *et al.*, 1994), it seems unlikely that any simple and effective gear modifications will be available in the near future.

One approach that has potential in some areas is a change of gear type e.g. from gillnets to longlines (Van Waerebeek and Reyes, 1994c; Corcuera, 1994). However, it is important to monitor the effect of such changes for several reasons. Firstly, cetaceans are only one part of the ecosystem – changing gear or methods may reduce cetacean bycatches but increase bycatches of other species (such as turtles, fish and sea birds) to unsustainable levels (e.g. see Joseph, 1994). Secondly, there is evidence from Venezuela, French Guiana and Ecuador that longline fishermen use dolphin meat as bait (Van Waerebeek and Reyes, 1994c; Félix and Samaniego, 1994). Finally, the new gear or method may also result in incidental catches or, in the case of longlines for example, direct kills by fishermen who observe cetaceans stealing fish from them.

A number of countries have taken legislative action since the Workshop (e.g. Philippines – Dolar, 1994; USA – Read, 1994; Peru – Van Waerebeek and Reyes, 1994c). However, it is clear that such action is only of value if it is enforced. The case of Peru provides a good example of this, as illustrated by Van Waerebeek and Reyes (1994c). The Government of Peru banned the capture and trade in small cetaceans in December 1990 but, in the absence of enforcement, the main effect appeared to be to make it more difficult to obtain information on catch levels, rather than a reduction in catch levels. A more recent law (August 1994) that elaborated enforcement measures and responsibility appears to be having more effect (Van Waerebeek, pers. comm.).

A number of lessons can be learned from the Peruvian experience. The most obvious is that while it is relatively easy to pass legislation and even to stress the need for enforcement, actually enforcing the law can be logistically very difficult, particularly in the case of fisheries involving large numbers of artisanal vessels in developing countries. It is not immediately obvious how this can be remedied. However, it is important that monitoring of the situation continues after legislation is passed (e.g. in the Philippines, where similar legislation was passed in 1992 – Dolar, 1994). Another factor that is relevant here is the need for education (e.g. Lescrauwaet and Gibbons, 1994); fishermen are more likely to obey a law if they can understand the need for it.

Several authors have stressed the need for the financial and subsistence needs of the fishermen to be taken into account when attempting to reduce bycatches. With the exception of 'deliberate' incidental catches (where the cetaceans have an economic or subsistence value), many fishermen see incidental catches of cetaceans as having a negative impact on their fishing, and may well be pleased to change the gear and/or operation if they can maintain their income (e.g. Corcuera, 1994; Crespo *et al.*, 1994).

CONCLUSIONS

Although some progress has been made, a considerable amount of work remains to be done. Incidental capture in fishing gear is probably the most serious threat to cetaceans today. The recommendations of the Workshop remain valid and it is to be hoped that Governments who have endorsed those recommendations in the context of the IWC and UNCED, do more than pay lip service to them. It is particularly important that financial and logistic assistance is provided to developing countries.

In closing, I would particularly like to stress certain points raised in the Workshop report.

(1) Fishing communities should be made aware of the reasons behind calls for a reduction in bycatches and become involved in the process of finding solutions.
(2) Research should focus on those fisheries where urgent action is required (as identified in the Workshop Report).
(3) Potential solutions must be evaluated in the context of all marine species, not only cetaceans.
(4) There is no universal cause or solution to the incidental capture of cetaceans in fishing gear. Each case should be evaluated in the light of local conditions.

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Résumés

Résumés

SECTION 1. PAPERS PRESENTED TO THE MEETING BUT NOT PUBLISHED. COPIES OF THE FULL PAPERS CAN BE OBTAINED AT COST FROM THE IWC SECRETARIAT.

SC/O90/G1. MORTALITY OF DOLPHINS IN SHARK GILLNET FISHERIES OFF URUGUAY. *Ricardo Praderi, Museo Nacional de Historia Natural Casilla de Correo 399, Montevideo, Uruguay.*

In the artisanal shark fisheries along the Uruguayan coast, sporadic accidental catches of small cetaceans have been recorded. The main species involved are: *Phocoena spinipinnis* (Burmeister's porpoise) and *Tursiops truncatus* (bottlenose dolphin). But, due to the kind of nets used (gillnets), a considerable number of *Pontoporia blainvillei* (franciscana) also die every year. In studying the incidental mortality of the franciscana, two factors are considered: fishing effort and types of nets used. The type and scale of fishing operations is, without doubt, the main determinant factor of the number of dolphins caught in nets. It is contingent upon climatic conditions, a factor which considerably limits the number of days suitable for fishing. The economic conditions of fishermen are also significant, because, in the absence of prior successful fishing, fuel and salaries are limited to the maximum. The type of nets employed is important in incidental mortality, because the nets with the largest mesh, used to catch large sharks, accounted for the largest number of dolphins killed (55% of the total) whereas the other two types of net used combined resulted in 45% of mortality. [24pp.]

SC/O90/G4. DRIFTNET FISHING IN THE SOUTH ATLANTIC. *Roger Krohn, Zoology Department, University of Cape Town, Rondebosch 7700, South Africa.*

Drift- and gillnetting by Japanese, Korean and China, Taiwanese fishing fleets has caused a large decline in the stocks of albacore (*Thunnus alalunga*), as well as large scale mortality of non-target species in the South Pacific. The first direct evidence to show that this activity has now extended its range to include the South Atlantic Ocean is presented. [6pp.]

SC/O90/G12. A REVIEW OF ENTANGLEMENT OF SMALL CETACEANS IN GILLNETS AND THE GILLNET FISHERIES OF THE INDIAN COAST. *R.S. Lal Mohan, Research Centre of Central Marine Fisheries Research Institute, West Hill, Calicut-673 005, India.*

The smaller cetaceans, *Stenella longirostris* (spinner dolphin), *Delphinus delphis* (common dolphin), *Tursiops truncatus* (bottlenose dolphin), *Sousa chinensis* (humpback dolphin) and *Neophocaena phocaenoides* (finless porpoise) get entangled in gillnets operated along the Indian coast. The Ganges river dolphin (*Platanista gangetica*) is a casualty in the nets operated in the rivers Ganges and Brahmaputra. Most of the entanglements occur along the southwest coast of India. The recent development of gillnets, mode of operation, structure of the nets, types of crafts and gear employed, species of fishes caught and the economics of the fishery are discussed. The important gillnet fisheries of India like pomfret fishery, shark fishery, skate and ray fishery, scombroid fishery, mackerel fishery, whitebait fishery, polynemid fishery, catfish fishery, oil sardine fishery, lesser sardine fishery, hilsa fishery, riverine catfish fishery and prawn fishery are described. Recommendations are made to try to make gillnet fisheries less harmful to dolphin populations. [70pp.]

SC/O90/G14. POSSIBILITIES OF REDUCING INCIDENTAL CATCH AND MORTALITY OF MARINE MAMMALS IN DRIFTNET FISHERIES. *Joel Prado and Andrew Smith, Fishing Technology Service, Fisheries Industries Division, FAO of the UN, Rome, Italy.*

The entanglement of cetaceans in fishing gear has been known for many years, but prior to the use of nylon twine in the fishing industry in the late 1950s it was not considered to be a problem. At this point driftnets and gillnets increased their efficiency by up to 50% and other species were sought which had not been traditionally fished by driftnets. Relatively recently this led to a high-seas development of gillnet fisheries for tuna, salmon and squid. Although the tuna and squid stocks are not considered overfished, the gillnet fishery for salmon has been subject to management measures agreed at an international level for a number of years. The international negotiations with regard to these measures have been very difficult, with each country trying to represent a number of vested interests. The problem of the catch of cetaceans is therefore only one factor in a complex controversy on high-seas gillnetting. Notwithstanding the demand for the banning of drifting gillnets on the high seas and the regulation of these nets in EEZs, it has got to be considered that during the last decade many developing countries have started fishing with driftnets for species which they had not previously harvested. Pragmatically, one has to consider not only what happens on the high-seas but also within areas under national jurisdiction where the management of the fisheries is vested in the coastal state and where the coastal state determines the allowable catch of the living resources in its exclusive economic zone. Therefore, in the context of good fisheries management practices, gillnetting does not pose a problem with regard to overfishing and the solution to the problem of the incidental catch of mammals will lie in seeking methods whereby the reduction of the amount of cetacean entanglements in the nets can be achieved. Although it is accepted that 'prevention is better than cure' it is proposed that an effective strategy for tackling the problem will contain elements of both. [12pp.]

SC/O90/G17. ENVIRONMENT, ACOUSTICS AND BIOSONAR PERCEPTION. OPTIMISING THE DESIGN OF PASSIVE ACOUSTIC NET MARKERS. *A.D. Goodson, Sonar and Signal Processing Group, Electronic and Electrical Engineering Department, Loughborough University of Technology, LE11 3TU, UK.*

The associated symposium paper 'Enhancing the acoustic detectability of fishing nets' (SC/O90/G16) discussed the foraging behaviour leading to fish detection and the extraction of target range parameters from recordings of the sonar emissions of a solitary *Tursiops truncatus*. The concept of increasing the target strength of fishing nets by adding simple sound scattering mechanisms has been investigated in recent years by a number of researchers. However, the methodology employed to date has not resulted in significant reductions in the incidental catch of cetaceans. These workshop notes attempt to examine some environmental acoustic factors which could affect behaviour and consider the design of passive markers optimised for detection by the small delphinoids. [5pp.]

SC/O90/G18. REVIEW OF CETACEAN NON-ACOUSTIC SENSORY ABILITIES. *Margaret Klinowska, Research Group in Mammalian Ecology and Reproduction, Physiological Laboratory, University of Cambridge, Downing Street, Cambridge, CB2 3EG, UK.*

This review provides a more detailed background to the discussion in SC/O90/G19 of the ways in which non-acoustic sensory abilities and behaviour might be exploited to prevent cetacean entanglement. [39pp.]

SC/O90/G19. SOME NON-ACOUSTIC APPROACHES TO THE PREVENTION OF ENTANGLEMENT. *Margaret Klinowska, Research Group in Mammalian Ecology and Reproduction, Physiological Laboratory, University of Cambridge, Downing Street, Cambridge, CB2 3EG, UK and A. David Goodson, Sonar and Signalling Research Group, Electronic and Electrical Engineering Department, Loughborough University, Loughborough, LE11 3TU, UK.*

The non-acoustic senses are reviewed for their potential to provide additional practical ways to prevent the entanglement of cetaceans in fishing nets and other gear. Two general approaches emerge. The first involves modification of gear deployment. It would apply to animals using environmental information such as the geomagnetic field, currents, temperature or salinity gradients as a travel cue, and simply consists of orienting the gear parallel to the environmental cue providing the travel path instead of across it. It should not be difficult, expensive or disruptive, to collect the extra data required to test this approach during routine fishery monitoring. However, if the target species of the fishery should happen to be using the same travel cues as the cetaceans, reorientation of gear will not be practical. Nevertheless, this approach deserves serious consideration, because it is easy to test, and if effective, would not be difficult or expensive for well-equipped modern fisheries to implement. The second approach involves gear modification. Increasing the visibility of gear underwater might be useful in some restricted circumstances, and it may even be worth exploring whether improving visibility above water would be helpful. Although little is known of the role chemoreception plays in cetacean food finding and social behaviour, it is a sense which can be invoked from a distance in water. Natural fibre nets, traditionally treated with a variety of oils, tars, etc., would be likely to leave a distinctive 'trail' in the water. The contents of any nets would be likely to provide a trail of excreta and other substances. Urgent investigation is required to elucidate the role such cues may have in attracting or alerting cetaceans to nets, because such broadcast chemical signals could well negate any other efforts to prevent entanglement. [7pp.]

