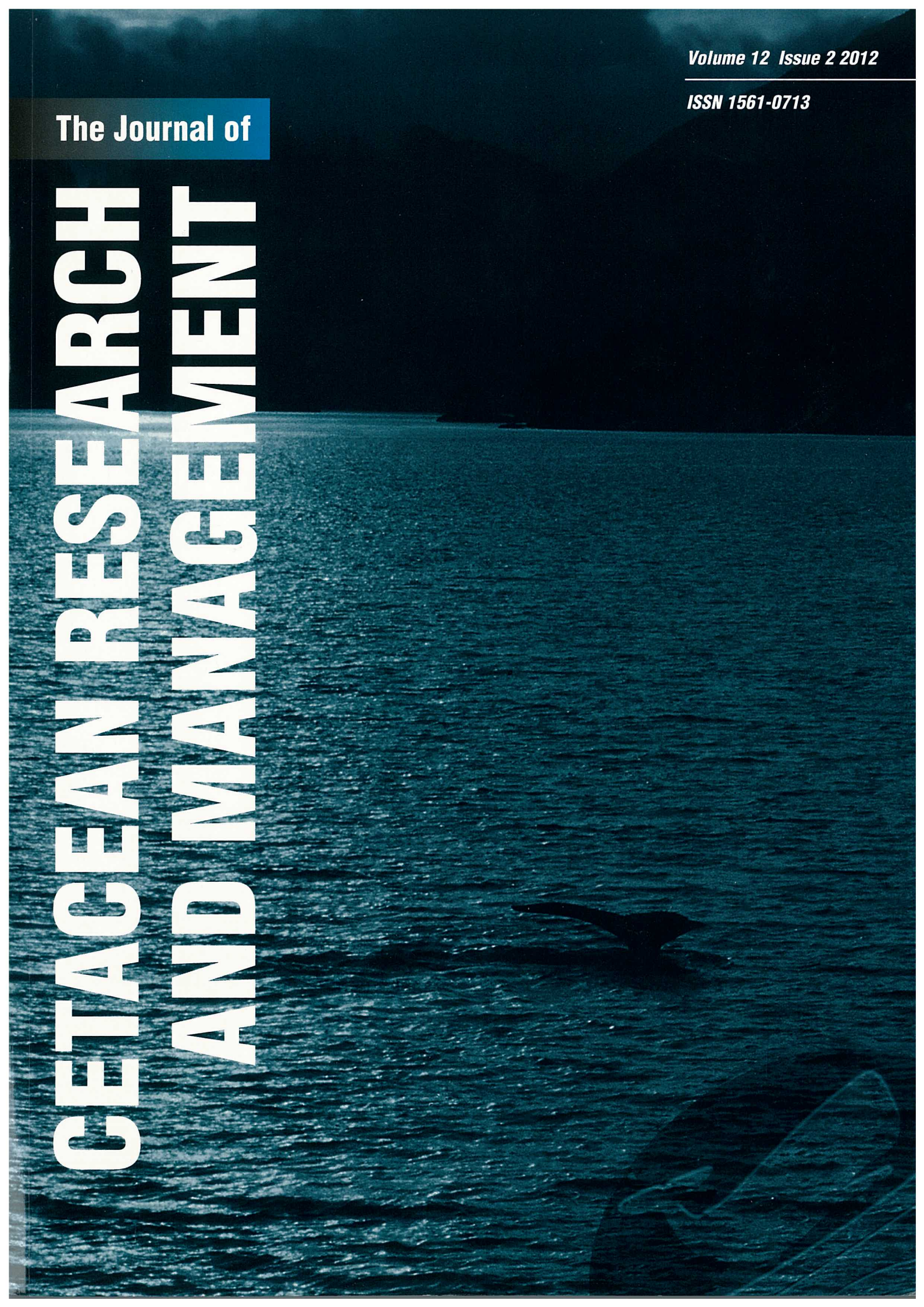


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Contents

Editorial	iii
Introduction	v
S. HOLT – Negotiating the Indian Ocean Whale Sanctuary	145
K. ADULYANUKOSOL, S. THAONGSUKDEE AND K. KITTIWATTANAWONG – Cetaceans and mass strandings in Thai waters	151
R.P. KUMARRAN – Cetaceans and cetacean research in India	159
K. SATHASIVAM AND K.S. NATARAJAN – Obtaining distributional information on Indian Ocean cetaceans: suggestions based on an Indian network experience	173
A.D. ILANGAKOON – A review of cetacean research and conservation in Sri Lanka	177
A. DE VOS, R. CLARK, C. JOHNSON, G. JOHNSON, I. KERR, R. PAYNE AND P.T. MADSEN – Cetacean sightings and acoustic detections in the offshore waters of Sri Lanka: March–June 2003	185
A.D. ILANGAKOON AND K. SATHASIVAM – The need for taxonomic investigations on northern Indian Ocean blue whales (<i>Balaenoptera musculus</i>): implications of year-round occurrence off Sri Lanka and India	195
R.C. ANDERSON, T.A. BRANCH, A. ALAGIYAWADU, R. BALDWIN AND F. MARSAC – Seasonal distribution, movements and taxonomic status of blue whales (<i>Balaenoptera musculus</i>) in the northern Indian Ocean	203
R.C. ANDERSON, S.A. SATTAR AND M.S. ADAM – Cetaceans in the Maldives: a review	219
R.A. CLARK, C.M. JOHNSON, G. JOHNSON, R. PAYNE, I. KERR, R.C. ANDERSON, S.A. SATTAR, C.A.J. GODARD AND P.T. MADSEN – Cetacean sightings and acoustic detections in the offshore waters of the Maldives during the northeast monsoon seasons of 2003 and 2004	227
M.A. GORE, M.S. KIANI, E. AHMAD, B. HUSSAIN, R.F. ORMOND, J. SIDDIQUI, U. WAQAS AND R. CULLOCH – Occurrence of whales and dolphins in Pakistan with reference to fishers’ knowledge and impacts	235
O.A. AMIR, P. BERGGREN AND N.S. JIDDAWI – Recent records of marine mammals in Tanzanian waters	249
V. DULAU-DROUOT, J. FAYAN, L. MOUYSET AND V. BOUCAUD – Occurrence and residency patterns of humpback whales off Réunion Island during 2004–10	255
S. PLÓN, K.H. ALBRECHT, G. CLIFF AND P.W. FRONEMAN – Organ weights of three dolphin species (<i>Sousa chinensis</i> , <i>Tursiops aduncus</i> and <i>Delphinus capensis</i>) from South Africa: implications for ecological adaptation?	265
E.J. EYRE AND J. FRIZELL – A note on observations of cetaceans in the Indian Ocean Sanctuary, Australia to Israel, April 1995	277

Editorial

This issue is dedicated to studies from the Indian Ocean. Most of these peer-reviewed papers were presented in some form at the Indian Ocean Cetacean Symposium (IOCS) held in Maldives, 18-20 July 2009 to mark the 30th anniversary of the IWC's Indian Ocean Sanctuary. Special thanks go to

Charles Anderson who has put in an enormous amount of work as guest editor to bring this volume to fruition.

G.P. DONOVAN
Editor

Introduction

The formation of the IWC's Indian Ocean Sanctuary in 1979 stimulated a flurry of cetacean research in the region during the 1980s. This included the voyage of the RY *Tulip*, the burgeoning of cetacean studies in Sri Lanka, as well as other work which was reported to the IWC scientific review meeting held in Seychelles in February 1987 (Leatherwood and Reeves, 1989; Leatherwood and Donovan, 1991; Whitehead, 1989). However, since then there had been no regional gathering of interested scientists. Key aims of the IOCS in 2009 were therefore to bring together cetacean researchers from across the region and to demonstrate the breadth and quality of cetacean research being carried out within the Indian Ocean Sanctuary.

In the event, the IOCS brought together 60 cetacean scientists from some 22 countries. The Symposium was inaugurated by the then Vice President of the Maldives Dr. Mohamed Waheed Hassan Maniku. A report of the symposium (Sattar *et al.*, 2009), including transcripts of opening speeches, abstracts of presentations, a list of participants and other details is available from the website of the Maldivian Marine Research Centre (<http://www.mrc.gov.mv>).

Some 43 presentations were made at the IOCS on a wide variety of topics relating to Indian Ocean cetaceans, under three general headings: regional reports, species reports and conservation and management. Several of those presentations were of works in progress, but just over a third have found their way into this peer-reviewed issue. An award for the best presentation at the IOCS by a coastal country scientist was presented to Muhammad Shoab Kiani (Pakistan), with Kanjana Adulyanukosal (Thailand) receiving a runner-up certificate.

In addition to presenting Indian Ocean research, another aim of the IOCS was to highlight the range of threats being faced by cetaceans within the Sanctuary. Fisheries bycatch emerged as a common problem in many countries, and that is reflected in several of the papers presented here. Other threats identified include ship strikes, oil and gas exploration, as well as pollution and (for coastal species) habitat degradation. The potential economic value of whale and dolphin watching, which is bringing employment and recreation to growing numbers of people around the Indian Ocean was also recognised.

The IOCS participants concluded the symposium with the formulation and adoption of the Lankanfinolhu Declaration¹. That declaration recognised the continuing contribution of the Indian Ocean Sanctuary to cetacean conservation within the region; noted the need for countries and organisations within the region to address issues of bycatch and directed catches of small cetaceans; to ensure appropriate mitigation when seismic surveys are carried out; and to work towards habitat protection, especially for cetacean hotspots and critical habitats. It also supported the

wider adoption of responsible whalewatching guidelines and regulations, and encouraged range states along with the IWC and others to develop a collectively agreed action plan to improve conservation outcomes for Indian Ocean cetaceans.

Other outcomes of the IOCS included: the production of a poster depicting the cetaceans of the tropical Indian Ocean, distributed to participants and to every school in Maldives; a presentation by OBIS-Seamap² demonstrating the possibilities and value of data archiving; two public lectures to schoolchildren by Dr. Michel Vély and Dr. Roger Payne; and this peer-reviewed volume.

The first paper in this issue is based on one of the two key note addresses at the IOCS. In his address, Sidney Holt discussed the background to the formation of the IWC's Indian Ocean Sanctuary. Holt was personally involved in the negotiations leading up to the formation of the Indian Ocean Sanctuary and his paper here provides his fascinating perspective on its origins.

In the second keynote address to the IOCS, Roger Payne described the findings of the five-year (2000–05) round-the-world *Voyage of the Odyssey*, which included two years in the Indian Ocean. (His address is not reported here, but details of the *Voyage* are available in: Ocean Alliance, 2009). Their global survey of sperm whales clearly demonstrated that these near-apex predators are concentrating potentially dangerous levels of toxic pesticides and metals. At the same time, the *Voyage of the Odyssey* provided a platform to survey cetaceans, often in areas where relatively little cetacean research has been carried out before. Reports from two such Indian Ocean areas (Sri Lanka and Maldives) are included here.

But the first of the regional reports published here is that of Adulyanukosal, Thaongsukdee and Kittiwattanawong who review cetaceans in Thailand. They look in particular at mass strandings, reporting on a series of five from the Andaman Sea (west) coast of Thailand involving four different species of odontocetes.

From India, Kumarran reviews cetacean records amassed over the past two centuries. Twenty five species of marine cetacean (plus one freshwater dolphin) are noted, with most records being from strandings and fisheries bycatch. There have been relatively few reports of sightings at sea, but most of those are recent, which suggests a hopeful trend towards more research on live cetaceans within India's extensive EEZ. On the other hand, Kumarran notes the real threat of fisheries interactions to small cetaceans and the poor quality of much existing data. Appropriately enough, in the next paper, Sathasivam and Natarajan outline a voluntary, web-based network being developed in India to improve the frequency and accuracy of data collected from cetacean strandings and bycatch.