SC/O90/G23. SOURCES OF A GLOBAL REVIEW OF MORTALITY OF CETACEANS IN PASSIVE FISHING NETS AND TRAPS. *Aleta A. Hohn and William F. Perrin, Southwest Fisheries Science Center, National Marine Fisheries Service, PO Box 271, La Jolla, CA 92038, USA.*

This provides a list of sources that may be useful during the IWC Workshop on Mortality of Cetaceans in Passive Fishing Nets and Traps. These sources include references pertaining to the species and numbers of cetaceans incidentally caught, types of gear, mitigation methods tried or suggested, coastal fisheries operating and possibly catching cetaceans even if such reports of incidental catches do not currently exist, and other potentially relevant papers. We have tried to include references on incidental mortality in passive gear from all regions of the globe where information exists. Generally, the list has been restricted to recent documents, within the past 10 years or so. Unpublished material has been included because much of it is very recent or contains details or information not otherwise available. All of the sources listed will be accessible during the workshop. [16pp.]

SC/O90/G25. CETACEAN MORTALITY IN PASSIVE FISHING NETS AND TRAPS IN THE BALTIC SEA: A REVIEW. *Carl Chr. Kinze, Zoological Museum, University of Copenhagen, Universitetsparken 15, DK-2100 Copenhagen O, Denmark.*

The dominant cetacean of the Baltic Sea is the harbour porpoise (*Phocoena phocoena*), and interactions between cetaceans and fisheries hence are almost totally with this species. A further 19 species have been reported occasionally from Baltic waters, usually in the westernmost part and may potentially become entangled in fishing gear. Since the end of the second world war, the harbour porpoise in the Baltic appears to have undergone a significant decline and in recent years the species has become very scarce in the Baltic proper. Amongst other factors, entanglements in passive fishing nets and traps has been mentioned as a cause of the decline. Harbour porpoises are or have been caught in gillnets and pond nets all over the Baltic Sea. Set gillnets are widely applied in Danish, Swedish and German waters whilst salmon drift nets are in use in the Baltic proper. Taking into account, however, the present distribution of the harbour porpoise in the Baltic Sea, incidental catches may only have an impact on the species in the westernmost parts of these waters, i.e. mainly in the Danish, German and Swedish parts of the Kattegat and the Belt Sea. [22pp.]

SC/O90/G26. REVIEW OF GILLNET AND TRAP FISHERIES IN THE BRAZILIAN REGION. *Graciela Cannella and Alfredo Ximenez, Laboratorio de Mamíferos Aguáticos e Ictiologia de la Universidad Federal de Santa Catarina, Caixa Postal 5132, Campus Universitario 88049 Florianópolis, SC, Brazil.*

This paper provides information on gillnet and trap fisheries that characterise each region of the Brazilian coast and on their impact on the marine mammals that frequent these areas. Artisanal fishing represents 50–60% of the total national fishing yield and is particularly important in the north and northeast regions. The southeast region concentrates most on industrial fisheries and together with the south has the highest fishing potential of the country. Different problems resulting from overfishing, fish handling, pollution, etc. are described. The impact of fishing activity on marine mammal populations cannot be assessed at present, given the lack of data. [39pp.]

SC/O90/G27. FRESHWATER DOLPHIN/FISHERIES INTERACTION IN THE CENTRAL AMAZON (BRAZIL). *Vera da Silva and Robin C. Best*, Laboratorio de Mamíferos Aquáticos, Instituto Nacional de Pesquisas da Amazonia (INPA), C.P. 478, 69011 Manaus, Amazonas, Brazil.*

The Amazonian freshwater dolphins, *Inia geoffrensis* (boto) and *Sotalia fluviatilis* (tucuxi), have been little studied and their actual populations and status are still unknown. As part of a general study of the biology and conservation of the aquatic mammals of the Amazon region, the Instituto Nacional de Pesquisas da Amazonia (INPA), in Manaus has undertaken a study of these two dolphins. The increasing fisheries pressure in the Amazon has greatly augmented the potential for dolphin/fisheries interactions which could adversely affect the status of the dolphins, both through higher rates of incidental mortality in fishing gear, and through direct competition for certain fish species. This paper summarises data for 67 dolphins (33 *Inia* and 34 *Sotalia*) collected between May 1979 and March 1984 in the central Amazon region. This collection is the result of our contacts with local, and our institute's fishermen and is by no means a quantitative sampling of all dolphin mortality for this region. [11pp.]

* Robin C. Best died on 17 December 1986. He was a Research Associate of the Vancouver Public Aquarium.

SC/O90/G30. INFORMATION ON FISHERIES OF PAKISTAN. *Mohammad Sadiq Niazi, Deputy Director, Marine Fisheries Department, Government of Pakistan, Westwharf, Fish Harbour, Karachi-74000, Pakistan.*

Pakistan is located in Asia having India to its east and Iran to the west, and the northern Arabian Sea to its south. It has a coastline of about 1,050km and has an Exclusive Economic Zone (EEZ) extending offshore to 200 n.miles (370km). The marine environment of Pakistan has been divided into two maritime provinces, viz. Sind maritime region and Baluchistan region. The former area, stretching about 350km, has Karachi harbour as its main base. It is characterised by a broad continental shelf (extending about 110km out from the coast to a depth of 200m), a coastline marked by the numerous small creeks and deltas of the Indus river, and by a muddy, easily trawlable bottom. The Baluchistan coastline, which extends some 700km, is characterised by a number of bays (Sonamiani, Ormara, Pasni, Gwadar, Jiwani) and the absence of any substantial river systems. The continental shelf of the Baluchistan coast is narrow (15 to 50km) and falls off steeply into very deep water. It has a comparatively hard bottom which makes it very difficult for bottom trawling. The shelf area is estimated to be about 35,740km^2 in Sind and 14,530km^2 on the Baluchistan coast (50,270km^2 total). [8pp. + Addendum 26pp.]

SC/O90/G31. FISHING OPERATIONS AND DEATH OF MARINE MAMMALS IN THE WATERS OFF KAMCHATKA. *V.N. Burkanov, Kamchatka Department of Nature, Pacific Geographic Institute, Far East Branch of the USSR Academy of Sciences.*

The Kamchatka region is one of the richest in the world. Throughout the year Soviet, Japanese, North Korea and China, Taiwanese and US vessels intensively harvest fish and other food species there. Numerous marine mammals are present including five Phocidae (*Phoca largha, Pusa hispida, Eryghothus barbatus, Histriophoca fasciala, Phoco vitulina richardi*), two Otariidae species (*Eumetopias jubatus, C. ursinus*), walrus (*Odobenus rosmarus*), sea otter (*Euchydra lutris*) and no less than 20 cetaceans (Cetacea). Species interactions between man and marine mammals during fishing give rise to serious potential problems of which little detail is known for Kamchatka. This paper attempts to give a general outlook on the impact of different fishing patterns on marine mammals. [3pp.]

SC/O90/G32. DOLPHINS IN THAILAND. *Suraphol Sudara, Chulalongkorn University, Bangkok, Thailand.*

Ten species of dolphins have been recorded in Thai waters, both in the Gulf of Thailand and in the Andaman Sea. Order Odontoceti (toothed whales): (1) *Sotalia plumbea* (Thai name: white-grey loma); (2) *S. bornecnsis* (Thai name: white loma of the south sea); (3) *S. chinensis* (Thai name: loma of the north sea); (4) *Steno bredanensis* (Thai name: spotted loma); (5) *Stenella malayana* (Thai name: bottlenose Malayan loma); (6) *Delphinus delphis* (Thai name: common bottlenose loma); (7) *Tursiops truncatus* (Thai name: bottlenose, short mouth loma); (8) *Orcaella brevirostris* (Thai name: bowl head, dorsal fin loma); (9) *Neophocaena phocaenoides* (Thai name: bowl head, smooth back loma); (10) *Stenella longirostris* (spinner dolphin). [3pp.]

SC/O90/G33. A REVIEW OF GILLNET AND TRAP FISHERIES IN MICRONESIA AND THE CENTRAL PACIFIC. *Eugene T. Nitta, NMFS, Southwest Region, Pacific Area Office, 2570 Dole Street, Honolulu, Hawaii 96822-2396, USA.*

Numerous variations of gillnet and trap fisheries occur throughout Micronesia and in Hawaii. The levels of effort and techniques are dictated in large part by the physiography of the islands or atolls where the fisheries occur. Conditions such as the width of the reef flat, whether or not there is a lagoon, depth of the waters immediately seaward of the finging reef, and currents and tides are all considerations in the selection and use of gear. These fisheries are now conducted with modern gear such as monofilament nets and lines, steel rebar and wire screening, outboard motors, fibreglass and aluminium boats and scuba; a significant change from traditional gear made almost entirely from natural materials. In many locations the distinctions between recreational, subsistence and commercial fishing by gillnet and/or traps are difficult to make because of the lack of formal markets or infrastructure, nonreporting of mixed subsistence and commercial catches and the continuation of some semi-traditional or cultural practices involving the sharing of catches, subsistence or otherwise. Commercial landings data, therefore, probably do not accurately reflect the true scale of local gillnet and trap fisheries in many areas of the Pacific. Cetacean interactions with gillnets and traps in what would be considered inshore reef fisheries in the central and western Pacific are rarely, if ever, reported. Gear set on the reef flats nominally separates most cetacean species from these fisheries. On occasion groups of small whales or dolphins become disorientated and trapped inside stoll lagoons and are sometimes taken for food in some areas of Micronesia. There are unconfirmed reports of humpback whales carrying away inshore gillnets in Hawaii over the past few years. This is in contrast to the reported high rates of incidental catch of cetaceans and other marine species in the high seas drift gillnet fisheries in the North Pacific and South Pacific regions. [38pp. + Revision 5pp.]

SC/O90/G35. DRIFTNET FISHERIES AND THEIR IMPACT ON NON-TARGET SPECIES. *Simon P. Northridge, Marine Resources Assessment Group, 8 Princes Gardens, London, SW7 1NA, UK.*

The major driftnet fisheries of the world are reviewed in terms of the numbers of vessels fishing, area and season of operation, major commercial species landed, and in a few cases in terms of fishing effort. Gear types are described and estimates of the amounts of netting deployed are made. The accidental captures of non-target species are described where they are known, and some indications of catch rates by species are also given. In some instances, broad estimates of total catches by species for individual fisheries are also given. Populations of non-target species which might most be at risk from entanglement in drift nets are discussed. Driftnet fisheries which have been little documented but which might be considered as potentially detrimental to individual species are also identified. [100pp.]

SC/O90/G36. REVIEW OF THE INCIDENTAL CATCHES OF CETACEANS IN JAPAN. *Teruo Tobayama, Kamogawa Sea World, Kamogawa-shi, Chiba-ken, 296 Japan, Yoshio Inagaki and Masahiro Ryohno, Hiyoriyama Marine Park, Toyooka-shi, Hyogo-ken, 669–61 Japan and Kenji Hiratsuka, Kamogawa Sea World, Kamogawa-shi, Chiba-ken, 296 Japan.*

Data on incidental catches of cetaceans in Japanese waters from 1970–1989 were gathered from 25 aquaria in Japan in 1990. In the last 20 years, a total 352 animals from 18 species caught incidentally were observed by aquaria. These were mainly caught by set nets (81%), seine nets (8%) or gillnets (7%). Major species were *Lagenorhynchus obliquens* (47%), *Neophocaena phocaenoides* (21%), *Grampus griseus* (7%), *Phocoena phocoena* (6%), *Tursiops truncatus* (5%) and *Balaenoptera acutorostrata* (4%). [6pp.]