¹ http://www.mrc.gov.mv/index.php/news_events/iocs_closing/

² <http://seamap.env.duke.edu>

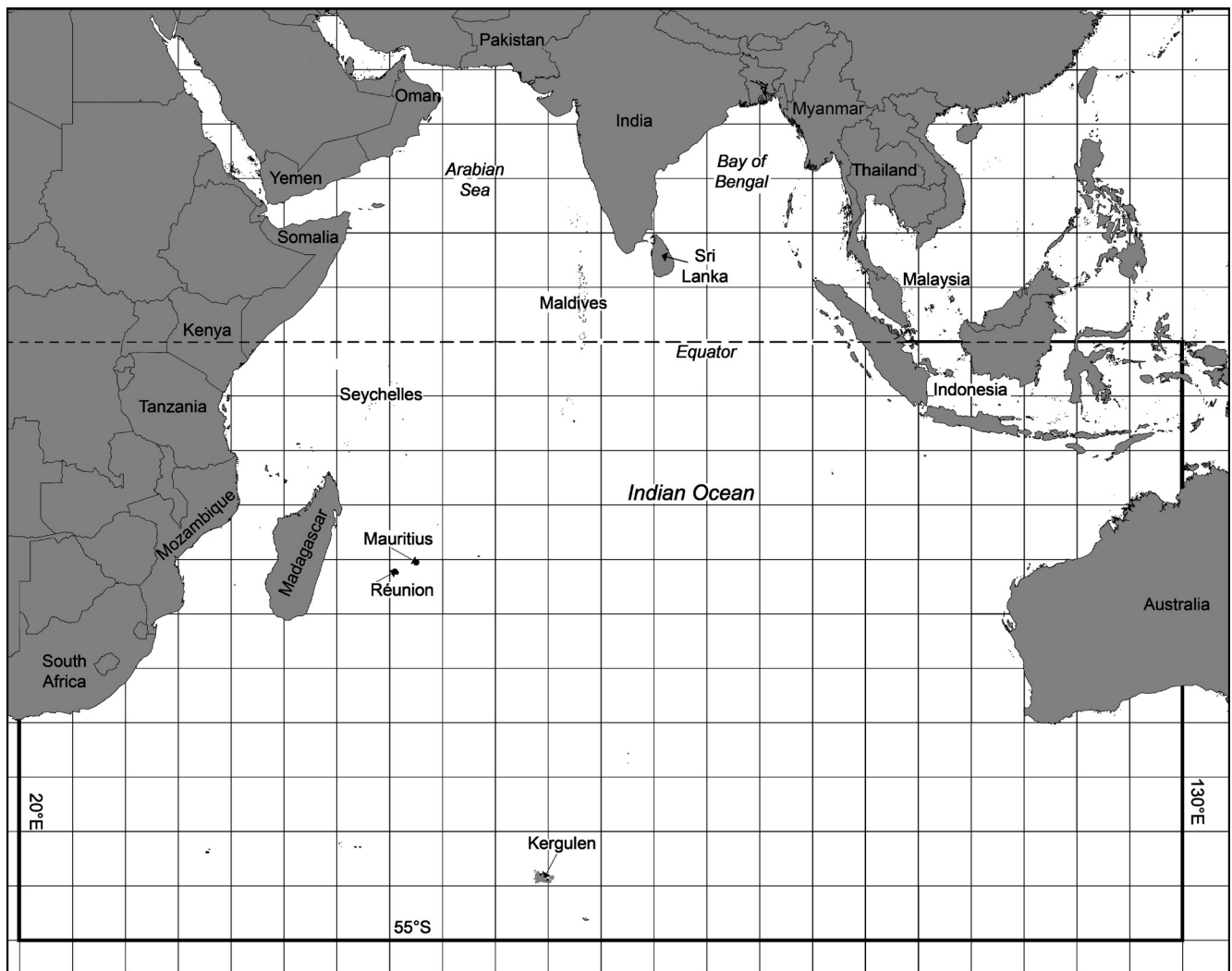


Fig. 1. Map of the Indian Ocean showing extent of the Indian Ocean Sanctuary. This encompasses all Northern Hemisphere waters from the coast of Africa to 100°E, including the Red Sea and the Gulf, and Southern Hemisphere waters from 20°E to 130°E, with the southern boundary set at 55°S.

From Sri Lanka, Illangakoon provides a review of information on and threats to cetaceans around this island nation. She notes that, with 27 species recorded to date (although there are still some unresolved taxonomic issues), Sri Lankan waters are home to a rich diversity of cetaceans. However, small cetaceans are particularly impacted as fisheries bycatch. There are also potential threats to larger cetaceans from shipping and a growing but currently unregulated whale watching industry. Still in Sri Lanka, De Vos *et al.* summarize the observations of the *Voyage of the Odyssey* in 2003. There were sightings of 11 different species, with sperm whales (*Physeter macrocephalus*) being the most frequently sighted and spinner dolphins (*Stenella longirostris*) being the most abundant. Canyons along the continental shelf edge were found to hold especially high concentrations of cetaceans.

Within the wider northern Indian Ocean, but particularly around Sri Lanka, there is growing interest in the local population of blue whale, which is likely a distinct subspecies, *Balaenoptera musculus indica*. Illangakoon and Sathasivam review blue whale records from Sri Lanka and India, confirming their year-round presence and highlighting the need for further taxonomic studies. Taking a broader

view, Anderson *et al.* compiled blue whale catch, sighting, stranding and acoustic data from right across the northern Indian Ocean. They demonstrate that these whales track seasonally shifting peaks in productivity, driven by seasonally shifting monsoon currents. While there is still much to be learnt, Anderson *et al.* successfully predicted and located a previously unknown concentration of blue whales off the south coast of Sri Lanka, which has kick-started significant whale-watching activity there.

From the Maldives, Anderson, Sattar and Adam review information on cetacean sightings and strandings. Recent research has brought the number of species recorded to 23, with the spinner dolphin being the most abundant, as is the case in much of the rest of the tropical Indian Ocean. What is unusual in the Maldives, however, is that the traditional pole and line technique for catching tuna continues to dominate the fisheries sector, and most forms of net fishing (including gillnetting and purse seining) are banned. As a result there is negligible bycatch of cetaceans, and the Maldives is in effect a sanctuary within the Sanctuary. Perhaps as a result of this, Clark *et al.* (who present observations from two visits of the *Voyage of the Odyssey* in 2003–04) recorded cetacean acoustic detections 2.5 times

higher in the Maldives than at other sites visited in the Indian and Pacific Oceans. They also report sightings, with 16 species being recorded during their 72 days at sea in Maldivian waters.

Continuing westwards, Gore *et al.* report on a cetacean research and conservation programme launched in Pakistan in 2004. During boat-based and shore surveys, 11 species were identified. Bottlenose dolphin (*Tursiops* sp.), Indo-pacific humpback dolphin (*Sousa chinensis*) and finless porpoise (*Neophocaena phocaenoides*) occur in good numbers inshore, while spinner dolphin is abundant further offshore. Work with fisher communities identified entanglement in fishing gear and opportunistic exploitation (for food, bait and medicine) as threats to small cetaceans.

From Tanzania, Amir *et al.* review data collected over 10 years, mostly from strandings and incidental fisheries bycatch, together with some dedicated boat-based surveys and incidental sightings. Specimens of 13 different cetacean species were recorded; over 90% were from gillnet bycatch, the remainder being from strandings. From these data, and sightings, Indo-pacific bottlenose dolphin (*Tursiops aduncus*), spinner dolphin and Indo-pacific humpback dolphin were recorded year-round, while humpback whales (*Megaptera novaeangliae*) were only observed during the austral winter, July to November.

Also in the southwest Indian Ocean, humpback whales are the subject of the next paper, by Dulau-Drouot. From boat-based surveys around the island of Réunion she records 724 sightings of humpback whales, with 312 individuals being photo-identified. Most were recorded during July–September, with numbers increasing in recent years. This is consistent with the assessment of the IWC Scientific Committee that Breeding Stock C is recovering from commercial whaling (IWC, 2010) and may be re-occupying its former range.

While most papers in this volume report on surveys of whole animals, the penultimate paper by Plön *et al.* reports on organ weights, from presumed healthy dolphins accidentally entangled in shark nets off South Africa. Three species were studied: Indo-pacific humpback dolphin, Indo-pacific bottlenose dolphin and long-beaked common dolphin (*Delphinus capensis*). The data obtained not only provide a baseline for future pathological examinations, but also illuminate the differing life histories and ecologies of these species.

The final paper in this issue, like the first, covers the entire width of the Indian Ocean Sanctuary. Eyre and Frizell report on a voyage right across the Indian Ocean from Western Australia to the Red Sea. One hundred and fifty six sightings were recorded within the Indian Ocean Sanctuary, with sperm whales being the most frequently sighted and spinner dolphins being the most abundant. This survey highlighted the NW Indian Ocean around the Horn of Africa and the Gulf of Aden as being an area of particular importance for cetaceans. Unfortunately, since that voyage was completed in 1995, this is also an area where such studies are currently restricted by the very real danger of piracy. With the exception of this one area, cetacean research is flourishing across the Indian Ocean, as the papers here demonstrate. Long may it continue.

R. CHARLES ANDERSON
Guest editor

ACKNOWLEDGEMENTS

The Editors are most grateful to those authors and referees who submitted their manuscripts and reviews in a timely fashion. To the tardy: congratulations on getting there in the end!

Charles Anderson and the rest of the Convening Committee of the Indian Ocean Cetacean Symposium also take this opportunity to thank all those organizations that provided sponsorship and support for the symposium, and ultimately this publication. These included:

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Fig. 2. Participants at the Indian Ocean Cetacean Symposium, Paradise Island Resort, Lankanfinolhu Island, Maldives, July 2009.

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Negotiating the Indian Ocean Whale Sanctuary¹

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ABSTRACT

This paper provides an overview of the establishment of the International Whaling Commission's Indian Ocean Sanctuary in 1979. The International Convention for the Regulation of Whaling enables the IWC to designate sanctuaries as well as open and closed areas for whaling. The author reflects upon the background to the issue of whale sanctuaries within the IWC and the particular role of the Seychelles Government in the development of the proposal for a sanctuary in the Indian Ocean. He notes the political, scientific and practical factors surrounding the acceptance of the proposal by the IWC and briefly discusses subsequent events.

KEYWORDS: MANAGEMENT; SANCTUARIES; INDIAN OCEAN

INTRODUCTION

The year 2009 represented the thirtieth anniversary of the establishment of the Indian Ocean Whale Sanctuary (IOWS)² by the International Whaling Commission (IWC). In 1979, a truncated form of a proposal by the Republic of Seychelles was adopted and incorporated into the IWC's Schedule³. It was truncated in the sense that the southern boundary of the sanctuary was set at 55°S rather than at the ice-edge of the Antarctic continent as originally proposed. This compromise ensured the requisite three-quarters majority since it allowed Japanese and Soviet pelagic whalers to continue pelagic whaling for Antarctic minke whales in the southern zone of the Indian Ocean. The boundary was effectively moved southward to the ice-edge when the entire Southern Ocean was declared as an IWC Sanctuary in 1994. The IOS was at first a temporary measure with limited existence, but after two reviews (IWC, 2003; Leatherwood and Donovan, 1991), the IWC Schedule was amended to read that 'in 2002 the Commission agreed to continue this prohibition [of commercial whaling] but did not discuss whether or not it should set a time when it should be reviewed again' (Busby and Holt, 2008).

This account derives from a longer study by the author, reviewing the history of the idea and efforts to implement international sanctuaries for cetaceans, especially whales (Holt, 2009a) and a shorter booklet published by IFAW (Holt, 2009b), as well as an earlier account in Holt (1983) and material from a booklet entitled 'Whale Sanctuaries and the South Atlantic' written by Leslie A. Busby, to be published by IFAW during 2012.

The idea of international sanctuaries for whales, on the high seas, was introduced in the League of Nations in 1929 by a committee of international lawyers, led by Sr José Leon

Suárez of Argentina. International whaling conferences in 1938 and 1939 recommended to participating governments that they take powers to establish sanctuaries, particularly in the Antarctic seas, but action was delayed by the Second World War. After the War, an appropriate provision was written into the International Convention for the Regulation of Whaling 1946 (ICRW, Article V (c)) and authority to designate sanctuaries was invested in the IWC.

A sanctuary for baleen whales in the southeastern sector (70°W–160°W) of the Southern Ocean south of 40°S was incorporated into the first IWC Schedule, adopted by the ICRW negotiators in 1946. This was suspended in 1955, after several years of debate, in which Japan, especially, repeatedly sought its abolition. This was understandable; Japan, as an occupied country, was not permitted to attend the 1945 Conference in Washington DC and could not join the IWC until the signature of the Peace Treaty with the USA. The occupying power did however permit – even encourage – Japanese pelagic whaling fleets to resume Antarctic whaling. These fleets entered the Antarctic region via the Pacific in contrast with those from Europe and the USSR that entered that region through the Atlantic and Indian Oceans, thus the sanctuary was considered to put Japan at a disadvantage. However, the reasoning used by those who wished to open the sanctuary to whaling was that this would relieve the whaling pressure in the other Antarctic sectors. The IWC scientists consistently opposed this, recommending instead that the arbitrarily set 'Blue Whale Unit' (BWU) catch limit set for pelagic catching of baleen whales be drastically reduced. Their pleas failed and eventually, in 1955, they reluctantly recommended the suspension of the sanctuary to the Commission as a hard compromise. This was accepted by the Commission notwithstanding the offer of Japan to agree to continuation of protection of a part of the sanctuary area (IWC, 1956a; 1956b).

The suspension was initially for three years with the provision for automatic closure after that time although this did not occur. In subsequent years various proposals for sanctuaries were put forward by groups of interested member states including the Northwest Atlantic, the Northeast

¹ This paper is a shortened and edited version of a presentation to the opening session of the Indian Ocean Cetacean Symposium held in the Republic of Maldives, 18–20 July 2009.

² This abbreviation is used here to avoid confusion with another IWC action – the International Observer Scheme (IOS).

³ The Schedule to the Convention contains the rules that govern the conduct of whaling. It can be amended at meetings of the Commission provided a proposed amendment obtains three-fourths of the votes of those voting for or against.

Pacific, the Mediterranean and Black Seas, the South Atlantic, the Southwest Pacific and – somewhat obliquely – the entire High Seas. To date only the Indian Ocean (in 1979) and Southern Ocean (in 1994) proposals have been adopted by the IWC. Their adoption has involved the general support for the concept, in both regions but especially in the Indian Ocean, of many states that are not members of the IWC or that joined the IWC after the IOWS had been established.

THE BEGINNINGS

In 1965, in a little known Sri Lankan journal, a Sri Lankan scientist, Dr P.E.P. Deraniyagala (Deraniyagala, 1965), suggested that the Indian Ocean between 20°E and 118°E, including the Southern Ocean sector thus bounded, be proclaimed by international agreement as a sanctuary for all cetaceans, as well as for dugongs and marine turtles. The period 1959–1965 was that in which the International Indian Ocean Expedition (IIOE), one of the largest collaborative oceanographic expeditions ever mounted, was organised by the Scientific Committee on Oceanic Research (SCOR) of the International Council of Scientific Unions (ICSU), following the first International Geophysical Year of 1957 which itself led to the negotiation of the Antarctic Treaty. Dr Deraniyagala had several arguments for his suggestion. One was that the requirement for one or two national inspectors to be placed on whaling expeditions was inadequate since in his view the fact that such officials were living with whaling crews for several months reduced the likelihood that they would provide objective reports on their ship-mates' activities. He also stated that a majority of the many dead and dying cetaceans he had studied washed ashore in Sri Lanka, especially the large whales, had suffered from harpoon strikes. He therefore believed that the number of whales that might thereby 'suffer a lingering death' might be equal to or more than the number actually secured and reported as caught. That seemed plausible to many people because the loss rate at the time was known to be substantial although reliable figures were not available. The stranded and wounded whales, especially in Sri Lanka and Southern India to which Deraniyagala referred, included blue, fin, and humpback whales, false killer whales, sperm whales and pygmy sperm whales, beaked whales of the genera *Ziphius* and *Mesoplodon*, although of the toothed whales only the sperm whale was a recognised target for modern whaling at the time, and bycatches of cetaceans in Sri Lankan fisheries are known that could have been responsible for some of the strandings. The author also referred to several specimens of what he knew as the slender *thalmaha* sub-species of minke whale found in tropical waters of the Indian Ocean.

Deraniyagala's paper was generally ignored but in 1978, the newly independent Government of the Republic of Seychelles, which was acquiring a huge Exclusive Economic Zone (EEZ)⁴ as a result of changes in the Law of the Sea, decided to accede to all relevant intergovernmental agreements concerning the ocean. That included the IWC.

Seychelles' decision to join the IWC should be seen in the perspective of the emergence of a broader interest in conservation in the first years of independence of the Republic in 1976, which also had roots in the concern of

British scientists in colonial times for the unique natural history of many of the islands, especially Aldabra⁵ and the birds of the central granitic islands Cousin, Bird and Aride. After the enactment of its EEZ based on UNCLOS principles, a group of Seychellois conservationists facilitated the legal protection of 42% of the new State's land, several marine parks and reserves including entire islands and the surrounding sea areas were created and specific protective legislation enacted for birds, turtles and giant tortoises. The Seychelles National Environment Commission was set up and programmes were run by the International Council for Bird Preservation (now BirdLife International) and the World Wildlife Fund (WWF) to train a new cadre of Seychellois rangers and managers. Thus Seychelles came into the IWC armed with a large array of policy and legal instruments and an advanced conservation ethic.

BACKGROUND TO THE DEVELOPMENT OF THE PROPOSAL

It is perhaps not surprising that in joining the IWC, this new state should do more than just cast its vote for or against the initiatives of others. It had before it the example of Malta that had 'made waves' by launching in the UN General Assembly a vast debate about the reform of the Law of the Sea. Seychelles was not quite so ambitious, although it was one of the main beneficiaries of the new international law. The momentum that began in 1972, with the UN call for a ten-year general moratorium to allow an interim respite from what some saw as virtually uncontrolled commercial whaling and give time for emplacement of better management, had diminished with the 1974 agreement on the Australian proposal for an 'amended moratorium' that came to be called the *New Management Procedure* (NMP) defined by paragraph 10(a–c) of the ICRW Schedule (e.g. see Allen, 1980; Gambell, 1977).

Application of the new rules in the second half of the 1970s had led to the setting of zero catch limits for most baleen whale stocks in the Southern Hemisphere, except that for the Antarctic minke whale (the smallest of the baleen whale species subject to whaling) – large-scale catching of which was begun at the opening of the decade by Japan and the USSR – and the Bryde's whale (which is not found as far south as Antarctic waters). Since the assessments of whale stocks at the time depended on long data series from commercial catches, providing reliable scientific advice on minke whale catch limits was practically impossible as reflected in the reports of the IWC Scientific Committee.

Southern Hemisphere Bryde's whales were partially protected by the prohibition of pelagic whaling in the zone north of 40°S. However, in the late 1970s, Japan had conducted large-scale pelagic whaling for that species under Special Permits allowed by Article VIII of the ICRW, south of Madagascar and on the fringe of the Indian Ocean near Indonesia, as well as near the Solomon Islands in the South Pacific. The Japanese authorities were thought to be considering two ways of opening up these resources for

⁵ The intervention by scientists and conservationists prevented Aldabra – since 1982 a World Heritage Site – from being turned into a US military base in the 1960s, resulting in such interest being turned to Diego Garcia in the Chagos Archipelago.

⁴ The Republic of Seychelles comprises over 100 islands.

systematic exploitation. One was to seek the abolition of the long-standing ban on pelagic whaling for baleen whales in tropical and temperate waters, but that would have been politically difficult, requiring a three-quarters majority in the IWC. The other was to open client land-stations in developing countries, not members of the IWC, in the Indian and Pacific Oceans near the discovered Bryde's whale concentrations – beginning with Madagascar and also Indonesia which had some small-scale 'traditional' (unmechanised) whaling. Bryde's whales in the eastern Atlantic had been taken by so-called 'pirate whalers' operating under flags of convenience to provide frozen baleen whale meat to the Japanese market. The seasonal timing would be such that the factory ships operating in the Antarctic could even pick up the frozen meat on their return journeys to Japan, thus saving transport costs and import-export inconveniences.

In 1979, Japan formally proposed an annual catch limit of 460 Bryde's whales for the putative 'Indian Ocean stock' of this species. However, the IWC's Scientific Committee did not accept the Japanese scientists' estimates of the number of whales from the surveys connected with the Special Permit catches of the previous three years, and so recommended that the Northern Indian Ocean stock be classified as an Initial Management Stock with zero catch limit pending satisfactory estimates of stock size (IWC, 1980b, pp.48–49 and pp.52–53). Two views were expressed within the Committee with respect to the Bryde's whales in the Southern Indian Ocean (including the area south of Madagascar). Most members recommended the same wording as for the Northern Indian Ocean. Others believed that satisfactory estimates of stock size had been obtained and proposed that catch limits should be 95 on the Western side and 282 in the East (where there had been successful Special Permit whaling near Indonesia). Most of the Committee noted that this would require an amendment to the Schedule to open some portion of the area between 40°S and 20°N to pelagic baleen whaling. Subsequently the IWC's Technical Committee (really a 'Committee of the Whole', not at all 'technical') recommended and the Commission Plenary (with no nation dissenting) adopted zero catch limits in both the southern and northern zones of the Indian Ocean (IWC, 1980a).

The ban on pelagic whaling in temperate and tropical waters did not apply to sperm whales. With the decline of baleen catches in the Antarctic the Soviet expeditions had steadily increased their catches of sperm whales – which yielded an industrial oil of strategic importance. Two of the Soviet expeditions were catching sperm whales in effectively unlimited numbers⁶ on their ways to and from the Antarctic via Suez; it was not known at the time how many baleen whales the Soviet expeditions were also killing – illegally and secretly – in these waters (Yablokov, 2000). People in Seychelles believed that sperm whales were far less abundant near the islands than a few decades earlier. While the inclination was to join with those nations that still favoured a general moratorium on commercial whaling, it was thought that it would not have been possible then to

secure the necessary three-fourths majority vote for such a move. Accordingly the Government embraced a strategy and programme including as one element the declaration of the Indian Ocean as a sanctuary, from the northern coastline to the Antarctic ice.

It was also believed within Seychelles in 1979 that 'pirate' operators were preparing two new vessels that might be destined for the Indian Ocean, although the Governments of South Africa and others were now interested in preventing that, particularly by refusing port facilities. The 'pirate' operations in the eastern Atlantic were under threat by the actions of IWC members to impose various types of sanctions against whaling under the flags of non-member countries. Some Commission members were also concerned that if these 'pirate' operations were legitimised by the countries whose flags they flew joining the IWC, this would swing the balance of power back towards the Commission again becoming what it had often been called – 'a Whalers' Club'.

THE 1979 SEYCHELLES INITIATIVE

Early in 1979, a Workshop on Protected Areas for Cetaceans, convened by IUCN in Mexico, with support from UNEP and WWF, had suggested that the eastern Indian Ocean be designated as a protected area. This was made feasible, it was thought, because of the recent decision by the Government of Australia for that country to get out of the whaling business and to work for a world-wide ban on whaling.

The Seychelles proposal was contained in a document entitled the Seychelles Initiative (Anonymous, 1979) and was presented both to the Scientific Committee and the Technical Committee and Plenary by the Alternate Commissioner, Dr L. Watson. I provided further technical information as observer for FAO (Holt, 1979).

The Seychelles' idea was that designation of the *entire* Indian Ocean would at least protect one or perhaps more of the putative Southern Hemisphere populations of all baleen species, as well as of the sperm whale⁷ and the killer whale. Marking experiments had shown that Antarctic minke whales from a particular breeding ground such as that off Brazil could feed at longitudes as much as 54° apart in summer, while other whales also moved across longitudinal boundaries during the same summer feeding season. Individual – visual – recognition of humpback whales in some parts of the Northern Hemisphere had revealed that individuals did not always return to the same breeding area in successive seasons, and it seemed reasonable to assume that this might also be the case for other baleen whale species in the Southern Hemisphere. Nevertheless, the IWC was necessarily dealing with fixed geographical definitions for the purpose of managing whaling and assessing putative whale populations and it seemed reasonable to assume that the various exchanges, mixings and movements that had been noted were exceptions rather than the rule.

It was far from clear to the Seychelles' authorities that a three-fourths majority would be obtainable at the time.

⁶ Catch limits were set by Division in the Southern Hemisphere, i.e. south of the Equator. The Indian Ocean spanned Divisions 3–5.

⁷ Seychelles believed that the NMP was even less adequate for sperm whales than it was for baleen whales and that this species needed global protection, so a second strategic aim was to secure a long-term moratorium on all catching of this species. Its 1979 proposal did not succeed but this aim was realised in 1981.

However, it seemed to be close enough that the balance could be shifted if Indian Ocean coastal states – few of which were yet members of IWC – expressed their support for such an action. Few of them had any special authority or claims under the emerging new Law of the Sea, but coastal states' special interest in areas adjacent to their expanding areas of national jurisdiction was becoming widely accepted. So the Seychelles Government discreetly consulted, at high level, governments of all the Indian Ocean coastal states and found most were favourable to the sanctuary proposal and none opposed it. Several said they would work to bring their countries into the IWC, but that could not practically be done before the 1979 meeting of the Commission. An additional move was the declaration by Seychelles of its own EEZ as a protected zone for all marine mammals and a hope that as many other Indian Ocean coastal states as possible would do likewise. Consideration was given to delaying the proposed action for a year until more Indian Ocean coastal states had joined the IWC but ultimately it was agreed that the element of surprise was very important and it was decided to proceed immediately.

The consultations also led to a suggestion that an Indian Ocean Alliance for Conservation be established, of which the proposals regarding whaling would be a part. In the background to this was the move being led in the United Nations by Sri Lanka to declare the Indian Ocean as a Sea of Peace, from which, *inter alia*, the navies of the superpowers would be invited to withdraw. Although this had support from most of the Non-Aligned Indian Ocean countries it was a practical impossibility. For example, the USA and UK (sovereign of the Chagos Archipelago, including the island of Diego Garcia) saw the Alliance for Conservation as the thin end of a Sea of Peace wedge and strongly opposed it; that initiative was pursued for a while but eventually abandoned.

ADOPTION OF THE SANCTUARY AT THE 1979 IWC MEETING

The IWC's Scientific Committee reviewed the proposal (IWC, 1980b) both in terms of the general concept of sanctuaries and of the Indian Ocean proposal and its boundaries. There were suggestions by some that 40°S or the Antarctic Convergence may be appropriate in particular, but – as the Report of that meeting brusquely says – 'no firm conclusions were reached' (IWC, 1980a, p.27). This was essentially because of the political implications of the discussion and because some mistakenly treated the proposal as if it had been presented more for promoting research than for achieving conservation by cessation of whaling. For example, there was considerable discussion of whether the cessation of commercial whaling in the region would cut short the provision of data coming from whaling activities and which some scientists insisted were needed for setting catch limits. This apparent confusion of objectives has persisted in all later discussions of sanctuaries in the IWC (Zacharias *et al.*, 2006). It arises from Article V.2 of the ICRW which states that regulatory – including conservation – actions to be taken *inter alia* 'shall be based on scientific findings'. Opponents of broad conservation measures (such as sanctuaries and moratoria) have sought repeatedly to

interpret this, erroneously in my view, as meaning that regulatory measures cannot be taken unless they have been proposed or fully supported by the Scientific Committee (which almost never votes and rarely achieves consensus on issues with strong political overtones such as sanctuaries and catching under special permit). In this case as in others, the Commission acted despite a lack of consensus within the Scientific Committee.