SC/O90/G37. LARGE SCALE TRAP NET FISHERY IN JAPAN. *Tooru Sakuma, Japan Fisheries Agency, Kasumigaseki, Chiyodaku, Tokyo, 100 Japan.*

This paper summarises the large scale trap net fishery in Japan. These can be divided into two types: 'salmon' (operating in Hokkaido, mainly September to October); and 'other' (operating year round along the coast of the other Islands) that take sardines, atka mackerel, scombrids and other species. [3pp.]

SC/O90/G38. THE GROUNDFISH GILLNET FISHERY IN THE GULF OF MAINE: FISHING GEAR AND METHODS. *Stephen C. Drew, MBO, Box 936, Manomet, Massachusetts 02345, USA.*

This paper describes the gear and operations of the Gulf of Maine groundfish gillnet fishery. Monofilament gillnets with stretched mesh size ranging from 5.5 to 9 inches (140–229mm) are set on the bottom and anchored at both ends. Such nets commonly present a profile from eight to twelve feet in height. Several sections of net, each net 300 feet (91.5m) long, are joined end-to-end to make 'strings'. The length of a string of gear generally ranges from 1,500 to 3,600 feet (457–1,100m), with some strings over 6,000 feet

(1,830m). In common practice, one boat may fish 30 to 70 nets, divided among 3–6 strings. The species most often targeted are cod, pollock and spiny dogfish (on a seasonal basis). Nets which target flatfishes are rigged to fish with the leadline on the bottom and the float rope 2–3 feet above the bottom, with the net webbing slack. A few multifilament and multimonofilament nets are also used. Over 150 vessels participate in this fishery on a year-round or seasonal basis. Most vessels fall into the 35–55 foot (11–17m) length range, fishing one-day trips, leaving their nets in the water and attempting to haul them on a daily basis when weather permits. Nets which target flatfish are often soaked longer, since these species live longer while entangled. A minority of gillnetters fish farther than 40 miles from shore, making trips lasting two to eight days, hauling their nets daily and bringing the catch ashore at the end of each trip. [4pp.]

SC/O90/G39. DISCUSSION PAPER ON MANAGEMENT OPTIONS TO CONTROL MARINE MAMMAL MORTALITY IN PASSIVE FISHING GEAR. *James M. Coe, NMFS, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115, USA.*

Public and political expectations have often clashed with industrial, managerial and biological views and capabilities over controlling the fisheries bycatches of a wide range of species. Domestic and international attention to this problem is increasing as the real or perceived value and wastage of living marine resources increases. This paper discusses some general features of the fisheries resource management process and makes some recommendations in hopes of provoking vigorous discussion of the priorities and practicalities of marine mammal bycatch control. Bycatch is the collection of non-target species caught but not retained in any fishery. Bycatch may be unharmed, injured or dead when discarded. It includes both commercial and non-commercial fish and shellfish, marine mammals, birds, turtles and invertebrates. Bycatch is a fact of life for most fisheries. It typically becomes a management issue when a second or third party attaches some value to the discarded animals. The higher the value, the more likely some authority will be created or invoked to justify management actions to control, reallocate, or eliminate the bycatch. The legal notions of property, due process, and reasonableness are ever present in the application of these authorities. Marine mammals have virtually zero commercial value to passive gear fishermen. As bycatch they are cumbersome, aggravating and occasionally dangerous. On the other hand, a significant segment of the population attaches considerable value to marine mammals, wishing to protect them from harm in fisheries through statute and regulation. By establishing an economic consequence to the taking of marine mammals in the act of fishing, some control may be exercised over that taking. This type of artificial valuation of marine mammals *will* be necessary if their bycatch in passive fishing gears is to be reduced or eliminated. This implies the creation of authority permitting governmental agencies to apply appropriate measures. This type of authority varies widely around the world as does the value people and cultures attribute to marine mammals. Within the US Exclusive Economic Zone (EEZ), the Marine Mammal Protection Act and the Endangered Species Act provide this authority under certain conditions. On the high seas, this type of authority is absent except as extended through bilateral or multi-lateral agreements. Energetic international debate is developing over the ways and means to manage the resources of the high seas, focusing on bycatch in large-scale driftnet fisheries. [10pp.]

SC/O90/G40. MITIGATING CETACEAN MORTALITY IN FISHERIES: APPROPRIATE ALTERNATIVES. *Ronald Joel Smolowitz and Clifford Goudey, Massachusetts Institute of Technology, Center for Fisheries Engineering Research, Mass., USA.*

The United States has a commercial fishing industry that is very important to its economy. Concerns about marine mammals have the potential of significantly impacting commercial fishing. Efforts are underway to develop cetacean-saving gear so that fisheries can be conducted without harming cetacean populations. Gear development proceeds best when the fishermen are economically motivated to innovate to solve the problem. Proper motivation can result in the most economically efficient solution. [11pp.]

SC/O90/G41. INTERACTIONS BETWEEN THE NEW ENGLAND SINK-GILLNET FISHERY AND THE HARBOR PORPOISE, *PHOCOENA PHOCOENA*. *P. Michael Payne and Charles T. Yustin, Manomet Bird Observatory, PO Box 936, Manomet, Massachusetts 02345, USA and Gregory Power, NMFS, Northeast Fisheries Center, Woods Hole, Massachusetts 02543, USA.*

Under the 1988 reauthorisation of the Marine Mammal Protection Act the New England sink-gillnet fishery was classified as a Category I fishery. This was due to a known, but not yet quantified, bycatch of harbor porpoise (*Phocoena phocoena*) by gillnetters in the Gulf of Maine. In August 1989 the National Marine Fisheries Service/Northeast Fisheries Center initiated sea sampling aboard vessels participating in this fishery. Sea sampling effort was distributed according to fishing effort by region and season. Sea samplers observed gillnetters on 234 days during this study period on approximately 80 different vessels. The percent coverage represented by this level of sampling effort (number of days sampled per month/the total number of days fished in the fleet per month) by DSSP samplers ranged from <1.0% of total fleet effort during each month, June through August, to approximately 3.2% coverage (September). Most fleet effort (therefore sea sampling effort) occurred in NMFS/NEFC Fishery Statistical Areas 513 and 514 located from approximately Muscongus Bay to Cape Cod in the western Gulf of Maine. From August 1989 to July 1990 sampling occurred on 158 sea days, and monthly sea sampling effort ranged from 4 days per month (July 1990) to 30 (September 1989) in these two areas. Fifteen harbor porpoise were taken between October 1989 and April 1990. All documented harbor porpoise takes occurred in NMFS Fishery Statistical Areas 513 and 514. There were no porpoise captured from June through September 1989 or from May to July 1990. The seasonal take in NMFS Statistical Areas 513–514 is consistent with known movement patterns of harbor porpoise. Harbor porpoise move north, out of the western Gulf of Maine into the Bay of Fundy-eastern Scotian Shelf region from early-summer through autumn, then back through the western Gulf of Maine during late-autumn and spring. The lack of incidental take in remaining areas of the Gulf of Maine may reflect sampling effort disjunct from known harbor porpoise concentrations in the Gulf of Maine. [29pp.]

SC/O90/G43. HIGH SEAS DRIFTNET FISHERIES OF THE NORTH PACIFIC OCEAN. *Linda Jones, Michael Dahlberg and Shannon Fitzgerald, NMFS, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115, USA.*

This paper reviews high seas driftnet fisheries in the North Pacific. For each of the fisheries it provides a summary of the available information on the following: flag state; ports; target species; regulations on fishing season and area; vessels and crew; fish handling methods; gear; operation details; economics and history; catch and effort data; interactions with cetaceans. The fisheries reviewed were for squid, albacore and salmon. [35pp.]

SC/O90/G44. FACTORS IMPORTANT IN INITIAL EVALUATION OF THE BIOLOGICAL SIGNIFICANCE OF CETACEAN BYCATCH. *T.D. Smith, G.T. Waring* and *T.W. Polacheck, Northeast Fisheries Center, Woods, Hole, Massachusetts, USA.*

This paper examines the information needed to evaluate the biological significance of cetacean bycatches and compares this with the data that are frequently available so that possible systematic biases in the appraisal of the biological significance can be anticipated and corrected for where possible, and so that statistical precision can be measured where possible. Such factors are considered here for data on bycatch rates, total fishing intensity, and population size. The interrelation of these data sources in the comparison of bycatch level and population size is then discussed. Examples are drawn from the tuna purse seine fishery in the eastern tropical Pacific (ETP) and the bottom-tending gillnet fishery in the Gulf of Maine (GOM) and nearby waters. [36pp.]

SC/O90/G45. [NOTE TO PARTICIPANTS] *John LaGrange, Captain, 'Cloud Nine', 533 North Rios Avenue, Solana Beach, CA 92075, USA.*

This note was presented by the captain of a gillnetter. He discusses the measures that were successfully used to reduce gray whale captures in nets, including closed areas and seasons and modifications to gear. He recognised that the solution for other species is not so simple, given the different behaviour, size and knowledge of other species. Some measures that may help are discussed including limiting total gear and suspending nets some distance below the surface. Problems and methods of reducing caught animals are described. [5pp.]

SC/O90/G46. GILLNETS AND MARINE MAMMALS. *K.S. Norris, Institute of Marine Sciences, University of California, 100 Shaffer Road, Santa Cruz, CA 95060, USA.*

Possible ways in which marine mammal bycatches can be reduced can be classified as: (a) behavioural solutions; (b) gear-related solutions; (c) operations related solutions and (d) regulatory related solutions. Only the first two are discussed.

Behavioural solutions. If a marine mammal is patrolling a net to take trapped fish from it, it automatically is placed at risk. Even if the animal is somehow warned of the danger involved it may be attracted to the nets because easy food lies there for the taking. Warning a marine mammal away from a net is not likely to be enough, although it might help avoid kills of animals blundering into undetected nets. A first step is to determine how the marine mammal in question becomes entangled. Second, it will be useful to keep in mind the sensory capabilities of the animals' being trapped, as opposed to the kinds of signals that may be produced by a drifting net. Not all odotocetes echolocate equally well. Delphinids in general, produce broad band clicks arranged in trains, while the phocoenids, such as the Dall's porpoise, produce very different rather narrow band signals at very high frequencies. Dall's porpoise signals have been called 'black and white sonar' as compared to the richer signals of the delphinids. Their signals are expected to be useful at short ranges; a few dozen yards, as opposed to the delphinid clicks that may be useful at hundreds of yards. Phocoenid clicks may not be useful for fine discrimination but may well be good enough to discriminate prey species. The dolphins and porpoises that produce the narrow band high frequency clicks are uniformly species that live in murky water environments. The high frequency of these signals is above the hearing of their prey so they can echolocate with impunity, in terms of alerting prey to their presence. Other senses should also be considered such as vision, touch and manoeuvrability. Knowledge of the diurnal behavioural cycle may be useful. Marine mammals have preferred times for various activities in their lives such as sleep, feeding, etc. If nets fish for more than 24hrs, a consideration of these is restricted in its usefulness, i.e. one cannot design a netting system that avoids marine mammal activity. What one can do is to learn during what activity period most marine mammal kills occur, and this might be tied to behavioural state. Such information might help define the causes of kills.

Gear-related solutions. If marine mammals blunder into nets it would be useful to warn them of the net's presence. However, a 'warning' might be an attractant into danger because the net might represent a source of food and the warned marine mammals might rush in. Behavioural observations are needed about how marine mammals regard these nets. Do they seek them, or avoid them? How do the different species that are taken react? Use of passive or active acoustic devices may be useful. If a net food is the same size range as the normal food of the marine mammal concerned there will be an attraction for the marine mammal. Therefore, if mesh size is regulated to exclude the major marine mammal foods (i.e. by use of meshes too large to take such food) the attraction should be reduced and we should be dealing with incidental take related to nets undetected by the marine mammal. In this case, a different set of solutions is indicated than if active attraction is involved. An assessment of the food types utilised by a given marine mammal species is needed. How does what the mammal eats match the kinds of fish the net takes or releases? [4pp.]