Prior to discussions in the decision-making Commission plenary session, the proposal was discussed in the IWC's Technical Committee. It became clear that a three-quarters majority would not be forthcoming without some compromise. The Seychelles delegation amended the original southern boundary proposal to 55°S thereby excluding the major Soviet and Japanese whaling grounds for the Antarctic minke whale from the Sanctuary. Several countries spoke in favour of the proposal. Japan, as it has consistently done, argued against the concept of sanctuaries, stating that individual stock management was preferable and monitoring of populations would be reduced by any pause in whaling. The USSR put forward similar views. Panama and Australia suggested a further amendment to provide for a ten-year review period to allow sufficient time for effects of disturbance and recovery rates of depleted stocks to be followed. The amended proposal was accepted in the Technical Committee by 14 votes to four with five abstentions.

In the Plenary, this was further amended by Seychelles and Australia to provide for a reduced review period (five years) but nevertheless establishing the sanctuary for ten years. This amended proposal was adopted by 16 votes to 3 with 3 abstentions. The Commission also adopted a non-binding Resolution proposed by Denmark instructing the Scientific Committee to look at the type and level of research needed for monitoring within the IOWS as well as to investigate whether it was necessary to initiate additional research simultaneously in areas where exploitation of whales continues, in order to make comparison possible between stocks under the two different regimes; this was a shadow of the pervasive idea that sanctuaries – if established – should be for scientific rather than conservation purposes.

Only part of that work was accomplished. With mainly NGO financing, a research plan for the Indian Ocean sanctuary was developed at a workshop held in the town of Zeist, in The Netherlands (Busby, 1981), and some expanded research on cetaceans was being promoted in several countries in the region, especially by Australia, India and Sri Lanka, where scientific symposia were subsequently held, and also – though on a very limited scale – in Oman, Kenya and Seychelles. However, the financial means to assist this work were not forthcoming either from the IWC or, as had been hoped, from UNEP, and supporters of the Seychelles initiative were subject to criticism by some opponents and skeptics who alleged that promises had not been fulfilled.

In the following years, several more Indian Ocean coastal states did join the IWC (previously only Australia, South Africa and the Seychelles were members): Egypt, India, Oman, Kenya and Mauritius. Sri Lanka, which had been enthusiastic about joining, did not do so, nor did Tanzania;

some thought that these changes of mind, along with Mauritius neither attending meetings nor paying its dues, resulted from external diplomatic pressures. But the influx of non-aligned ‘developing countries’, encouraged and supported by NGOs, began to prepare the IWC for the adoption of a global ‘moratorium’ on commercial whaling, of unlimited duration, which it did in 1982 on the basis of a specific proposal by Seychelles to set all catch limits to zero regardless of existing classifications under the NMP. It had also been envisaged that measures to protect cetaceans (as well as other vulnerable marine species in the region regarding the conservation of which several governments insisted that the IWC did not have legal competence), would be taken by other international institutions, as implied by the original Alliance for Conservation idea, but this happened only to a very limited degree. To this day there is, unfortunately, no comprehensive plan or authority for the conservation and the management of use of the marine life of the region as a whole.

ACKNOWLEDGEMENTS

Many people were directly involved in the action to designate the Indian Ocean as a sanctuary for whales; here only a prominent few can be singled out for special acknowledgement. I begin with Harold Eidsvik, of IUCN, who prepared and steered the IUCN/WWF/UNEP workshop in Baja California, Mexico, in February 1979, which set the sanctuary ball rolling again. Dr Paul Spong was the Rapporteur on that occasion.

The actions later that year, centred on the Republic of Seychelles, were supported vigorously by the then President of the Republic, M. Albert France René and led by the late Dr Lyall Watson, serving as Alternate Commissioner for Seychelles to the IWC. Others on the delegation were the Commissioner, M. Laustau-Lelanne, Ms Cornelia Durrant (Political advisor) and Mr Malcolm Forster (Legal adviser). My superiors in FAO and UNEP allowed me – then in my final year of service with the UN system – to serve unofficially as scientific and technical advisor to the Seychelles delegation.

A small, developing country such as Seychelles could not have pursued this objective successfully without substantial outside help, both financial and personal. This was provided particularly by the Threshold Foundation, which had been established by Prince Shahram Pahlavi-nia, a resident of Seychelles, and the World Wildlife Fund International (WWF), with the dedicated involvement of two of its stars: Sir Peter Scott and Dr Sylvia Earle. Mr Harold Wicks lubricated the pipeline from Threshold, which was headquartered in London. When Threshold ran out of money a few years later, Mr Brian Davies, Founder and CEO of the International Fund for Animal Welfare (IFAW) helped to find ways to continue the necessary financial support for Seychelles’ involvement in cetacean conservation. The Government of Sweden generously gave financial assistance for the convening of the Indian Ocean Alliance consultation, and the vigorous and helpful role of the Commissioner for Sweden, Dr Bertil Hägerhäll, IWC Commissioner for Sweden from when his country rejoined the IWC in 1979, must be acknowledged here.

The workshop held in Zeist, Netherlands, after the 1979 success, was funded by WWF Netherlands on the initiative of its Director, Mr. Niels Halbertsma. I was Convener of the workshop; Ms Leslie Busby organised it and wrote the Report. Halbertsma, after the declaration of the IOS, also supported the voyage of the research yacht *Tulip* to conduct research on sperm whales near Seychelles and Sri Lanka, led by Dr Hal Whitehead, assisted by scientists Dr Vassili Papastavrou and Dr Jonathan Gordon, who both later served with IFAW. Simultaneously Brian Davies arranged for the IFAW twin-engined aircraft to fly to Seychelles to conduct a sperm whale survey there, a project carried out by Mr Ronald Keller; the results of that were published by the IWC (Keller *et al.*, 1982).

Several diplomats based in London at the High Commission offices served as Seychelles Commissioner to IWC in the following years, but the burden of steering the Indian Ocean Sanctuary through the IWC processes to quasi-permanence was borne by Mr Robert Delpech, a brilliant diplomat, sailor and raconteur. For part of that period I served as Alternate Commissioner. After Mr Delpech’s retirement the lead was taken by Dr Nirmal Shah, founder and leader of the very active and successful NGO: *Nature Seychelles*.

Among the neighbouring countries of Seychelles the delegation was perhaps closest, for many years, to the Sultanate of Oman, whose Commissioner, Mr Mohamet Al-Barwani, was particularly supportive during the critical decade after the establishment of the IOWS in 1979. Mr James Carr, who had been helping me in research at the Seychelles High Commission, served for a while on the delegation of Oman. I am indebted to Mr R.P. Kumarran for reminding me, after this paper was written, of the singular contribution made in the 1960s by the Sri Lankan scientist Dr P.E.P. Deraniyagala. Lastly I wish to express appreciation of the work of the Editor for assistance in bringing the words of my Maldives talk into publishable form.

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Cetaceans and mass strandings in Thai waters

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ABSTRACT

A total of 25 species of cetaceans have been recorded in Thai waters from stranding and sighting records. A summary of these, together with details of five mass strandings on the Andaman Sea coast of Thailand, are reported here. The first mass stranding, of nine spinner dolphins (*Stenella longirostris*) was at Talibong Island, Trang Province, in January 1999; six carcasses were examined and three were lost. The second record comprised five spotted dolphins (*Stenella attenuata*) stranded at Ban Ko Kho Khao, Phang-nga, in February 1999; two dolphins were released alive. The third stranding was of eight spotted dolphins at Mai Phai Island, Phang-nga, in March 2006; five animals died and three were released alive. The fourth mass stranding was of 30 false killer whales (*Pseudorca crassidens*) at Racha Yai Island, Phuket, in June 2008; 29 animals were released while one drowned. The fifth record consisted of three rough-toothed dolphins (*Steno bredanensis*) stranded at Nam Bor Bay, Phuket, in July 2008; all three were returned to the open sea. It was difficult to determine the causes of death of the stranded dolphins. However, it was possible that the first two mass strandings were caused by disease. Some strandings were possibly influenced by the landscape of the stranding locations (narrow bay in one case, wide gently sloping beach in another).

KEYWORDS: IRRAWADDY DOLPHIN; INDO-PACIFIC BOTTLENOSE DOLPHIN; FINLESS PORPOISE; FALSE KILLER WHALE; STRIPED DOLPHIN; SPINNER DOLPHIN; PANTROPICAL SPOTTED DOLPHIN; INDO-PACIFIC HUMPBACK DOLPHIN; SPERM WHALE; MASS STRANDING; ANDAMAN SEA; GULF OF THAILAND

INTRODUCTION

Strandings, particularly mass strandings, of marine mammals attract a great deal of public attention. In recent years, the public has generally supported the laboratory investigation of dead animals in order to further scientific knowledge, as well as the return of live animals to the sea (Harwood, 2002; St. Aubin *et al.*, 1996).

Thailand has conducted regular cetacean research since 1993, mostly undertaken by the Phuket Marine Biological Center (PMBC) under the Department of Marine and Coastal Resources (DMCR). Its cetacean research programme was initiated through a collaboration with Danish scientists under the Small Cetaceans in the Gulf of Thailand and the Andaman Sea Project (Chantrapornsyl *et al.*, 1996; 1999; 1991). Information on species distribution and abundance, including biology and behaviour of cetaceans was obtained from interviews, stranding records and surveys under this programme. A stranding network for marine endangered animals (cetaceans, dugong and sea turtles) was set up and has been operated in cooperation with villagers, non-government and government organisations in coastal provinces. This network has worked well, and as a result most data currently available on cetaceans in Thailand were obtained from stranded animals.

Nevertheless, some information is available from other sources. Boat and aerial surveys have been conducted to investigate species distribution, abundance and behaviour (Adulyanukosol and Kittiwattanawong, 2004; Adulyanukosol *et al.*, 2000; Chantrapornsyl, 1996; Chantrapornsyl *et al.*, 1996; 1999; Intongcome *et al.*, 2005a; 2005b; Mahakunlayanakul and Surada, 1999; Ninwat *et al.*, 2008; Thongsukdee and Swangarraraks, 2005; Yamada *et al.*, 2000; 2006).

This report provides updated information on species diversity and distribution of cetaceans in Thailand and on mass stranding events, including details of attempts to rescue live-stranded animals. Other aspects of cetacean biology are not considered here.

MATERIAL AND METHODS

The information on species diversity and distribution of cetaceans in Thailand in this study was compiled from the database of PMBC (1993 to 30 June 2009), together with earlier publications: Anderson and Kinze (1999); Adulyanusokosol (1999); Adulyanukosol *et al.* (2009; 2000); Chantrapornsyl *et al.* (1996; 1999; 1991); Intongcome *et al.* (2005a; 2005b); Ninwat *et al.*, (2008); Sirimontraporn and Sritakorn (1995); Thongsukdee and Swangarraraks (2005); Yamada *et al.* (2000; 2006). The PMBC database includes information from reports of stranded cetaceans as well as details of many specimens which were transferred to PMBC or to other DMCR centres for species identification and necropsy. During necropsy, tissue samples were collected for studies including genetics, parasitology, histology and investigations of both heavy metal and organochlorine pollutants (Harino *et al.*, 2007; 2008). Skeletal material was retained for species identification and osteological examination. With large whales or badly decomposed specimens, the carcasses were examined on-site and buried afterwards.

RESULTS AND DISCUSSION

Species and distribution

Stranding records

Eighteen species of cetaceans were recorded in Thailand up to 1993 (Anderson and Kinze, 1999). Subsequently, an

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additional five species were reported by Chantrapornsyl *et al.* (1999) and Adulyanukosol and Kittiwattanawong (2004). More recently, Yamada *et al.* (2006) studied Thai specimens of balaenopterids, including morphological investigations of skulls and skeletons, and molecular analysis. Prior to that work, all balaenopterid specimens (except one record of fin whale) were identified as Bryde's whale *Balaenoptera edeni*. However, Yamada *et al.* (2006) demonstrated that some of those specimens were in fact Omura's whale *Balaenoptera omurai*. These recent studies brought the total number of cetaceans found in Thai waters to 25 species, belonging to six families: Balaenopteridae (4 species), Physeteridae (1), Kogiidae (2), Ziphiidae (2), Delphinidae (15) and Phocoenidae (1). Twenty-three of these species have been recorded in the Andaman Sea and 18 in the Gulf of Thailand (Table 1 and Fig. 1).

There were a total of 553 stranding records in the PMBC database as of 30 June 2009. Strandings of offshore species and mass strandings occurred only along the Andaman Sea coast, not on the coast of the shallow Gulf of Thailand. Species/groups with more than 10 individuals stranded were: balaenopterids (104), Irrawaddy dolphin *Orcaella brevirostris* (98), Indo-Pacific bottlenose dolphin *Tursiops aduncus* (63), finless porpoise *Neophocaena phocaenoides* (58), false killer whale *Pseudorca crassidens* (45), striped dolphin *Stenella coeruleoalba* (40), spinner dolphin *S. longirostris* (34), pantropical spotted dolphin *S. attenuata* (30), Indo-Pacific humpback dolphin *Sousa chinensis* (25) and sperm whale *Physeter macrocephalus* (13) (Table 1). Among these records, 161 specimens from 20 species were deposited in PMBC. The stored samples of species/group with more than 10 specimens were striped dolphin (28), Indo-Pacific bottlenose dolphin (20), pantropical spotted dolphin (19), spinner dolphin (18), finless porpoise (13), the group of Bryde's and Omura's whales (12), and Irrawaddy dolphin (11) (Table 1).