SC/O90/G48. A REVIEW OF GEAR AND ANIMAL CHARACTERISTICS RESPONSIBLE FOR INCIDENTAL CATCHES OF MARINE MAMMALS IN FISHING GEAR. *Dawn Nelson, Memorial University of Newfoundland, Department of Psychology, St. John's, Newfoundland, Canada, A1B 3L1.*

World-wide incidental capture of marine mammals in fishing gear is a serious problem. Bycatch seriously affects some populations; losses to fishermen are, in some instances, substantial. Because of the extent of the problem, there have been many studies which have attempted to alleviate it. This paper provides an overview of these studies and their findings. Biological factors which influence entrapment of marine mammals include: (1) species distribution; (2) seasonal and migratory movements; (3) various behavioural traits; (4) sensory capacities and (5) attention and searching images. While additional information is needed on all of these factors, the most promising area in which solutions may be found and which requires the most investigation is that of attention. This biological trait interacts with a number of gear characteristics including: (1) target traits and strength; (2) location of sets and (3) rigidity and rigging characteristics. Solutions to bycatch problems for marine mammal populations and fishermen can be found by cooperative investigations involving both gear technologists and marine mammalogists. [26pp.]

SC/O90/G49. RESPONSES OF NAIVE, CAPTIVE DOLPHINS TO PROTOTYPE WHALE ALARMS. *Dawn Nelson, Dolphin Research Center, Grassy Key, Florida and Memorial University of Newfoundland, Department of Psychology, St. John's, Newfoundland, Canada and Jon Lien, Ocean Science Centre and Memorial University of Newfoundland, Department of Psychology, St. John's, Newfoundland, Canada.*

Every year, thousands of cetaceans worldwide become entangled in fishing gear. One possible explanation for this phenomenon is that certain types of gear may be difficult for cetaceans to detect. If this is the case, then enhancing the detectability of a net should cause a decrease in the number of entrapments. One possibility is to place sound generators onto fishing gear. Such devices need not frighten cetaceans away, but merely serve to inform them that there is something in their vicinity. It is thought that after encountering 'alarms' on nets, cetaceans will associate the alarm noise with the presence of a net and will stay away. Preliminary work with various types of alarms in Newfoundland waters indicated that the costs of humpback whale (*Megaptera novaeangliae*) collisions with fixed fishing gear were less when alarms were placed on the gear, possibly indicating that the whales were indeed attempting to avoid the nets. The purpose of this study was to discover what initial reactions captive dolphins might have to a novel sound generator. In order for the alarms to be most effective, cetaceans should initially be both curious and wary of them, so that they will approach cautiously and discover the net without becoming entangled. [10pp.]

SC/O90/G51. REACTIONS OF HUMPBACK WHALES TO NOVEL SOUNDS: CURIOSITY AND CONDITIONING. *Jon Lien, Ocean Studies Centre and Department of Psychology, Memorial University of Newfoundland, St. John's, Newfoundland, Canada, A1C 5S7; Amy Verhulst, School of Oceanography, University of Rhode Island, Narragansett, Rhode Island, USA; Tim Huntsman, Whale Research Group, Memorial University of Newfoundland, St. John's, Newfoundland, Canada; Janice Jones, Environmental Studies, Oberlin College, Oberlin, Ohio, USA and Rosie Seaton, Biopsychology Programme, Memorial University of Newfoundland, St. John's, Newfoundland, Canada.*

Add-on acoustical devices, which produce biologically novel sounds, have been proposed as a means of alerting cetaceans to the presence of cryptic fishing gear. To accomplish this, there are two prerequisites: the whale must notice the sound and learn it is associated with nets. Experiments during the summer of 1990 were designed to evaluate the reactions of humpback whales to sounds from devices developed as net 'alarms'. In the first experiment, two underwater acoustical 'alarm' devices were installed in a small bay where humpback whales were plentiful. Positions of the devices were marked with buoys which could be observed from shore. Movements of the whales in relation to the alarms were measured from shore by a theodolite. Throughout the observations, alarms were switched on and off; the observers did not know which were activated, or when. Results indicate that humpbacks closely approached alarm positions when they were producing sounds; approaches were not as common when the devices were off. The second experiment paired the presentation of these same sounds with a standard biopsy procedure used to obtain skin and blubber samples from individually identified whales. Humpbacks were photographed for individual identification and were later biopsied with or without sound; behaviours observed were recorded. Later, individuals were approached a second time with and without the sound. Behaviours observed in both approaches were compared. Individual reactions to biopsies vary as do the reactions to later presentations of sounds alone. Circumstances prevented completion of this experiment; results presented will evaluate the humpbacks short-term memory for novel sounds when they are paired with more meaningful stimuli. [13pp.]

SC/O90/G53. THE FRENCH ALBACORE TUNA FISHERY IN THE NORTH ATLANTIC. *J. Bonnemains and M. Kanas, Robin des Bois, 15 rue Ferdinand-Duval, 75004 Paris, France.*

The French albacore tuna fishery in the North Atlantic uses driftnets 4.35 miles long and 49.5 feet deep and is currently practised by 37 ships of less than 82.5 feet in length roughly between June 15 – September 15 of each year. This fishery began in 1986 with 2 vessels. Testimonies by crew members as well as observers from IFREMER (French Research Institute for the Exploitation of the Sea) during the 1988–90 fishing seasons have contributed to the Robin Des Bois' study which is based on an observer report from a fishing trip of average duration between July 31 – August 15, 1990. Estimates of the number of dolphins taken incidentally each year by this fleet have not been disproved by Robin Des Bois' observers. The question remains as to whether certain indications of abundance can permit us to claim that this incidental take does not pose a threat to regional populations. There is a need for systematic studies which suspend nets below the surface for an entire fishing season by 1 or more boats, as similar studies in the South Pacific have had encouraging results. The French albacore tuna fishery – a small-scale artisanal fishery – needs to be part of a European regulated fishery so as to avoid proliferation of the number of vessels, collapse of resources and increasing numbers of marine mammal takes. [9pp.]

SC/O90/G56. HEALTH STATUS AND BYCATCH OF HARBOUR PORPOISE (*PHOCOENA PHOCOENA*) IN DANISH WATERS. *B. Clausen, National Environmental Research Institute, Moerkhoej Bygade 26, H, DK-2860 Soeborg, Denmark.*

The report summarises available information on the health status and bycatch of harbour porpoise (*Phocoena phocoena*) in Danish waters for the last 50 years and the conclusions which may be drawn hereupon. In general it is not known how much the stock of harbour porpoise in Danish waters has decreased, but we know that there has been a migration of large numbers of harbour porpoise in and out of the Baltic Sea. This migration seems more or less to have stopped after the second world war, but before the intensive fishery started. Further, the area of distribution of harbour porpoise in the inner Danish waters seems reduced. Recent sightings from 1983–1989 do not indicate changes in the population during this period. Necropsis of harbour porpoise caught in poundnets from 1960 to 1970 revealed heavily parasitised animals. Animals caught alive in poundnets usually die due to lungworm infestation if not dewormed shortly after capture. Various information on heavy metals and chlorinated hydrocarbons have caused concern for the health and especially reproduction among marine mammals. Finally, information has been received that harbor porpoise are often incidentally caught in Danish waters. Therefore, there have been investigations conducted in order to assess: (1) whether changes in the population size have occurred; (2) the health status of the population; (3) whether it is just the sick animals which end up in the fishermens net; (4) the levels of toxichemicals, and the possible influence of pollutants on the reproduction and (5) the impact of the bycatch. [12pp.]

SC/O90/G58. PRELIMINARY REPORT ON THE JAPANESE FISHING EXPERIMENTS USING SUBSURFACE GILLNETS IN THE SOUTH AND THE NORTH PACIFIC, 1989–1990. *Shigeo Hayase and Yoh Watanabe, National Research Institute of Far Seas Fisheries, 7-1 Orido, 5 chome, Shimizu-shi, Shizuoka 424, Japan and Takashi Hatanaka, Japan Marine Fishery Resource Research Center.*

In order to develop fishing methods and techniques for avoiding or reducing the incidental takes of non-target species including cetaceans without the reduction of target species, the Fisheries Agency, Government of Japan, conducted the following two types of fishing experiments. (1) Experimental trials were conducted from November 1989 to March 1990 in the Tasman Sea and east of New Zealand setting 178mm large mesh gillnets both at the surface (about 900 tans/operations) and at 2m below the surface (100 tans simultaneously) for comparing the fish and dolphins catches between two different fishery gears. (2) During 4–31 May 1990, trials were conducted on the Japanese squid fishing ground in the North Pacific by seven Japanese commercial squid driftnetters, using surface gillnets (subsurface nets at average 2m) (88 tans). All data used were obtained through radio communications. In the experiment in the South Pacific, 57,940 tans of surface gillnets and 6,898 tans of subsurface gillnets were deployed. The CPUEs (catch in number/1000 tans) on albacore, the target species, were 533.8 in the surface net, and 644.5 in the subsurface net, respectively. Thus the result indicated that there was no significant difference in albacore catch rates between the surface and subsurface nets. A total of 97 common dolphins, 17 striped dolphins, and 9 other cetaceans were caught by the surface nets. Only one Baird's beaked whale was caught by the subsurface nets. In the experiment in the North Pacific, 124,881 tans of surface nets and 16,021 tans of subsurface net (8,751 at 1m, 7,270 at 2m) were deployed, respectively. CPUEs (kg/1,000 tans) on neon flying squid were 1,330 for the surface net and 1,310 for the subsurface nets (2m). This result indicated that there was no significant difference in squid catch among these three types of fishing operation. A total of 44 dolphins (CPUE: 0.35 individuals/ 1,000 tan) by surface nets; 3 dolphins (0.34) by 1m nets and one dolphin (0.14) by 2m were caught. This suggests that alternative fishing methods submerging nets below the surface may be more or less effective in reduction of cetacean catch rate. Although

these trials are preliminary, the results suggest that subsurface gillnets may be effective for reducing cetacean bycatch while maintaining catch rate of target species at almost the same level as with surface net. Further extensive trials will be required to confirm these results. [11pp.]

SC/O90/G59. ENCOUNTERS WITH GILLNETS: PRELIMINARY RESULTS FROM A SIMPLE MODEL AND SIMULATION OF THE PROBABILITY OF ENCOUNTERS WITH LONG PELAGIC DRIFTNETS BY CETACEANS.
Gordon R.V. Anderson, Australian National Parks and Wildlife Service, PO Box 636, Canberra City, ACT 2601, Australia.