Sighting records

Cetacean sightings surveys (boat and aerial) have been concentrated in a few areas: the upper Gulf of Thailand (Phetchaburi, Samut Songkhram, Samut Sakhon, Bangkok, Samut Prakan, Chachoengsao and Chonburi Provinces); Trat Province; Chaiya Bay in Surat Thani Province; Khanom Bay in Nakhon Si Thammarat Province; Songkla Lake in Phatthalung Province; Sriboya, Cham and Pu Islands in Krabi Province; Tase village in Trang Province; and Salai Islands in Satun Province. Among the total of 25 species recorded from Thailand, only 13 species were observed during these surveys (Table 2).

Mass strandings

There were five records of mass strandings in the Andaman Sea: one case in Trang Province, two cases in Phang-nga Province and two cases in Phuket Province (Table 3, Fig. 3).

The first stranding, of nine spinner dolphins (necropsy code End 128–136), was at Talibong Island, Trang Province (99°21.7'E, 7°13.9'N), on 25 January 1999. Among the nine carcasses, six were examined and three were lost (Table 3 and Fig. 2). The six carcasses examined were all male, with body lengths of 1.77–1.90m and weights of 37 to 48kg.

Table 1

Species of cetacean recorded in Thai waters, by region. Adapted from Chantrapornsyl *et al.* (1999), Adulyanukosol *et al.* (2004; 2009), Yamada *et al.* (2006) and the PMBC database from 1993 to mid-2009. AS = Andaman Sea, GT = Gulf of Thailand, N1 = Number of stranding records, N2 = Number of skeletons at PMBC, * = sighting record.

Common name	Scientific name	AS	GT	N1	N2
Balaenopteridae					
Fin whale	<i>Balaenoptera physalus</i>	–	•	1	–
Bryde's whale	<i>Balaenoptera edeni</i>	•	•	104	12
Omura's whale	<i>Balaenoptera omurai</i>	•	•		
Humpback whale	<i>Megaptera novaeangliae</i> *	•	–	–	–
Physeteridae					
Sperm whale	<i>Physeter macrocephalus</i>	•	–	13	5
Kogiidae					
Pygmy sperm whale	<i>Kogia breviceps</i>	•	•	8	2
Dwarf sperm whale	<i>Kogia sima</i>	•	–	6	6
Ziphiidae					
Ginkgo-toothed whale	<i>Mesoplodon ginkgodens</i>	•	–	1	–
Cuvier's beaked whale	<i>Ziphius cavirostris</i>	•	–	1	1
Delphinidae					
Killer whale	<i>Orcinus orca</i>	•	•	1	–
False killer whale	<i>Pseudorca crassidens</i>	•	•	45	6
Pygmy killer whale	<i>Feresa attenuata</i>	•	•	4	2
Short-finned pilot whale	<i>Globicephala macrorhynchus</i>	•	•	2	1
Melon-headed whale	<i>Peponocephala electra</i>	–	•	2	–
Indo-Pacific humpback dolphin	<i>Sousa chinensis</i>	•	•	25	7
Indo-Pacific bottlenose dolphin	<i>Tursiops aduncus</i>	•	•	63	20
Rough-toothed dolphin	<i>Steno bredanensis</i>	•	•	8	2
Long-beaked common dolphin	<i>Delphinus capensis</i>	•	•	3	3
Spinner dolphin	<i>Stenella longirostris</i>	•	•	34	18
Striped dolphin	<i>Stenella coeruleoalba</i>	•	•	40	28
Spotted dolphin	<i>Stenella attenuata</i>	•	•	30	19
Fraser's dolphin	<i>Lagenodelphis hosei</i>	•	–	4	3
Irrawaddy dolphin	<i>Orcaella brevirostris</i>	•	•	98	11
Risso's dolphin	<i>Grampus griseus</i>	•	–	2	2
Phocoenidae					
Finless porpoise	<i>Neophocaena phocaenoides</i>	•	•	58	13
Total		23	18	553	161

Parasites were found in the stomachs while cysts were found around the genital areas in all specimens. The stomachs of all specimens were empty.

The second stranding consisted of five spotted dolphins (End 137–139) at Ban Ko Kho Khao, Phang-nga Province (98°15.1'E, 8°53.9'N), on 3 February 1999. Two dolphins were released soon after stranding and three dolphins died. The three carcasses were transferred to PMBC for necropsy. All three carcasses were male, with body lengths of 1.9–2.2m and weights of 57.5 to 81kg (Table 3). Their stomachs were empty, thus it is likely that the dolphins had been ill for some period of time before stranding (see below). However, their tissues have yet to be examined to determine the cause of stranding/death.

The third stranding consisted of eight spotted dolphins (End 403–407) at Mai Phai Island, Phang-nga Province (98°32.5'E, 8°20.0'N) on 24 March 2006. Five dolphins died while three were released. The five dead dolphins comprised three males and two females. Their body lengths ranged from 1.87–2.14m and they weighed 47.5 to 75kg (Table 3 and Fig. 2). Three of the dead dolphins appeared to be healthy. One was assumed to have died from drowning as some water was

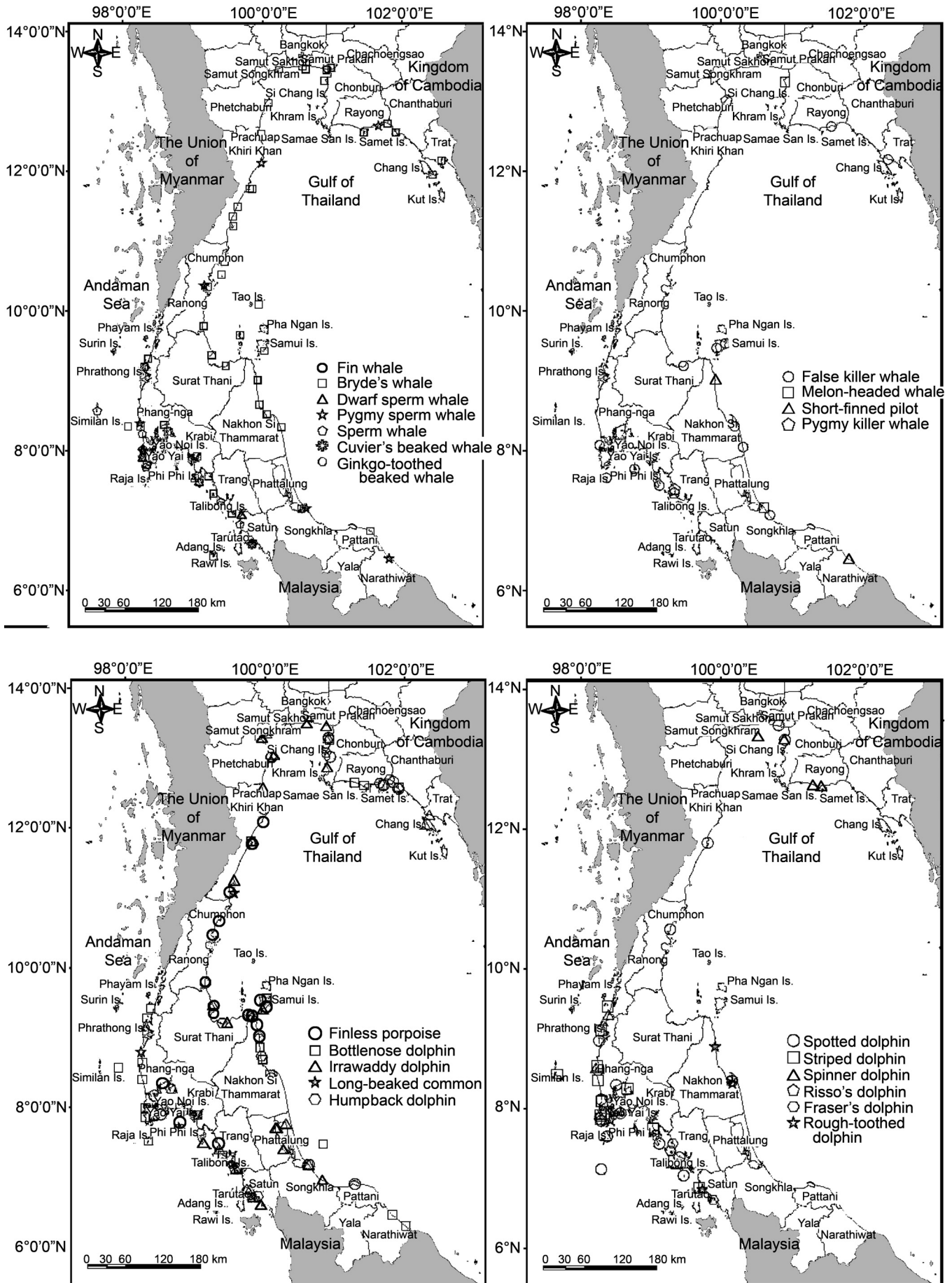


Fig. 1. Locations of cetacean strandings in Thai waters.

Table 2

Summary of records of 13 cetacean species sighted during boat and aerial surveys, including opportunistic sightings. Information collected from 1993 to mid-2009 based on Adulyanukosol *et al.* (2000; 2009); Intongcome *et al.* (2005b); Kiatkarnjanakul (1994); Ninwat *et al.* (2008); Thongsukdee and Swangrerraks (2005); database of PMBC; E. Hines (pers. comm.); A. Intongcome (pers. comm.); S. Man-anansap (pers. comm.); S. Ninwat (pers. comm.); S. Pratip Na Talang (pers. comm.); S. Thongsukdee (pers. comm.); S. Yossundara (pers. comm.)

Species	Location (province)	
	Andaman Sea	Gulf of Thailand
Bryde's whale	N of Phang-nga (2 ind.); Racha Is., Phuket (3–4 ind.); Satun (2 ind.)	Chonburi (4 ind.); Petchaburi (about 5 ind.); Prachuap Khiri Khan (1–3 ind.); Surat Thani (1 ind.); Nakhon Si Thammarat (1 ind.); Songkhla (1 ind.)
Omura's whale	Phuket (4 ind. between Racha Is. and Similan Is.)	–
Humpback whale	E of Phuket Is. (1 ind.)	–
Short-finned pilot whale	W of Phuket Is. (a pod of about 10 ind.)	–
Killer whale	Phuket and Phang-nga (8 times, pod size about 2–30 ind.)	Surat Thani (2 ind. at once)
False killer whale	Similan Is., Phang-nga (A large group of about 50 ind.)	–
Indo-Pacific humpback dolphin	N of Phang-nga (5 ind.); around Sriboya Is. and Krabi Bay, Krabi (5 ind.); Tase village, Trang (30–40 ind.); around Saria Islands, Satun (10 ind.)	Rayong to Trat (15 ind.); Samut Songkhram (5 ind.); Prachuap Khiri Khan to Surat Thani (65 ind.); Khanom Bay, Nakhon Si Thammarat (35 ind.); Sonkhla to Pattani (10 ind.)
Indo-Pacific bottlenose dolphin	N of Phang-nga (10 ind.); Yao Is., Phang-nga Bay (20 ind.); Khai Nok Is., Mai Thon Is-Hae Is, Phuket (20 ind.)	Rayong to Chathaburi (5 ind.); Samui Is, Surat Thani (6 ind.); Nakhon Si Thammarat (10 ind.); Sonkhla (5 ind.)
Spinner, striped, and pan-tropical spotted dolphins	W and S of Phuket (30–40 ind.)	–
Irrawaddy dolphin	Trang (5 ind.); Salai Is., Satun (20–25 ind.)	Trat (> 100 ind.); upper Gulf in Petchaburi, Samut Songkhram, Samut Sakhon, Bangkok, Samut Prakan, Chachoengsao and Conburi (about 100 ind.); Chumphon to Surat Thani (11 ind.); Khanom Bay, Nakhon Si Thammarat (21 ind.); Songkla Lake in Phatthalung and Sngkhla (36 ind.)
Finless porpoise	Inner part of Phang-nga Bay (10 ind.); Sriboya Is., Krabi (10 ind.); Trang (10 ind); Satun (20 ind.)	Petchaburi to Chonburi (25 ind.); Rayong to Trat (20 ind.); Prachuap Khiri Khan to Surat Thani (40 ind.); Khanom Bay, Nakhon Si Thammarat (20 ind.); Songkhla (5 ind.)

found in its respiratory system. One other had been struck by a hard object which presumably contributed to its stranding and eventual death.