Scattered observations on the distribution of entanglement sites of small cetaceans in long pelagic driftnets show non-random distributions along the net, with higher frequencies of entanglement toward the ends of the nets than in the central areas in some sets of observations. Explanations for the observed differences have included attraction of cetaceans to the net-end buoys and locating gear or differential soak times for nets shot and hauled from the same end. The preliminary results of a simple model and computer simulation of encounters of small cetaceans with a gillnet are described. The model: a two dimensional model of a single 50km driftnet; soak time of 10 hours; dolphin movement on random headings each ten minutes from a randomly assigned starting point, travelling at 100 to 2,000m/10 minutes, density of animals 100 per 50km by 200m strip parallel to the gillnet axis, strips from 0 to 20km, with equivalent density in quadrants beyond net ends. Simulations were run for swimming speeds of 100 to 2,000m/10 minutes in increments of 100m/10 minutes, with variance estimated from ten replicates for each speed. For the area beyond the net ends, 10 replicates were run for each swimming speed. Initial results indicate that for the area perpendicular to the net, the probability of encounters along the net is not uniform, with progressively greater differences between encounter rates in the central sections and the ends of the net with increasing swimming speed. For even quite modest swimming speeds, there is a significant chance of encountering the net for animals many kilometres away when the net is set and a significant encounter rate well into the soak period. There is also a probability that an animal well beyond the end of the net when it is set may move far enough during a ten hour soak time to encounter the net. Encounters along the net for animals moving from the areas beyond the net ends show strong peaks towards the ends of the net; the peaks spreading along the net with increasing swimming speed. Those peaks are strong enough to mask the lower probability of encounter towards the ends of the net for animals from the areas along the nets. The combined distributions for all areas fished by a net show strong peaks towards the net ends, with the form of the distribution dependent on swimming speed. While pelagic species of small cetaceans may travel considerable distances at speeds of 10 knots or more, foraging and resting movements may be very much slower. For inshore species, sustained speeds of 2–5 knots are reported commonly, although the horizontal distance covered in any 10 minute period may give a lower overall speed. (For a speed of 5 knots, the distance travelled in 10 minutes is approximately 1,300 metres). [7pp.]

SECTION 2. ABSTRACTS AS INCLUDED IN THE SYMPOSIUM BOOKLET (EXCLUDING THOSE WHERE A FULL PAPER WAS SUBMITTED AND MADE A DOCUMENT FOR THE WORKSHOP). ABSTRACTS ARE IN ALPHABETICAL ORDER BY AUTHOR.

PRELIMINARY REPORT ON DEATH OF CETACEANS IN GILLNETS IN NORTHEASTERN VENEZUELAN WATERS.
Ignacio Agudo, Fundacetacea Fundación Venbezolana para la Investigación, Defensa y Conservación de Mamíferos Cetáceos y Afines, P.O. Box 1273, Carmelitas, Caracas 1010, Venezuela.

In Venezuelan waters between 9°55′-11°25′N and 61°50′-64°30′W, local fishermen use gillnets 50–200m long and 5–12m deep constructed of 8–13cm-mesh webbing (Mihara *et al.*, 1971; MAC, 1982). In February 1987, 1,537 nets were reported operating in the area. *Morro de Puerto Santo* of August 26 1988 reported the sale of six dolphins to the crew of a shark-fishing boat. The dolphins were cut into pieces and placed in refrigerated storage for use as bait on bottom longlines. The skulls were obtained and have been placed in the Estación Biológica Rancho Grande (EBRG). The six dolphins were identified as *Stenella frontalis* (EBRG 16884, 16889), *S. longirostris* (EBRG 16885, 16886, 16887) and *S. clymene* (EBRG 16888). According to preliminary reports, since the beginning of 1988 deaths of cetaceans in gillnets have been very frequent. They have been used both for bait and for human consumption (Dollinger, 1985). In addition to the above three species of *Stenella*, cetaceans involved include *Delphinus delphis, Tursiops truncatus, Sotalia fluviatilis* and *Balaenoptera* sp. There have been no systematic efforts to determine capture rates, total mortality, species composition or impact of the incidental kills on the cetacean populations.

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Mihara, T., Brito, A., Ramírez, J. and Salazar, J.V. 1971. Artes y Métodos de Pesca para las Pesquerías Venezolanas Primera Parte. Consideraciones Generales. Proyecto Inv. Des. Pesq. MAC-PNUD-FAO. Informe Técnico 37, 38pp + illus.

INCIDENTAL CAPTURE OF SMALL CETACEANS ON THE COASTS OF RIO DE JANEIRO, ESPIRITU SANTO AND BAHIA STATES, BRAZIL. *L. Capistrano, R. Ramos* and *A.P. Beneditto, Fundação dos Estudos do Mar (FEMAR) World Wildlife Fund-US Project No. 3807, Rua Marques de Olinda, 18, Botafogo – Rio de Janeiro, Brazil 22.230.*

Between October 1988 and September 1989 we surveyed approximately 1,400km of the Brazilian coast from the village of Parati in the north (23°13′S, 44°43′W) to Santa Cruz de Cabrália in the south (16°13′S, 39°04′W). Fishing activities occur throughout the area surveyed. The main types of gear used are gillnets, seines, trawlnets and handlines. According to the fishermen, small cetaceans are incidentally captured in gillnets and seines in almost all of the places visited. The animals are generally used for fishing bait; an exception is the village of Regência (19°40′S, 39°45′W), where they are used for human consumption. We collected 25 small cetaceans at three localities (Atafona 21°37′S, 41°01′W, Regência and Conceiçao da Barra 18°30′S, 39°45′W); 21 were from gillnets and 4 from strandings. Of these, 17 were of the marine form of *Sotalia fluviatilis*, 7 were *Pontoporia blainvillei* and one was unidentified. The gillnets varied from 146–2,000m in length and 2–10m in depth. Mesh size ranged from 3–20cm. Because of the very long coastline involved and the brief period of time available for the survey, no attempt has been made to assess the impact of the incidental kills on the dolphin populations.

DOLPHIN CATCHES IN TAIWAN. *Che-Tsung Chen, National Taiwan Ocean University, 2 Pei Ning Road, Keelung 20224, Taiwan.*

There is a long history of catches of marine mammals in Taiwan. The primary species has been *Tursiops truncatus*, caught by gillnet, purse seine, drag net, drives using nets, tuna longline, troll line and harpoon. The main landing ports have been Peng-Fu, Suao and Tung-Kang. The meat is sold locally for human consumption at an attractively low price. At Peng-Fu the

fishermen use nets in a drive fishery to encircle the dolphins and hold them in inshore areas for sale to oceanaria in Taiwan and abroad. In recent years, about 60–100 dolphins have been captured during their annual migration in February. Local fishermen report that dolphins often interfere with hook-and-line fisheries, scaring the fish away and removing hooked tuna. Some dolphins are harpooned by fishermen when they follow the fishing vessels. Recommendations are made for future conservation and management of dolphins in Taiwanese waters.

BIOLOGICAL, ENVIRONMENTAL AND PHYSIOGRAPHIC FACTORS IMPLICATED IN THE INCIDENTAL CATCH OF BOTTLENOSE AND HUMP-BACKED DOLPHINS IN GILLNETS. *V.G. Cockcroft, Port Elizabeth Museum, PO Box 13147, Humewood 6013, South Africa.*

On the east coast of South Africa, gillnets are set to catch and deplete the numbers of sharks which may interact with bathers. Although the annual incidental catches of bottlenose and hump-backed dolphins (32 and 8, respectively) in these nets are low, neither population seems capable of sustaining such mortality and both appear to be in danger of local extinction. An analysis of biological, environmental and physiographic data for each animal captured provides some insights into the reasons for the incidental capture of these dolphins. The biological characteristics of the catch of the two species were generally distinct, although a few commonalities were evident. The majority of captures were single events, but mother and calf pairs of both species were often captured, although much more so for bottlenose dolphins. Most captured dolphins had almost full stomachs, implying that the capture of individuals of both species occurred either during or subsequent to feeding. Environmental parameters generally appeared to have no influence on captures. However, for the majority of captures of both species, current direction on the day of capture was different to that normally prevailing, possibly resulting in local prey movement and abundance. None of the physiographic factors analysed seemed to have an influence on capture. These results suggest that both bottlenose and hump-backed dolphins are captured during or immediately subsequent to feeding and although the exact mechanisms of capture are unknown, it is feasible that inattentiveness during or following feeding may result in capture. In conclusion, these data infer that efforts to prevent incidental captures should concentrate at the species level. Additionally, as both cetaceans and fisheries harvest in areas of relative prey abundance, it may be difficult to minimise captures without modifying fishing gear.

CAPTURE OF SMALL CETACEANS IN GILLNETS OFF THE PROVINCE OF SANTA CRUZ, ARGENTINA. *R.N.P. Goodall* and *M. Iniguez, 3410 Ushuaia, Centro Austral de Investigaciones Cientificas, Tierra del Fuego, Argentina. P. Sutton, Fundación Vida Silvestre Argentina, Buenos Aires, Argentina.*

The Province of Santa Cruz, Argentina (46°S to 52°20′S) has some 1,000km of coastline facing the southwestern South Atlantic, with low areas at the mouths of rivers and streams interspersed with long stretches of high cliffs. The province is sparsely populated, with few large towns. In the southern part of the province, fishing takes place sporadically during summer months with fixed gillnets set in the tidal zone perpendicular to shore for coastal fish. During brief coastal surveys in 1983 and 1986, we found 31 Commerson's dolphins (*Cephalorhynchus commersonii*) taken in nets at Bahia Laura, San Julian, Bahia Media Luna, Angelina and Cabo Buen Tiempo. Remains of Peale's dolphins (*Lagenorhynchus australis*) and spectacled porpoise (*Australophocaena dioptrica*) could have come from net fisheries. Coastal fishing with gillnets set from small beaches is common in the northern part of the province and in rivers such as the Rio Gallegos. One or more captures are known from Bahia Laura, but no recent cetacean mortality has been reported from Puerto Deseado, the largest port, where nets evidently are not set if dolphins are present. At least 20 ocean-going vessels of over 30m in length are based in Puerto Deseado and a few leave from the ports of Santa Cruz and San Julian. These work over the continental shelf with mid-water or bottom awl nets for shrimp, abadejo (*Genypterus blacodes*), merluzas (hakes, Merluccide) and others. In some of these fisheries, especially for abadejo in mid-water trawls, cetaceans are taken incidentally; the species involved to date are *C. commersonii* and *L. australis*. Monitoring for incidental catch in this province began only recently and the data are far from complete.

ASSESSMENT OF THE IMPACT OF DRIFTNET FISHING ON OCEANIC ORGANISMS: TASMAN SEA, JANUARY 1990, THE RESULTS OF THE GREENPEACE EXPEDITION. *Michael R. Hagler, Greenpeace Ocean Ecology Campaigner and Leader of the Tasman Sea Driftnets Expedition, Private Bag, Wellesley Street, Auckland, New Zealand.*

While numerous scientific observer programs had documented the devastating toll being exacted by driftnets on marine wildlife in the North Pacific, no data existed at all on their impact in the Tasman Sea or South Pacific region. Concerned about this lack of data, Greenpeace launched an expedition into the area during the 1989/90 albacore tuna fishery season. Driftnet fishermen in the Tasman laid an average of 40km per boat, per night between January 12 and 21, 1990. Japanese vessels deployed an average of eight individual nets, five kilometers in length, end to end: Taiwanese vessels deployed an average of five individual nets, eight kilometers in length, end to end. These nets were laid north/south across the expected easterly migration path of albacore tuna. Quantitative catch data were recorded for 23 complete nets and part of two additional nets of nine different days. Data recorded were fishing activities carried out between approximately [3?] to 41°S, and 156° to 161°E. Total net length surveyed for quantitative catch data was 126km, or an estimated 1.6% of the total length of driftnets deployed during this period. Eighteen nets were surveyed during net haulage; seven were surveyed during net soakage. Total catch records for nets which were quantitatively surveyed included 1,419 tuna (albacore and skipjack), 5 sunfish, 6 sharks, 7 billfish, 7 dolphins and 31 miscellaneous animals. A rare southern bottlenose whale was found entangled in an additional net. On the basis of mean calculated catch rates, twenty driftnet vessels in the Tasman Sea were predicted to have caught between some 780,000 to 900,000 tuna, 3,000 sunfish, 4,000 sharks, 3,000 billfish, 6,400 dolphins and 20,000 Ray's bream during the 3 month season. In the case of marine mammals, one dolphin was caught per 113 tuna, or per 11km of net during the net haulage (using calculated means). A major concern raised by this investigation was the apparent extent of 'high grading' (discarding of damaged target species) by Japanese driftnet vessels. These data fully support reports that this fishing practice is directly responsible for an unacceptable number of marine mammal deaths in the Tasman Sea and that it presents a hazard to non-target animals such as sharks and sunfish.