The fourth mass stranding, of 30 false killer whales (End 517–527), was at Batok Bay (a small semi-enclosed bay) on Racha Yai Island, Phuket Province (98°22.0'E, 7°36.5'N, Table 3 and Fig. 3), at 16:00h on 26 June 2008. The weather at the time of stranding was stormy with rough seas. Staff and tourists from the Racha Hotel, together with local people, helped push 19 whales towards the open sea before 18:30h. It was decided that the remaining 11 whales should be moved to the more open Ter Bay, some 950m away (Figs 3a and 3b). A team from PMBC (about 22km from Racha Yai Island) arrived at 19:30h and whales were transferred

onto a truck using a backhoe and man power. The bed of the truck was lined with fabric (Figs 3c and 3d). At this stage, a veterinarian applied dexamethasone (anti-inflammatory, 1mg/kg) to relax the whales and disinfected their wounds with gentian violet. Ten whales were released at around 22:00h, with volunteers pushing their heads towards the open sea and helping them balance their bodies as they moved into deep water. By about 22:30h eight whales had been released. However, two whales swam back to the bay twice and a speedboat was used to transport them to deeper water. By the time these two whales were released, it was too dark to observe them. Nevertheless, there was no report of re-stranding. In summary, a total of 29 whales were returned to the sea, with only one death. This was the biggest mass

Table 3

Records of mass strandings in the Andaman Sea. End=field number (necropsy specimens only); n = total number of animals; M = male; F = female; BL = body length; and BW = body weight.

No.	Date	Species	Location	n	BL (m)	BW(kg)	Remarks
1	25 Jan. 1999	Spinner dolphin <i>Stenella longirostris</i> (End 128–133)	Ban Lang Khao, Talibong Is., Trang	9	1.77–1.9 (n = 6, 6M)	37–48	6 were diagnosed and 3 were lost.
2	9 Feb. 1999	Spotted dolphin <i>Stenella attenuata</i> (End 137–139)	Ban Ko Kho Khao, Phang-nga (AS)	5	1.9–2.2 (n = 3, 3M)	57.5–81	2 dolphins were released and 3 died.
3	24 Mar. 2006	Spotted dolphin <i>Stenella attenuata</i> (End 403–407)	Mai Phai Is., Phang-nga	8	1.87–2.14 (n = 5, 3M, 2F)	47.5–75	5 animals died and 3 were released.
4	26 Jun. 2008	False killer whale <i>Pseudorca crassidens</i> (End 517–527)	Batok Bay, Racha Yai Is., Phuket	30	3.52 (F) 2.6–4.2 (n = 10)	346 (End 517 only)	1 whale died, 29 whales were released.
5	5 Jul. 2008	Rough-toothed dolphin <i>Steno bredanensis</i> (End 529–531)	Nam Bor Bay, Phuket	3	2.45–2.6 (n = 3, 1M, 2F)	–	All were released.

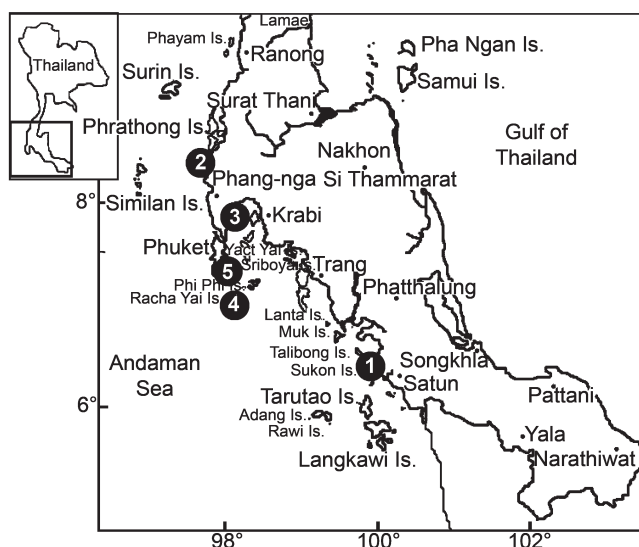


Fig. 2. Locations of the five mass strandings (black circles) in Thailand between 1993 and mid-2009. The number in each black circle corresponds to row number in Table 3.

stranding in our records in terms of the number of individuals. The body lengths of 10 whales ranged from 2.6–4.2m and they weighed approximately 300 to 400kg. The one dead female false killer whale was transferred to PMBC for a detailed examination. The head of this whale was stuck on the rocks when found. It was 3.52m long and weighed 346kg. The necropsy found no sign of diseases, but there was some water in its trachea and a small amount of sand in its

blow hole. It was concluded that this whale died from drowning.

The fifth stranding, of three rough-toothed dolphins *Steno bredanensis* (End 529–531) occurred at Nam Bor Bay, Phuket Province ($98^{\circ}24.1'E$, $7^{\circ}50.8'N$), on 5 July 2008 (Table 3; Figs 2 and 4). Local fisherman saw the dolphins at 05:00h and reported to the Center. PMBC staff arrived at the beach at 07:30h. This bay has a mangrove beach and muddy-sand sea bottom. The dolphins stranded during the low tide period at a distance of approximately 1km from the shoreline, and around 200m apart. Hollows were dug beside each dolphin to allow some sea water to flow underneath in an attempt to reduce stress. The attending veterinarian then applied anti-shock medicine to the dolphins, which were all male. The dolphins were carried to the edge of sea where they were held while waiting for the tide to rise. Later, the dolphins were transported by two speedboats and released in the open sea between Nam Bor Bay and Racha Yai Island. The release was successful; the three dolphins swam out to sea together at 10:30h. Thereafter, PMBC staff patrolled the area by speedboat for approximately 30mins to check for any re-strandings.

It was difficult to ascertain the causes of these mass strandings. The first two strandings were likely caused by diseases since the dolphins involved were thin and their stomachs empty. Some of the animals also had numerous parasites in their stomachs and cysts in their genital areas.

The three dolphins from the third record appeared to be in good health. Nonetheless, one drowned and one was struck by a hard object. Animals from the fourth and the fifth mass

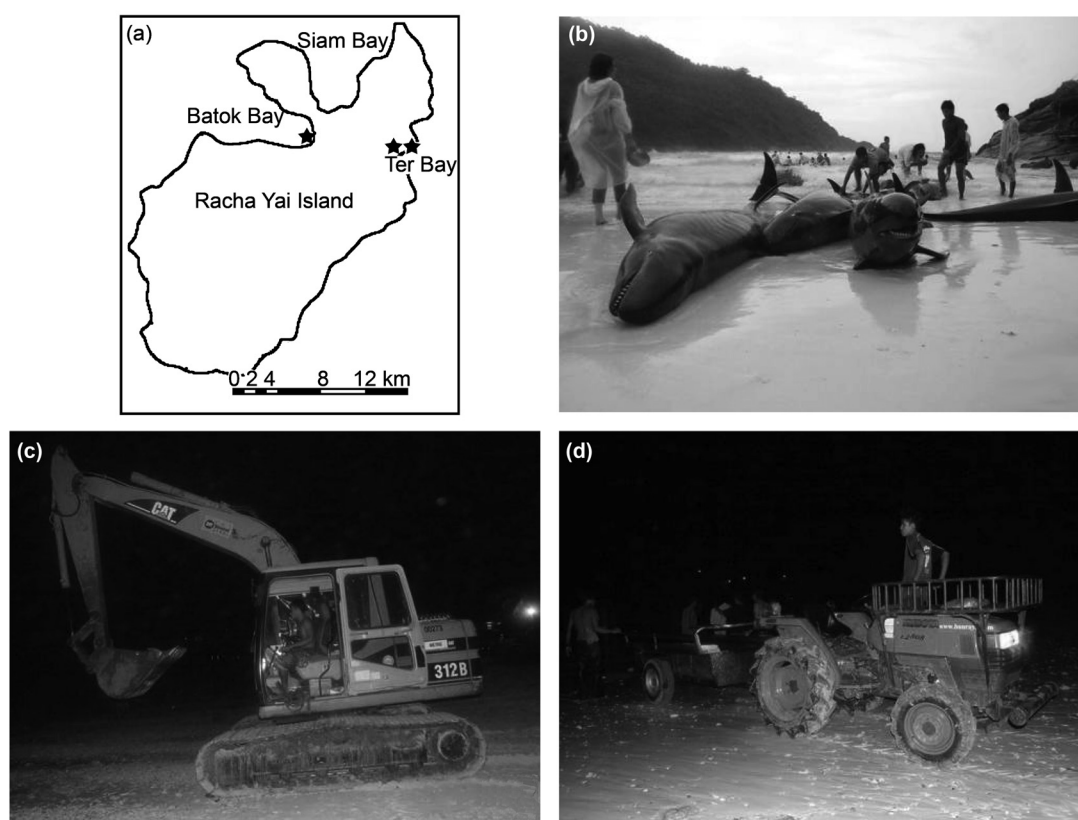


Fig. 3. (a) Map of Racha Yai Island the stranding location (showing Batok Bay) and releasing location (Ter Bay). (b) False killer whales stranded at Batok Bay. (c) A backhoe lifting stranded whales onto a truck. (d) A truck individually transferring 10 whales from Batok Bay to Ter Bay.

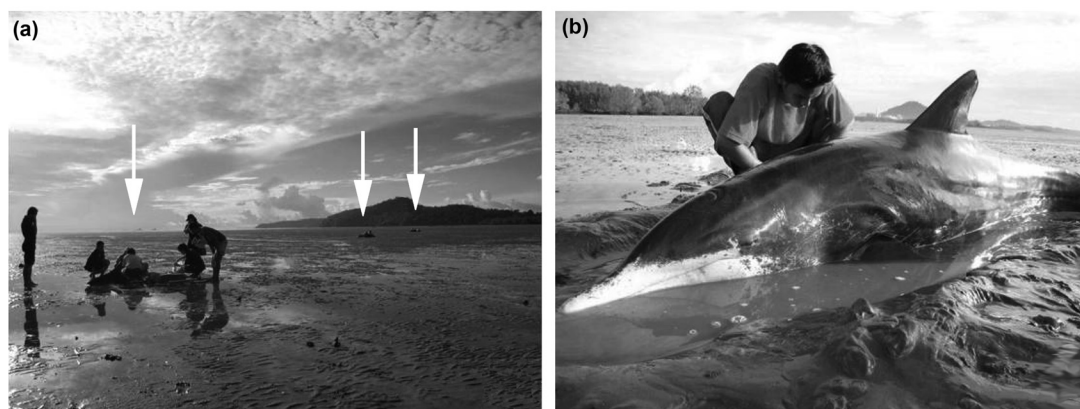


Fig. 4. (a) Three rough-toothed dolphins stranded at Nam Bor Bay, Phuket, on 5 July 2008 (arrows). (b) A hollow was dug beside the dolphin to reduce stress.

strandings also appeared to be in good health. These strandings were possibly the result of mis-navigation, especially given the topography of the stranding locations. In the case of the fourth record, 30 false killer whales swam into a small, narrow bay (Batok Bay, Racha Yai Island). The width at the mouth of the bay is 745m while its length is 925m. The whales possibly lost their way and swam into this semi-enclosed bay when sea conditions were very rough as a result of which they could not swim back to the open ocean. The 10 false killer whales transferred to Ter Bay sustained a few wounds on their bodies, but appeared generally very healthy and strong enough to be released. In the case of the fifth stranding, involving rough-toothed dolphins, Nam Bor Bay in Phuket has a length of 3.7km and a width of 2.1km. It is believed that the gently sloping beach and rapidly falling tide led to a navigational miscalculation by the dolphins causing them to be trapped in a shallow bay (Fig. 4).

In addition to these five mass stranding events, nine Irrawaddy dolphins *Orcaella brevirostris* (End 587–595) were found at Ban Bor Beach, Samut Sakhon Province (100°3.2'E, 13°3.5'N), on 25 March 2009 around noon, at low tide. The dolphins were trapped inside a man-made obstacle, a 'sand sausage', used to reduce coastal erosion. Local people helped return all the dolphins to the sea (Fig 5).

On 3 June 2009, another Irrawaddy dolphin was found stranded inside the sand bags and released. Without human intervention, all the animals would have died during low tide

because most of the area between shore and the sand bags dried out. These structures were purpose built to reduce beach erosion in the upper Gulf of Thailand, but they are clearly a problem for dolphins foraging in these areas. Solutions need to be developed to strike a balance between beach protection and safeguarding the survival of dolphin populations in the area.

CONCLUDING REMARKS

Understanding the consequences of strandings on marine mammal populations is often difficult because baseline data on the size and status of affected populations are often unavailable (Harwood, 2002). Nevertheless, in Thailand, some impacts of human activities on coastal species are evident, particularly from small-scale fisheries. Many cases of dolphin entanglements in gillnets have been documented, i.e. finless porpoises in the inner Gulf of Thailand and Irrawaddy dolphins in Songkla Lake (Ninwat *et al.*, 2008; Sirimontraporn and Sritakorn, 1995; Thongsukdee and Swangarrarak, 2005; Thongsukdee, unpub data) (Figs 6a and 6b).