INCIDENTAL TAKE OF CETACEANS BY FISHING ACTIVITIES IN THE NEARSHORE WATERS OF THE NORTHEASTERN US, 1975–1989. *Scott D. Kraus, New England Aquarium, Central Wharf, Boston, MA 02110, USA. Colleen Coogan, National Marine Fisheries Service, 1 Blackburn Drive, Gloucester, MA 01930, USA. Patricia M. Fiorelli, New England Fishery Management Council, 5 Broadway, Saugus, MA 01906, USA.*

A total of 428 cetacean entanglements have been documented from 1975 through 1989 in the nearshore waters of the Gulf of Maine and the New York Bight. Gillnets, lobster gear, weirs and seines are the primary sources of entanglement. When the documented entanglements are analysed by species, mortality rates are inversely correlated with the size of the animals involved. In harbor porpoise encounters with gillnets, mortality exceeded 99%. The reported minke whale entanglement mortality is 64%, for humpbacks it is 12% and for finback whales 0%. These figures are probably overestimates of large whale mortality per entanglement, since some whales are likely to escape before they are discovered in fishing gear. In right whales, for example, 58% display scars indicative of entanglement at some time in their lives, but only three are known to have died incidental to fisheries activities (Kraus, 1990). However, because most entanglement reporting has been opportunistic the total number of entanglements is probably far larger than the 428 reported here. Further data from the NMFS marine mammal exemption program are not included here. For harbor porpoise, extrapolations from a limited systematic study conducted by Dr. James Gilbert in the early 1980s, combined with a review of the published literature, suggests that nearly 1,000 harbor porpoise are taken from the Gulf of Maine annually. This represents about 6.5% of the highest estimate of 15,300 for the Gulf of Maine harbor porpoise population (Read and Gaskin, 1988). Significant life history changes in the Bay of Fundy population indicating a serious population decline (Read and Gaskin, 1988) combined with this estimate suggest that the Gulf of Maine harbor porpoise population is being threatened by the gillnet fisheries of both the US and Canada.

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MORTALITY OF HARBOUR PORPOISES IN THE SWEDISH GILLNET FISHERY. *Ingalill Lindstedt, Institute of Marine Research, PO Box 4, S-453 00 Lysekil, Sweden.*

Data on the mortality of harbour porpoises (*Phocoena phocoena*) in fishing gear in Sweden in the years 1988–1890 are presented. In June 1988, a collection of harbour porpoises found dead in Swedish waters was started. Animals killed in the Swedish fishery as well as animals that have died of other causes are taken to the Museum of Natural History in Goteborg where they are examined. Data on the location of the catch, the kind of fishing gear used, etc. are obtained from the fishermen. During the first two years of this project 272 animals were collected of which 137 (50%) were found in fishing gear, of these 116 (85%) were from the coastal gillnet fishery. Currently most of the harbour porpoises incidentally killed in the commercial fishery are collected, this is supported by interviews among fishermen. The findings have been evaluated in terms of distribution of different kinds of fishing gear, seasonal and geographical distribution and sex and age of the animals. All major types of gillnets used in the Swedish fishery were represented, but most of the animals were taken in large mesh nets, (70–170mm) set for cod (*Gadus morhua*), pollack (*Pollachius pollachius*) and dogfish (*Squalus acantias*). Fishery statistics indicate that large meshed nets show the highest catch per unit effort. Most animals were taken in nets set at 10 to 60 meters. Few animals were taken in driftnets, probably because the fishery with large mesh driftnets for salmon largely occurs in the Baltic Sea where the harbour porpoise nowadays is rare. The number of animals caught in the gillnet fishery shows a peak in April, most probably reflecting the migratory behaviour of the species as well as seasonal changes in the fisheries involved.

SURVEY OF INCIDENTAL NET CATCHES OF MARINE *SOTALIA FLUVIATILIS*, *PONTOPORIA BLAINVILLEI* AND OTHER SMALL CETACEANS IN BRAZIL. *Liliane Lodi* and *Salvatore Siciliano, Projeto Baleia Jubarte, Parque Nacional Marinho dos Albrolhos, Praia do Kitongo s/no., Caravelas, Bahia, Brazil 45.900. Monica Borobia, St. Lawrence National Institute of Ecotoxicology, 310 Avenue des Ursulines, Rimouski, Québec, Canada, G5L 3A1.*

Unknown numbers of small cetaceans are killed annually by net entanglement in fishery operations in Brazil (Lodi and Capistrano, 1990). As a preliminary assessment of the nature and magnitude of catches, specimens were collected opportunistically from Pará (01°00'S 48°30'W) to São Paulo (25°15'S 48°00'W) States and available information complied from the literature. Marine tucuxi (*Sotalia fluviatilis*) and the franciscana (*Pontoporia blainvillei*) appear to be the most common species incidentally caught in gillnets (of various dimensions) from coastal artisanal fisheries throughout most of their range in Brazil. To date, 90 *Sotalia* are known to have been taken incidentally by 22 fishing villages in the surveyed region, with 73% of these catches from 1986–1990. Twenty-nine franciscanas were captured by three fishing villages between 1984–1988, from Espírito Santo (19°38'S 39°49'W) to São Paulo (24°43'S 47°33'W) States. Sex ratios for *Sotalia* (n=54) and *Pontoporia* (n=23) were similar, being approximately 1:1. Catches for both species were higher during the austral summer, with adult *Sotalia* (87%, n=45), and juvenile and subadult *Pontoporia* (62.5%, n=24) predominating. Other species identified from bycatches were the rough-toothed dolphin (*Steno bredanensis*) (n=3), the common dolphin (*Delphinus delphis*) (n=2), one false killer whale (*Pseudorca crassidens*) and one spotted dolphin (*Stenella frontalis*), all from the coast of Rio de Janeiro State. Target fish vary regionally, but the main species include mullet (*Mugil* spp.), croaker (mainly *Micropogonias furnieri*), weakfish (*Cynoscion* spp.) and marine catfish (Ariidae). Captured dolphins are stored and sold to serve mostly as bait for local shark fisheries (mainly Carcharhinidae) but in poorer villages for human consumption. From the coasts of Pará to São Paulo, at least 83 fishing villages operate gillnets year round. In spite of its low sampling effort our survey indicates that *Sotalia* and *Pontoporia* are highly vulnerable, especially considering the rudimentary nature of some fisheries. The impact of such interactions on dolphin populations, of yet unknown size, requires further evaluation for the achievement of sound management and conservation policies.

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PROPOSAL FOR COLLECTION OF INFORMATION ON THE VAQUITA (*PHOCOENA SINUS*) FROM FISHERMEN IN THE GULF OF CALIFORNIA. *Roman G. Maldonaldo, Coordinator of Nature and Exact Sciences, University Iberoamericana, Mexico Parq. Ave. No. #403, Z.C. 22200, Beaches of Tijuana, B.C., Mexico.*

The production and distribution of a simple brochure will provide an opportunity for fishermen to cooperate in efforts to preserve the vaquita. The fishermen may see the porpoise during or apart from fishing operations and potentially can collect data useful for scientific investigations. The brochure should include at least: (1) a complete description of the characteristics of the vaquita, including external proportions, with photographs; (2) a map showing all previous records; (3) a description, with illustrations, of the various types of nets in which the vaquita may be entangled; (4) a list of the kinds of observations of appearance, behaviour and fishery interactions that will be useful for research. The goal of this program, in addition to collection of data, will be to educate the fishermen and make them part of the program to save the vaquita.

ACCIDENTAL CATCH OF *SOTALIA BRASILIENSIS* IN SOUTHEAST BRAZIL. *Emygdio L.A. Monteiro Filho, Departamento de Zoologia, Instituto de Biologia, Campinas, SP, CP 6109, Cep. 13.081, Brazil.*

The estaurine complex of Cananéia is a mangrove region of high fertility, located in the south of the state of São Paulo, Brazil (25°01'S, 47°55'W). In this region, the local fishermen utilise two principal methods of fishing: the waiting net, which is extended in certain areas, although this method of fishing has not been used frequently; and the 'cercos' which is a fixed trap set in all seasons of the year in some mud banks, within the tidal range. *Sotalia brasiliensis* is frequently found in this habitat where it feeds in the surroundings of the mud banks. In 1984 a young female was found (approximately four months old) which had been killed in a waiting net in the mouth of a river. In 1989, young dolphins were found twice inside the 'cerco', with sufficient space for swimming and diving. In these occasions, the two dolphins were withdrawn from the 'cerco' with the help of a special net and subsequently were returned to the sea without any injury. However, these accidents in this region are rare and only one of the methods utilised (waiting net) may be harmful to the dolphins, although, without danger to the stock population.

REACTIONS OF BOTTLENOSE DOLPHINS DURING THE FIRST ENCOUNTERS WITH MONOFILAMENT GILLNETS. *Dawn Nelson, Biopsychology Programme, Memorial University of Newfoundland, St. John's, Newfoundland, Canada and Dolphin Research Center, Grassy Keys, Florida. Jon Lien, Ocean Sciences Centre and Department of Psychology, Memorial University of Newfoundland, St. John's, Newfoundland, Canada.*

Reactions of captive bottlenose dolphins that had no previous experience with monofilament gillnets were recorded by underwater video camera. The dolphins were released in a familiar enclosure which contained a single gillnet. Trials continued for one hour. Later, latency of first behaviours directed toward the net, type and frequency of behaviours were scored from analysis of the videotape. Each animal was tested at least twice. In this presentation, videos of the dolphins' reactions to nets were shown. The relationship of behaviours during first encounters with gillnets to entrapment and net mortality will be discussed. Often the incidental entrapment of young dolphins in gillnets is considered the result of a failure to detect or pay attention to nets. This study suggests that exploratory behaviours and attention actually directed toward nets is responsible for many gillnet entrapments.

AN UPDATED WORLD REVIEW OF INTERACTIONS BETWEEN MARINE MAMMALS AND FISHERIES. *Simon P. Northridge, Imperial College Centre for Environmental Technology, Marine Resources Assessment Group Ltd., 8 Princes Gardens, London, SW7 1NA, UK.*

This review is presented as an update to a previous work (Northridge, 1984) on interactions between marine mammals and fisheries. Each of the FAO statistical areas of the world oceans are treated in turn and published information for each area is used to collate an updated account of the ways in which marine mammals and fisheries interact. Particular attention is paid to the accidental capture of marine mammals in fishing gear and some new fisheries with potentially significant impacts on marine mammal populations are noted.

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ACCIDENTAL CAPTURES OF MARINE MAMMALS BY FISHERIES IN BRITISH WATERS WITH PARTICULAR EMPHASIS ON GILLNET FISHERIES. *Simon P. Northridge, Imperial College Centre for Environmental Technology, Marine Resources Assessment Group Ltd., 8 Princes Gardens, London, SW7 1NA, UK.*

Records of accidental captures of marine mammals in British waters have been collected from a wide variety of sources. Such records indicate that accidental captures of marine mammals have occurred over a long period of time and in a wide variety of fisheries. Catches are reviewed by fishing method. Trawlers are economically the most important part of the fishing fleet in Britain and these vessels evidently catch a number of marine mammals every year. Although gillnet fisheries are economically far less important, the numbers of boats employing gillnets is very large. Accidental captures of marine mammals in these fisheries are discussed on a regional basis. Certain areas and types of gillnet fisheries appear to catch significantly more marine mammals than others. The reasons for this are discussed and recent trends in gillnet fisheries in Britain are reviewed in terms of changes in vessels size distribution and fishing effort by region.