Marine litter also poses problems. Two cases of cetacean deaths resulted from ingestion of or entanglement in marine litter. The first was a dwarf sperm whale in Phuket which died following ingestion of 1.6kg of plastic bags (Fig. 6c). The second was a bottlenose dolphin that was trapped in a long (45m) piece of discarded fishing net (Fig. 6d). Cetaceans are not the only marine animals affected; in

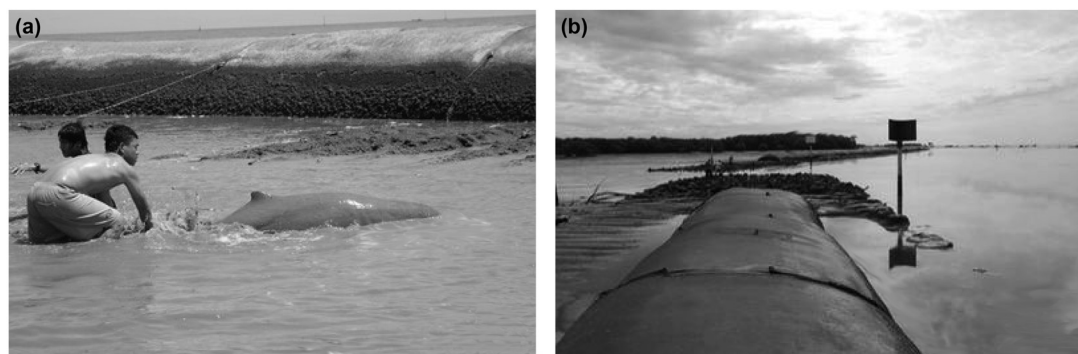


Fig. 5. Irrawaddy dolphins stranded at Ban Bor, Samut Sakhon Province, on 25 March 2009. (a) Local people trying to release the dolphins. (b) Giant sand bags protecting the beach from erosion likely trapped the dolphins during low tide. Each sand bag was about 100m in length and 4m in width with a 50m gap between the two.

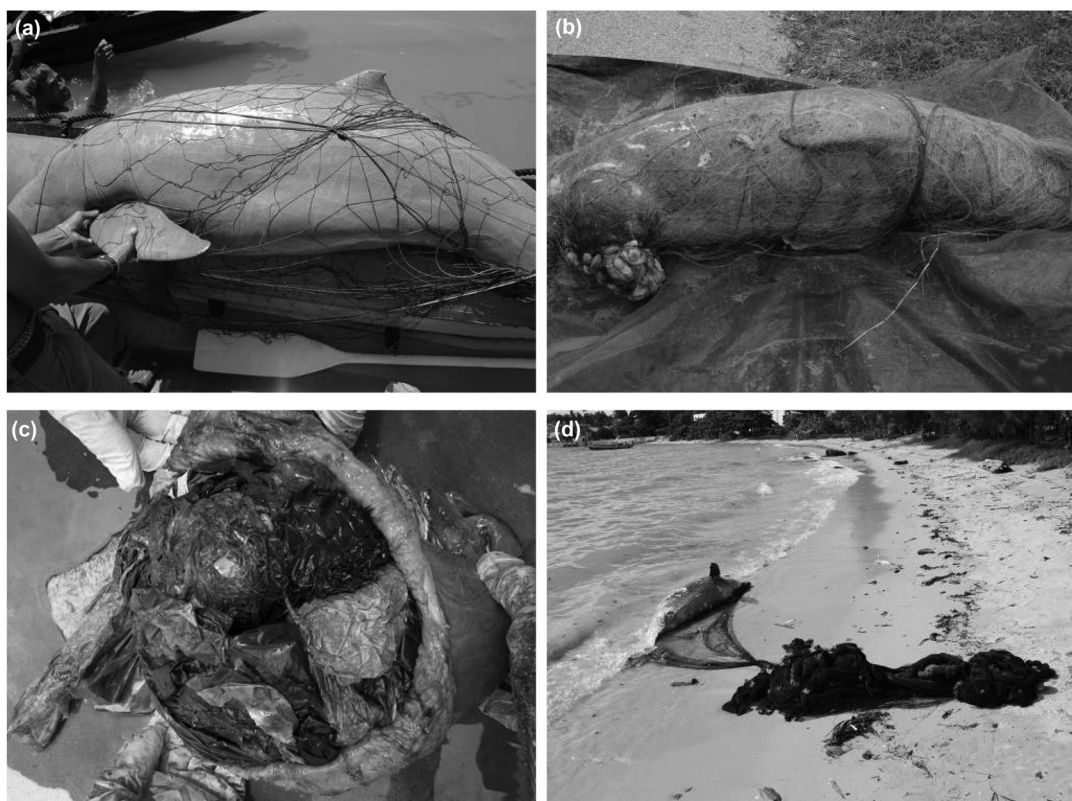


Fig. 6. Photographs illustrating some causes of cetacean death. (a) Irrawaddy dolphin in Songkhla Lake drowned by a large-mesh gillnet for catching giant catfish. (b) Irrawaddy dolphin in Songkhla Lake entangled in a small-mesh gillnet for catching sea bass. (c) Stomach of a dwarf sperm whale stranded in Phuket filled with plastic bags. (d) Bottlenose dolphin in Phuket drowned by a long piece of fishing net. [Photos (a) and (b) courtesy of Mr Santi Ninwat.]

Thailand, 26% of turtle strandings were caused by gillnets and ghost nets (Adulyanukosol and Ruangkaew, 2002).

At present there appears to be a good network for marine endangered animal stranding rescue and response along both coastlines. The DMCR has already developed protected areas for cetaceans using a ‘community based management’ approach in specific locations: (1) Irrawaddy dolphins in Bangprakong river mouth, Chachoengsao; (2) Irrawaddy dolphins in Songkhla Lake; (3) Indo-Pacific humpback dolphins in Khanom Bay, Nakhon Si Thammarat; (4) Indo-Pacific humpback dolphins and bottlenose dolphins in Tase village, Trang; and (5) Irrawaddy dolphins, Indo-Pacific humpback dolphins, and finless porpoises in Sarai Islands, Satun. The large numbers of Irrawaddy dolphins along the coast of Trat near to the Cambodia border should also be protected in a similar way. In that case it would be necessary to collaborate with Cambodia for transboundary conservation. Molecular studies are also important for species identification since some species found in Thai waters seem to be smaller than conspecifics elsewhere, e.g. dwarf spinner dolphins in the Gulf of Thailand.

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Cetaceans and cetacean research in India

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ABSTRACT

The diversity of cetacean species in Indian waters is high, with 25 species recorded so far. Records of cetaceans from India during the last 200 years have provided insights into their spatiotemporal distribution, behaviour, feeding, reproduction, fishery interaction and pollution. The cetacean fauna is dominated by pantropical species, with a relatively high abundance of spinner dolphins, which is similar to other areas studied within the northern Indian Ocean. Historical records were analysed to propose an inventory of cetaceans. Cetacean diversity was highest in the Gulf of Mannar on the southeast coast of India, which with 14 species recorded from a small area can be considered a 'hot spot' for further research. Fishery interactions, domestic consumption, pollution and lack of quality information to inform management are the main threats for successful survival of cetaceans. The status of information regarding cetaceans in India could be classified based on this study as: six species with adequate data; five species where data is restricted to a few geographic locations; four species for which data collection is being initiated; five species with sparse data; and six species which are difficult to observe.

KEYWORDS: INDIA; ARABIAN SEA; BAY OF BENGAL; HISTORICAL DATA; STRANDING; FISHERY INTERACTION; DOMESTIC CONSUMPTION; POLLUTION; DATA QUALITY; INVENTORY; FALSE KILLER WHALE; INDO-PACIFIC BOTTLENOSE DOLPHIN; INDO-PACIFIC HUMPHBACK DOLPHIN; IRRAWADDY DOLPHIN; KILLER WHALE; LONG-BEAKED COMMON DOLPHIN; MELON-HEADED WHALE; PANTROPICAL SPOTTED DOLPHIN; RISSO'S DOLPHIN; ROUGH-TOOTHED DOLPHIN; SHORT-FINNED PILOT WHALE; SPINNER DOLPHIN; STRIPED DOLPHIN; BLUE WHALE; BRYDE'S WHALE; COMMON MINKE WHALE; FIN WHALE; HUMPHBACK WHALE; SEI WHALE; SPERM WHALE; DWARF SPERM WHALE; PYGMY SPERM WHALE; BLAINVILLE'S BEAKED WHALE; CUVIER'S BEAKED WHALE; FINLESS PORPOISE

INTRODUCTION

India has one of the richest diversities of cetaceans within the International Whaling Commission's (IWC) Indian Ocean Sanctuary (IOS). Twenty six species of cetaceans (including 25 marine species and the Ganges river dolphin, *Platanista gangetica*) have been recorded. According to the IUCN¹ Red List (<http://www.iucnredlist.org>) these 26 species are catalogued as Endangered (4 species), Vulnerable (3), Near Threatened (1), Least Concern (8) and Data Deficient (10). In addition, one sirenian (the dugong, *Dugong dugon*, also Vulnerable) is recorded from Indian waters. There is ample scope for cetacean research in India, and research has indeed gained momentum since the declaration of the IOS in 1979.

Mention of cetaceans in Indian literature started as early as 246BC (Table 1), when river dolphins were protected during Emperor Asoka's reign. Current understanding of marine mammals in India developed with the establishment of European colonies and subsequent scientific collections amassed by their museums. Specimens such as skulls, skeletons, internal parasites, sketches and photographs of Indian cetaceans have been curated in various museums in UK, France and USA (Heyning and Perrin, 1994; Leatherwood, 1986). These include type specimens of finless porpoise *Neophocaena phocaenoides* (Cuvier, 1829; Amano, 2002) and dwarf sperm whale, *Kogia sima* (Owen, 1866). Owing to India's largely inland and vegetarian population, the Europeans were not keen on commercially exploiting whales in India. However, aboriginal hunting was not uncommon among island communities in Lakshadweep (Burton, 1941; Manikfan, 1991) and the Andaman and Nicobar Islands (Prater, 1928). Lack of commercial interest, expertise and dedicated research teams have severely limited

basic research on marine mammals in India (Kumaran, 2002).

Nevertheless, there were developments during Victorian times (e.g. Blyth, 1859). The real beginning of marine mammal research in India might be attributed to the collection and transportation (by sea) of a stranded blue whale, *Balaenoptera musculus*, from Mangalore in 1874 for displaying in the government museum at Madras (present Chennai). Since 1876 the skeleton of that specimen has been on display to the public. By the late 19th Century a few British naturalists showed great interest in collecting and cataloguing the flora and fauna of India. Some of those accounts remain of value even today (Blandford, 1888–91; Lydekker, 1903; 1905; Thurston, 1895). Their provisional identifications were in use in India until very recently (Kumaran, 2002), even after those nomenclatures had undergone much taxonomic revision (Perrin *et al.*, 2002; Rice, 1998).

Few species of marine mammals are protected under the Indian Wildlife Act, 1972 (Anon., 1991; Kumaran, 2002) and its subsequent amendments. While this legal protection is welcome, it does make the collection of specimens for research very difficult. Sample collection is mainly dependent on fishery catches for dolphins and porpoise, and occasional strandings for large whales.

Conservation of marine mammals in India requires reliable data on their distribution, reproduction, population characteristics, fishery interactions and pollutant levels. The need to reassess the earlier records in the light of present knowledge was reiterated during two dedicated meetings on marine and fresh water cetaceans in 1985 and 1992 respectively (Table 1). For example, an analysis of stranding records in Europe provided valuable new insights into the distribution of several species of marine mammals (Evans and Hammond, 2004). However, very limited progress has

¹ International Union for the Conservation of Nature.

Table 1
History of major developments in Indian marine mammalogy.

Date	Development	Source
246 BC	Protection of Indian river dolphins in the 'Moral Edicts of King Asoka'	Pilleri (1979)
Between 1483–1530	Reference to the Ganges River dolphins in Baburnama	Pilleri (1979)
1748	Note on two whales, one with unusual length from Pondicherry by Ananthangamramam Pillai	Moses (1947b)
Mar.–Apr. 1761	First record of sperm whale	Leatherwood (1986)
1801	First record of the Ganges River dolphin	Pilleri (1978)
1827	First record of Indo-Pacific humpback dolphin	Leatherwood (1986)
1827	First record of finless porpoise	Leatherwood (1986)
Prior to 1829	First record of long-beaked common dolphin	Blyth (1859)
1848?	First record of blue whale?	Blandford (1888–91); Moses (1947b)
Jul. 1852	First record of short-finned pilot whale first mass stranding	Blandford (1888–91)
Jul. 1852	First record of Irrawaddy dolphin	Blandford (1888–91)
28 Feb. 1853	First record of dwarf sperm whale	Owen (1866)
20 Mar. 1853	First record of Indo-Pacific bottlenose dolphin	Owen (1866)
23 Aug. 1853	First record of melon-headed whale	Leatherwood (1986)
1859?	First record of rough-toothed dolphin	Leatherwood (1986)
1866	First record of pygmy sperm whale	Blandford (1888–91)
1874	First confirmed record of blue whale	Blyth (1859)
1874	Transportation of a stranded blue whale from Mangalore to Chennai by sea	Anon. (1951)
1876	Mounting of a complete skeleton of blue whale	Anon. (1951)
1889	First record of dugong	Thurston (1895)
Prior to 1890	First record of spinner dolphin	Blandford (1888–91)
Prior to 1890	First record of spotted dolphin	Hershkovitz (1966)
14 Feb. 1901	First record of false killer whale	Ferguson (1903)
21 Mar. 1939	First record of fin whale	Moses (1940)
23 Jan. 1943	First record of humpback whale	Mathew (1948)
28 Jan. 1947	First record of sei whale	Jacob and Menon (1950)
Nov. 1935	First record of Risso's dolphin	Burton (1941)
Mar. 1943	First record of killer whale	Moses (1947a)
1949–50	Compilation of stranding records	Moses (1947b)
1950	Successful maintenance of dugongs in captivity	Jones (1959)
24 May 1961	First record of common minke whale	Silas (1964)
26 to 27 Dec. 1961	Transportation of a dugong from Rameswaram to Chennai by road covering a distance of 592km in 13.5hrs. First initiative to create awareness by displaying a live animal at the National Agricultural Fair (1962)	Thomas (1966)
14 Jan. 1971	Second mass stranding of short-finned pilot whale	Alagarwami <i>et al.</i> (1973)
1971	First publication on Eocene cetaceans from the Kachchh district, Gujarat proving archaeocetes reached Indian Ocean during Eocene time	Tandon (1971); Bajpai and Thewissen (1998)
1972	Indian Wildlife Act	Anon. (1991)
2 Jul. 1979	First record of Bryde's whale	Mohan (1992)
1979	Establishment of Indian Ocean Sanctuary by International Whaling Commission (IWC)	Leatherwood and Donovan (1991)
1981	Membership of International Whaling Commission	Donovan (2002)
10 Nov. 1982	First record of Cuvier's beaked whale	Pillai <i>et al.</i> (1981)
1984	Initiation of programme to collect information on stranded/accidental entanglement of marine mammals	Silas (1984)
12–16 Jan. 1985	First seminar on endangered marine animals and parks, Kochi	Silas (1985)
25 May 1989	First confirmed record of striped dolphin	Kumaran (2003)
4 Mar. 1991	Issue of stamps of the Ganges River dolphin and dugong	CMFRI*
18–19 Aug. 1992	Seminar on the conservation of river dolphins of the Indian sub-continent, New Delhi	Reeves <i>et al.</i> (1993)
Phase I – 2002–07 and Phase II 2008–12	First dedicated long-term project on marine mammals	CMFRI*
5 Sep. 2003	First record of Blainville's beaked whale	Said Koya (pers. comm.)