DOLPHIN DETERRENTS TESTED IN SHARK NETS OFF NATAL, SOUTH AFRICA. *Vic Peddemors, Natal Sharks Board, Private Bag 2, Umhlanga Rocks, 4320, South Africa. Vic Cockcroft, Port Elizabeth Museum, PO Box 13147, Humewood, 6013, South Africa.*

Shark nets are permanently set off 44 beaches on the Natal coast to protect bathers from shark attacks. Although these nets have proved very effective in preventing shark attacks, they have also caught a substantial number of harmless animals, including dolphins (Cockcroft, 1990). Concern for the effect of these incidental shark-net captures on populations of *Tursiops* and *Sousa* led to experiments with dolphin deterrent devices in the nets. These deterrents included both active and passive devices which were manufactured as cheaply as possible to enable future mass production if the tests proved successful. (1) Active devices emitted sounds and were of three types: (a) *clangers*: hollow copper cylinders with a pendulum suspended underwater and set in motion through wave action; (b) *rattles*: loose metal balls rolling with wave action inside the plastic net floats; (c) *bell buoy*: a floating 7kg gas bottle with a pendulum suspended inside the sealed cavity and activated through wave action. (2) Passive devices did not produce audible signals: (a) *plasticised aluminium foil*: 25cm squares attached to 4m intervals along the net centre; (b) *aluminium disc*: 23.5cm diameter flat discs were attached to net ends; (c) *stainless steel twine*: a double strand of 0.16mm diameter stainless steel twine was included in the braid of a new net. 2(a) and 2(b) were intended to act as possible visual and echolocatory stimuli, whereas the braid was to act as an echolocatory stimulus. Dolphin behaviour did not change when in the vicinity of the nets containing the active devices, however, the net containing the rattles caught a juvenile dolphin after 15 days and a humpback dolphin was caught 300m from the bell buoy. Although shark catches did increase during the period of experimentation in the net containing clangers, the rattles and bell buoy appeared to cause no change to the shark catch rate. Electrolytic reaction between salt water and the aluminium foil resulted in clear plastic panels where sealing had broken. The aluminium discs tarnished (reducing visual stimulus), caused minor entanglements and cut the nets. No dolphin movements were observed around the nets during these two experiments and no shark or dolphin catches occurred. The stainless steel twine was not affected by corrosion but broke during normal net handling, resulting in numerous steel burrs which rendered the net unmanageable. These operational problems and an extremely low annual CPUE for dolphins led to the discontinuation of these experiments. Results from this work suggested that more data should be obtained regarding factors influencing the dolphin catches before continuing attempts to deter dolphins from these nets. Subsequent behavioural observations indicate that the dolphins are normally aware of the presence of the nets, suggesting that a form of distractant behaviour exists during capture. This usually takes the form of feeding behaviour, however, spontaneous behaviour such as play may be important, especially during the captures of younger animals. Experimentation has therefore started using nets of varying mesh sizes in an attempt to reduce catches of smaller/younger animals. This represents the first approach at modifying net selectivity rather than attaching possible deterrent devices to nets, although this is possibly not directly applicable to the problem of incidental captures elsewhere. The international lack of success with deterrent devices suggests that *ad hoc* experimentation of this type should be reduced in favour of gaining a better understanding of the species interacting with the fishery. It is also the authors' opinion that cheap, homemade devices would probably be insufficient to warn dolphins of nets and that electronic acoustic devices would be more effective.

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STATUS AND CONSERVATION OF SEA DOLPHINS ALONG THE EAST COAST OF ANDHRA PRADESH, INDIA. *Rayavarapu J. Rao, School of Zoology, Jiwaji University, Gwalior, 474 011, India.*

An investigation was carried out during the months of May and June, 1990 to study the mortality of dolphins in fishing nets in the coastal belt of Andhra Pradesh near Kakinada. Data were also collected from the Fisheries Department, A.P. It was reported by the fishermen that dolphins (*Tursiops aduncus*), vernacular name:

Gadumi, Torra) were occasionally caught in the gillnets. According to them sightings of dolphins are occasional and usually dolphins are sighted during October-April in groups of 6–10 animals. Along with sea turtles (*Lepidochelys olivacea*), dolphins were also killed along the east coast due to gillnet operation (Rao, 1985; Silas *et al.*, 1983). Fishermen reported that earlier dolphins were not used for any purpose: however, these days they use the flesh of dolphins as bait for sharks, which is a growing fishery on this coast. Fishermen also sell dolphins as food. The price for one dolphin varies from Rs500 to 1,000 (US$30–60). According to the reports given by the Fisheries Department, a total of 7,892 fishermen using 1,973 boats operate gillnets along this coast. Each gillnet measures 30–40m in length and 12m in width, with a mesh size of 15–25cm. Detailed information on dolphin mortality rate along this coast is not available. It was learned that no measures are taken by the gillnet operators to avoid incidental catch of dolphins. It is suggested that a conservation programme for the protection of dolphins be started along the coast, where a sanctuary was created in 1978 for the conservation and management of the saltwater crocodile (*Crocodyles perosus*). Incidental catch of whales along this coast in gillnets has not been reported.

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A TANGLED WEB: HARBOUR PORPOISES AND GILLNETS IN THE BAY OF FUNDY. *Andrew Read, Department of Zoology, University of Guelph, Guelph, Ontario, Canada, N1G 2W1. Laurie Murison, Grand Manan Whale and Seabird Research Station, PO Box 129, North Head, Grand Manan, New Brunswick, Canada, E0G 2M0. Per Berggren, Department of Zoology, University of Stockholm, S-10691, Stockholm, Sweden. Thomas Woodley, Andrew Westgate and David Gaskin, Department of Zoology, University of Guelph, Guelph, Ontario, Canada, N1G 2W1.*

We have been studying incidental catches of harbour porpoises (*Phocoena phocoena*) in the Bay of Fundy gillnets since 1985. Each summer harbour porpoises and groundfish move into the Bay of Fundy where the porpoises become entangled in gillnets set for the groundfish. In this paper we briefly review the fishery, the nature of the entanglement process, the effects of these incidental catches and explore potential resolutions to the problem. The gillnet fishery in the western Bay of Fundy is relatively small, composed of between 19 and 28 vessels each season. Typically, each fisherman use 15 webs (183 × 3.65m each) of 15cm mesh monofilament net, anchored on the bottom in depths of 35–100m (Read and Gaskin, 1988). The nets are usually set in the morning and retrieved the following day. Indirect evidence suggests that porpoises are entangled while the nets are on the bottom. We have received very few reports of live porpoises recovered from gillnets; most of the 300+ specimens we have examined exhibited rigor mortis and damage by benthic scavengers. In addition, many porpoises have remains of hagfish (*Myxine glutinosa*) in their stomachs, suggesting that the porpoises are feeding on hagfish that are themselves foraging on fish in the nets. It is unclear whether or not the porpoises can detect the nets. Preliminary evidence indicates that rates of incidental mortality from all gillnet fisheries, including those of the Gulf of Maine, lie between 2 and 10% per year. It is unlikely that the population can sustain such incidental catches, given their low potential for increase (Woodley and Read, 1990). Harbour porpoises have virtually disappeared from some areas in the Bay of Fundy in which they were formerly abundant, perhaps due to a decrease in total population size. There have also been changes in life history parameters, such as a decrease in age at sexual maturity and an increase in calf size, that are consistent with a reduction in density (Read and Gaskin, 1990). There are several potential resolutions to this problem, including area closures, gear modification, or elimination of the fishery. We suggest that the most efficient solution to this particular conflict is to replace gillnets with other, more selective forms of fishing gear such as longlines.

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THE IMPACTS OF PASSIVE NETS AND TRAPS ON THE GANGETIC DOLPHIN. *Tej Kumar Shrestha, Royal Nepal Academy of Science and Technology and Department of Zoology, Kirtipur Campus, Kathmandu, Nepal.*

Gillnetting is widely practised in the hydrographically unique mountain rivers of Nepal. Both fishermen and the susu (*Platanista gangetica*) rely on food from the rivers for survival and therefore interact in many ways. In the present paper, design and construction of various kinds of driftnets and gillnets are described. Entangling properties of the nets and their impacts on breeding and calving populations of dolphins are evaluated. Synthetic twine is widely used in the nets; this may be deadly, because it is not easily detected visually or acoustically by dolphins in the murky run-off waters generated by the annual monsoon (May-July). Dolphins are an indirect target of such fishing efforts and their populations are often negatively affected by interactions with fisheries. The fishermen compete for limited fish resources. In the process, dolphins become entangled in gillnets or are otherwise harvested inadvertently. The low water of winter attracts commercial gillnet fishermen, who use stretched gillnets and capture juvenile dolphins. Gillnets are often stretched across the river at night to capture everything that passes, placing them in direct competition with the dolphins. An estimate of mortality of juvenile dolphins and endangered game fish is made. Incidence of entanglement and effects of stranding events are evaluated. Possible ways and means to reduce dolphin kills in nets are discussed, including recommendations for regulation of mesh size. The dead and dying dolphins are retrieved immediately. Their eyes, foetuses and genitalia are used by folk healers as charms and in medicines. The need and opportunity for educating the riverside people about the value of the endangered dolphin are highlighted and suggestions are made for effecting fishing regulations and enforcement.

FRESHWATER DOLPHIN/FISHERIES INTERACTIONS IN THE AMAZON REGION (BRAZIL). *V.M.F. Da Silva and R.C. Best*, Laboratorio de Mamíferos Aquáticos, Instituto Nacional de Pesquisas da Amazônia, (INPA), Brazil.*

An analysis of the relative importance of different types of fishing gear in Amazon dolphin mortality based on samples of 33 *Inia geoffrensis* (boto) and 34 *Sotalia fluviatilis* (tucuxi) revealed the lampara seine was most lethal (82.8%) for *Inia*. Whereas, drifting (38.3%) and fixed gillnets 35.3% were the major contributors in *Sotalia* mortality. These three types of gear accounted for a total of 97% of all *Inia* captures and 88.2% of *Sotalia* incidental captures. The use of nylon gillnets in fisheries in the Amazon, although recent, is widespread throughout the whole region, with increasing fisheries pressure and the potential for dolphin-fisheries interaction is much greater. Competition between man and dolphin for commercial fish is still minimal in the Central Amazon. Food habits analysis have shown that only 43% of 53 identified prey species are of commercial value and that the dolphins generally prey on size-classes of fish below the size-classes of commercial interest. Interviews with fishermen in the boats, in the fishmarket and in the shops supposedly selling dolphin products were conducted in an attempt to quantify the overall incidental kill attributed to commercial fisheries operations. The results showed that in the Central Amazon dolphin catches are incidental and only a very small number of these carcasses are used for commercial purposes.

* Robin C. Best died on 17 December 1986. He was a Research Associate of the Vancouver Public Aquarium.

INCIDENTAL CATCHES OF SMALL CETACEANS IN DRIFTNETS DURING SALMON TAGGING EXPERIMENTS IN THE NORTHWEST ATLANTIC. *Garry B. Stenson* and *Dave G. Reddin, Science Branch, Department of Fisheries and Oceans, PO Box 5667, St. John's, Newfoundland, Canada, A1C 5X1.*

We examined incidental catches of cetaceans in surface driftnets used to obtain salmon (*Salmo salar*) for tagging experiments. From 1965 to 1989, 29 cruises with a total of 5,365nm-hrs (nm*hr) of fishing effort were undertaken in offshore areas from the southern Grand Banks of Newfoundland to West Greenland. In addition, 12 cruises totalling 887nm*hr of fishing effort, occurred in inshore areas around Newfoundland and Labrador between 1969 and 1981. Data on the species and numbers of individuals caught, dates and locations of capture and catch per unit fishing effort were obtained using trip summaries and onboard observations. Although earlier sets used multifilament gillnets, monofilament nets with mesh sizes from 102 to 140mm were used for the majority of sets. Four species of small cetaceans were identified as bycatch. Harbour porpoise (*Phocoena phocoena*) were the most frequently caught species in all areas except for the Labrador Sea, where white-sided dolphins (*Lagenorhynchus acutus*) were more common. Long-finned pilot whales (*Globicephala melas*) and common dolphins (*Delphinus delphis*) were also caught. Low numbers (1–3) of harbour porpoise were regularly caught in the West Greenland, Grand Banks and inshore areas. Occasional large catches occurred in some sets. CPUE averaged 0.008/nm*hr inshore (spring and summer), 0.01/nm*hr in West Greenland (summer), 0.03/nm*hr on the Grand Banks (spring) and 0.14/nm*hr in the Newfoundland Basin (spring). Although considered primarily an inshore species, harbour porpoise were found in waters of all depths, including the deep waters (>2,000m) of the Newfoundland Basin and Labrador Sea. White-sided dolphins were caught sporadically (6 trips only) but in larger groups than harbour porpoise. CPUE varied from 0.04–0.05/nm*hr in the Newfoundland Basin (spring) and Labrador Sea (summer) to 0.004/nm*hr on the Labrador Shelf. White-sided dolphins tended to be caught in warmer waters and along the shelf edge. None were caught inshore, in West Greenland, or on the Grand Banks proper. Catches of all species varied greatly along years and were highly skewed. No animals or seasonal trends were obvious although the large number of cetaceans caught during the only major trip to the outer slope of the Grand Banks in May suggest that this may be an important area for all four species.

ENTANGLEMENT OF TWO HUMPBACK WHALES AND ONE GRAY WHALE IN PASSIVE FISHING GEAR IN SOUTHEASTERN ALASKA. *Janice M. Straley, Glacier Bay National Park* and *Preserve Gustavus, Alaska 99826, USA. C. Scott Baker, Victoria University, Wellington, New Zealand.*

In August 1986, a humpback whale (*Megaptera novaeangliae*) calf (defined as a whale less than one year old and accompanied by another, larger whale, presumed to be the cow) was observed towing fishing gear in Frederick Sound. The gear consisted of 100m of small diameter, green, polypropylene ground line, trailing a large, 1m diameter, fluorescent-pink bag buoy attached to a 2m tall, weighted aluminium flag pole. This type of gear is used in long-line bottom fishing in southeastern Alaska. The pod consisted of the cow, calf and a companion. To disentangle the whale, the pole and buoy were cut loose and the ground line was reeled in and cut off in 8m sections. It was not obvious where the line was attached to the whale, it was assumed to be around the tail stalk. All but 5–8m of line was removed. This procedure took about three hours. All three whales stayed together during this time, not diving or fluking. The pod was then observed for 20 minutes and behaviour appeared to resume to normal. In July 1988, a 16m, gray whale (*Eschrichtius robustus*) became entangled and died in a gillnet set at the mouth of the East Alsek River. The net was set in accordance with state law. The whale was presumed to be feeding in shallow water, nearshore on a rising tide. It apparently became entangled in the haul out line of the set gillnet on the outgoing tide. The whale appeared to have been in good health. The entanglement occurred near the tail as there was no gear or scarring on the body of the whale. In August 1988, a humpback whale calf was observed towing a yellow, 1/2m diameter float in Icy Strait. The calf was accompanied by a larger whale presumed to be the cow. The whales were approached and the line disentangled in a similar manner described above. The fishing gear consisted of 160m of small diameter, green, polypropylene ground line. Entangled with this line were ground line snaps, circle hooks and salmon trolling gear (flashers and hoochies). This whale had apparently caught other fishing gear while towing this longline gear. This cow and calf were seen subsequently throughout the summer season. The two humpback entanglements occurred in gear left after a fishing opener. This could have been avoided by stricter regulations on gear removal. The gray whale entanglement and death could have been avoided by a closer watch by the regulatory agencies. It is known that gray whales feed close to shore and there were observations of grays and humpbacks feeding in the area prior to the incident. The biology and behaviour of individual cetacean species needs to be considered when establishing guidelines for reducing entanglement and developing methods for disentanglement in passive fishing gear.

THE SOUNDS OF SILENCE: ACOUSTICS OF FISHING NETS AND BAIT. *Sean Todd, Biopsychology Programme, Memorial University of Newfoundland, St. John's, Newfoundland, Canada, A1B 3X9* and *C-CORE (Centre for Cold Ocean Research and Engineering), Memorial University of Newfoundland, St. John's, Newfoundland, Canada. Jacques Guigne, C-CORE, Memorial University of Newfoundland, St. John's, Newfoundland, Canada. Jon Lien, Ocean Sciences Centre and Department of Psychology, Memorial University of Newfoundland, Canada.*

A series of experiments were conducted to determine acoustic signatures of fishing gear and fish schools. The objective was to determine those signals which would be available to cetaceans in locating such objects and the acoustic interactions between fish and fishing gear. Sounds from different types of nets were measured in a flume tank under different water flows. Nets vary considerably in the noise they produce. Field data on number of the entrapments of humpback whales correlates inversely with noise of fishing gear. Acoustic signatures of a bait fish, capelin, were obtained for schools of different sizes and sex compositions in both laboratory and field tests. The presence of bait modifies and reduces noise associated with nets and may make them more difficult to detect. Complex fishing gear, such as traps, were studied as they filled with target species such as codfish. Sounds produced by this gear were also modified by the presence of fish. Sounds produced by fishing gear may be an important factor in determining the frequency of entrapment of at least some cetaceans, but the acoustic characteristics of fish in the nets modifies sound of the nets. Thus entrapment frequency is a function of net acoustics and how well the net is fishing.

ESTIMATE OF VAQUITA, *PHOCOENA SINUS*, MORTALITY IN GILLNET FISHERIES IN THE NORTHERN GULF OF CALIFORNIA, MEXICO. *Peggy T. Turk Boyer, The Intercultural Center for the Study of Deserts and Oceans, 2601 E. Airport Road, Tucson, AZ 85706, USA. Gregory K. Silber, Institute of Marine Sciences, University of California, Santa Cruz, CA 95064, USA.*

The vaquita, *Phocoena sinus*, is vulnerable to the point of extinction. While the species apparently suffers substantial mortality in gillnets, the magnitude of incidental mortality and its impact on the population are not known. We interviewed fishermen in an attempt to determine fishing effort in the northern Gulf of California and to quantify vaquita mortality levels in gillnets. Though some problems are inherent to these types of data, the information can guide management decisions until more complete studies on incidental mortality are conducted. A total of 70 fishermen were interviewed from three communities in the northern Gulf of California. Gillnet fishermen reported capturing 22 vaquita, at a rate of 0.05 vaquita/fisherman/year resulting in an overall mortality estimate of 32.3±14.1 (95%CI) vaquita/year. This estimate may represent as much as 10% of the entire vaquita population. The majority of vaquita (90.1%) were caught in the most frequently used nets which consisted of 25.4–30.5cm mesh. Ninety-five percent of the vaquita were captured in water depths between 9 and 50m and mean depth was 24.9±SD 17.61m. The greatest fishing effort and 75.0% of the porpoise captures occurred in March through June corresponding with the northward migration of totoaba (*Cynoscion macdonaldi*). The taking of totoaba is prohibited by law. In addition to vaquita, 43.5% of the fishermen reported capturing sea turtles, 32.6% caught sea lions, 28.3% caught common dolphins and 21.7% caught bottlenose dolphins. Of all reported incidental catches of reptile and marine mammal species, 95.7% occurred in 25.4–30.5cm mesh gillnets. We recommend that gillnetting activities in the northern Gulf of California be ceased immediately. If complete moratoriums are not feasible, restrictions should be considered with respect to mesh size, fishing location, water depth or season.

INCIDENCE OF GEAR ENTANGLEMENT FOR RESIDENT INSHORE BOTTLENOSE DOLPHINS NEAR SARASOTA, FLORIDA. *Randall S. Wells, Conservation Biology Department, Chicago Zoological Society, Brookfield, IL 60513, USA. Michael D. Scott, Inter-American Tropical Tuna Commission, c/o Scripps Institution of Oceanography, La Jolla, CA 92038, USA.*

Bottlenose dolphins residing in the shallow inshore waters along the central west coast of Florida are exposed to gear from a variety of commercial fishing activities, including gillnets, trammel nets, purse seines and crabtraps. We have found evidence of apparent gear entanglement on 11.0% of the 146 dolphins we have handled during our capture, sample, mark and release efforts during 1975–1990. Evidence of apparent entanglement includes direct observations, as well as records of cuts and scars around the torso, fins and gape of the mouth that match the diameters of lines commonly used in fishing gear. Mortality from entanglement with fishing gear, however, appears to occur infrequently. Only one of the resident dolphins is known to have died directly from entanglement during 1975–1989. A subadult male entangled in a beach-set pompano gillnet during a squall in 1976. Two other entangled dolphins would probably have died save for human intervention. One 9 month old female entangled in a mullet gillnet was released unharmed by our research team. A 7 year old male became tangled in a crabtrap floatline; the trap and float were cut free by boaters. A minimum estimate of the annual mortality rate due to entanglement is 0.001±0.0011 (1 confirmed mortality during 898 animal years), but could have been 0.003±0.019 (3 mortalities) if human rescue had not occurred. These mortality rates are minimum estimates because not all dolphin carcasses may have recovered or have shown signs of entanglement. Annual loss from the approximately 100 residents of the Sarasota population due to natural in incidental fishery mortality and emigration averaged 0.189 for young of the year and 0.038 for older animals (Wells and Scott, 1990). A disproportionately high number of subadult dolphins were involved in entanglement. At least 9 of 16 apparent entanglement records involved subadults; the scarring on the remaining adults occurred at an undetermined age.

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FIRST EVALUATION OF THE INTENTIONAL AND ACCIDENTAL CATCH OF CETACEANS AT SANTA CATARINA ISLAND, BRAZIL. *Alfredo Ximenez, Laboratorio de Mamíferos de Universidade Federal de Santa Catarina, Caixa Postal 5132, Campus Universitario, 88049 Florianópolis, SC, Brazil.*

Until 1985, the level of mortality of cetaceans caused by fishing activities in Santa Catarina State was unknown. In that year a program began which included collection, preparation and conservation of stranded specimens all along the littoral (172km) of Santa Catarina located between the parallels 27°10' and 27°50'S and the meridians 48°25' and 48°35'W. Between February 1985 and June 1990, 40 specimens have been obtained showing marks of gillnets and mutilation. One intentional take of *Pontoporia blainvillei* was recorded. The following species were stranded and collected: *Steno bredanensis, Sotalia fluviatilis, Tursiops truncatus, Stenella frontalis, Delphinus delphis, Pseudorca crassidens* and *Balaenoptera acutorostrata*. Also collected was the head of a specimen identified as *Tursiops truncatus* but the morphology of its skull shows combined characters of both *Tursiops* and *Steno*; this suggests that the specimen is an intergeneric hybrid that should be the central point for further studies. Artisanal fishing is developed in the region in ancient traditional communities that use several kinds of nets with mesh size between 40mm and 200mm. The impact of this kind of activity on the cetacean population still remains unknown. Nevertheless a well directed study could yield valuable information in the future.

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