*CMFRI = Central Marine Fisheries Research Institute, Kochi, India.

been made in this direction in India (Blandford, 1888–91; James and Soundarajan, 1979; Moses, 1947b). Major gaps in the data on Indian cetaceans mean that the information available is inadequate to address questions pertaining to their conservation (Kumaran, 2002).

Despite India's large geographical extent, its high cetacean diversity, and its membership of many international conservation efforts (such as IUCN, CITES², CBD³, CMS⁴ and IWC), it has failed to develop a professional approach

to cetacean research. With no direct economic implications, India has been reluctant to pursue serious marine mammal research until recently. However, cetacean research received an impulse from 2002, when a fall in trawl catches prompted the administration to develop an ecosystem-based management strategy which requires information on top predators.

The purpose of the present study is to address two major gaps for effective conservation and management of marine cetaceans in India: (1) to review records of marine cetaceans from 1800 to 2006 in order to prepare a statewide inventory; and (2) to evaluate the current status of cetaceans in the different maritime states.

² Convention on International Trade in Wild Species of Endangered Fauna and Flora.

³ Convention on Biological Diversity.

⁴ Convention on Migratory Species.

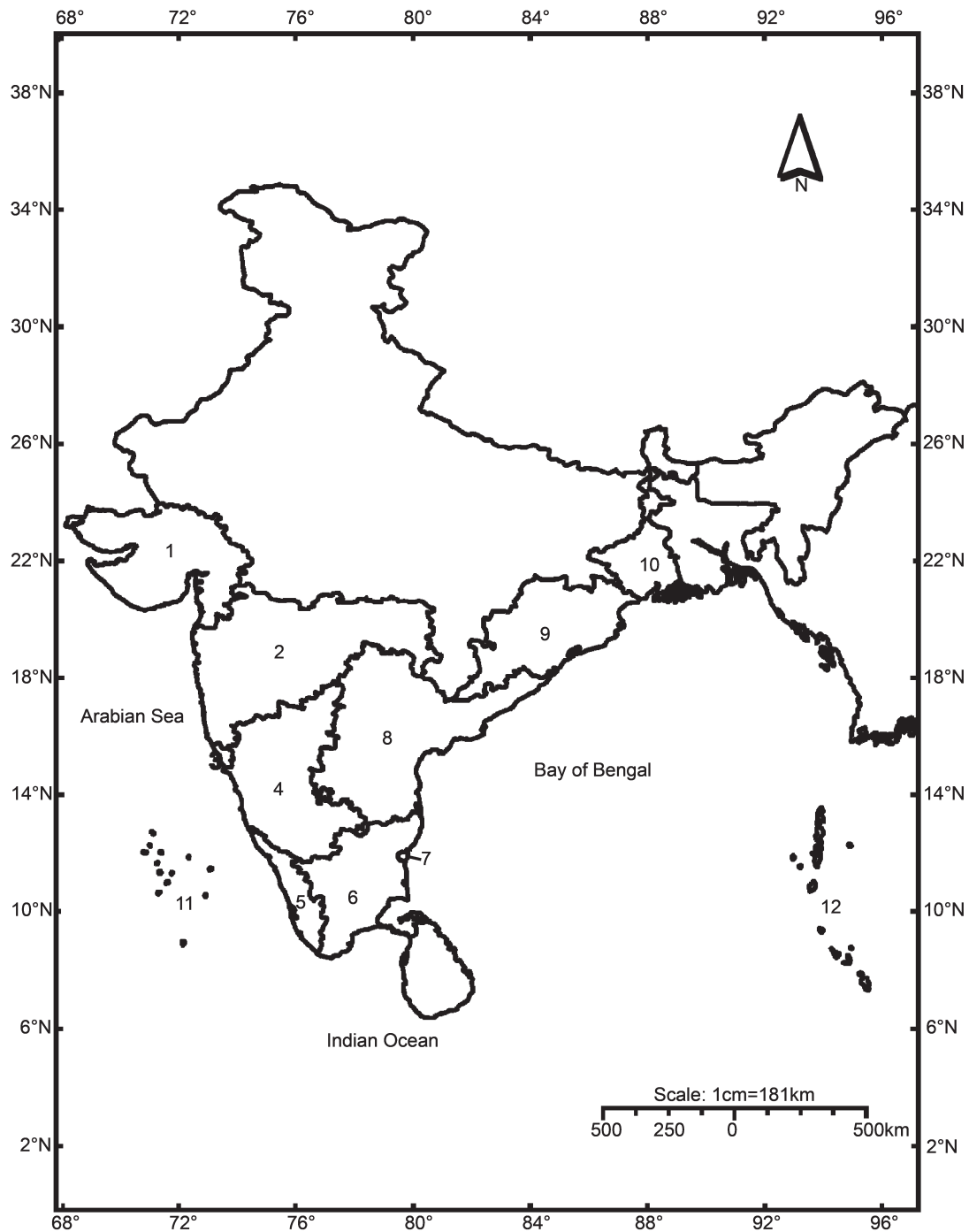


Fig. 1. India map showing the maritime states. Key: 1. Gujarat; 2. Maharashtra; 3. Goa; 4. Karnataka; 5. Kerala; 6. Tamil Nadu; 7. Pondicherry; 8. Andhra Pradesh; 9. Orissa; 10. West Bengal; 11. Lakshadweep; 12. Andaman and Nicobar Islands.

MATERIALS AND METHODS

Study area

India has a coastline of 8,129 km (Fig. 1) and an EEZ of 2.02 million km². There are ten maritime states: on the west coast Gujarat (GU), Maharashtra (MA), Goa (GO), Karnataka (KA), Kerala (KE); on the east coast Tamil Nadu (TN), Pondicherry (PO), Andhra Pradesh (AP), Orissa (OR) and West Bengal (WB); and two island groups Lakshadweep (LD) in the Arabian Sea and Andaman and Nicobar Islands (A&N) in the Bay of Bengal. Although small areas of Tamil Nadu and Pondicherry are on the west coast, their administrative capitals and the bulk of their coastlines are on the east coast.

Compilation of records

Reports on the Indian marine mammals published by more than 250 authors in over 220 papers from numerous sources varying from conference abstracts to books during the years 1800 to 2006 (plus one record from 1748) were considered for this analysis. A total of 2,095 records were extracted from the literature and reliable unpublished sources. Nine major sources of cetacean records have been identified (Table 2): fishery interaction (50.2% of records); live stranding (4.4%); washed ashore dead (3.3%); sighting (29%); museum specimen (1.5%); carcass (1%); captivity (0.4%); mass live stranding (8.3%); mass mortality (1.8%); and type unknown (0.1%). Although 29% of the records were from sightings,

Table 2
Major sources of cetacean records in India (values expressed as percentage).

Species	Record sources (<i>n</i> = 2,095)										Total
	Fishery interaction (50.2%)	Stranding (44%)	Washed ashore (33%)	Sighting (29%)	Museum specimen (1.5%)	Carcass (1%)	Captivity (0.4%)	Mass stranding (8.3%)	Mass mortality (1.8%)	Type unknown (0.1%)	
Baleen whales	1.5	40	50	—	3.2	10	22.2	—	—	33.3	4.5
Sperm whale	0.6	10.9	11.4	0.2	3.2	—	—	—	—	—	1.2
Pygmy/dwarf sperm whales	0.1	3.4	—	—	6.4	—	—	—	—	—	0.3
Beaked whales	0.1	2.4	1.6	—	—	—	—	—	—	—	0.2
Dolphins	91.4	39	27	99.8	74.3	70	22.2	100	100	33.4	89.3
Porpoise	6.3	—	4.3	—	12.9	20	55.6	—	—	33.3	4.1
Unid. whales	—	4.3	5.7	—	—	—	—	—	—	—	0.4
Total	100	100	100	100	100	100	100	100	100	100	100

the specific identifications of several are questionable owing to the lack of local expertise. Only sightings from reliable sources were considered for comparative analysis.

Among the publications reviewed here, the frequencies of the major species groups considered were: dolphins (55%) > baleen whales (27.4%) > sperm whale (7.5%) > porpoise (7%) > pygmy and dwarf sperm whales (2.6%) > beaked whales (0.5%). Similarly from the total of 2,095 records, the frequencies of the major species groups recorded were: dolphins (89.3%) > baleen whales (4.5%) > porpoise (4.1%) > sperm whale (1.2%) > pygmy and dwarf sperm whales (0.3%) > beaked whales (0.2%). In addition unidentified whales accounted for 0.4% of records; however, the true percentage of unidentified animals will be more, since several unreliable records were not considered in this analysis.

Validation of records

The records considered here are pooled from different sources over a period of 200 years, and so they lack uniformity. This analysis of records does not include duplications, for example (i) in the works of different authors (e.g. Grubh and Pereira, 1965; Kharbari *et al.*, 1966; Kuthalingam *et al.*, 1982; Nammalwar and Thanapathi, 1982; Subramani, 1989; Anonymous, 1988a); (ii) of records by the same author with alterations in species name (e.g. James and Mohan, 1987; Mohan, 1992); and (iii) publication of the same record in different journals (e.g. Dhandapani, 1992; 1995; James, 1984; 1985). When the same work is published more than once (e.g. Kizhakudan, 2002; Kizhakudan and Kizhakudan, 2001), the earliest publication is considered in this study. Dubious records, such as a record including a measurement from tip of the snout to second dorsal fin (Jani and Patel, 1995) and records of deep water species inhabiting shallow waters (Singh, 2003) or vice versa (Sathasivam, 2000; 2004) are ignored. In a few cases, where journal publication was delayed, the reported (i.e. intended not actual) publication date precedes the record date.

Correct specific identification is of key importance to a review such as this. Reports were examined for accuracy of species identification based on Hershkovitz (1966), Jefferson *et al.*, (1993), Perrin *et al.*, (2002) and Rice (1998). Further, whenever possible, these records were verified with personal observations, body measurements, museum collections,

photographs, reports of DNA analysis and other related information from India and abroad.

Specimens reported in the literature as *Delphinus delphis* or *D. tropicalis* (Mohan, 1985a; Thomas, 1983) are considered here to be *D. capensis* (long-beaked common dolphin) based on DNA analysis of a fresh specimen from Andhra Pradesh (Jayasankar *et al.*, 2008). For Indo-Pacific humpback dolphins (*Sousa chinensis*), two different morphotypes have been reported from Indian waters. The animals from the west coast have a prominent hump (Mohan, 1983; Parsons, 1998; Sutaria and Jefferson, 2004), whereas forms without humps are reported from the east coast (Kasim *et al.*, 1994; Kumaran, 1989; 2002; Sutaria and Jefferson, 2004). In this study, the two morphotypes are considered to be the same species; genetic studies are underway and should help clarify the issue. Blue whales reported from India are considered as *B. musculus* for want of more detailed information on possible subspecies. The presence of fin whales (*B. physalus*) (Brownell Jr, 2009) and sei whales (*B. borealis*) (Perrin, pers. comm.) in the northern Indian Ocean has been subject to debate. It is possible that neither species occurs in this region, but until more concrete evidence becomes available the provisional identifications of fin and sei whales from Indian seas are treated as such. Details and limitations on the identification of whales used for this study were published by Kumaran (2002).

Table 3 provides an overview of the literature, by species, subject and state; in cases where species identification has been corrected here, there may be a mismatch between paper titles and assignment in the table. Forty-two keywords were extracted from the publications on Indian cetaceans.

RESULTS AND DISCUSSION

Species composition

The number of cetacean species reported was higher on the east coast with 24 (96% of the 25 species reported nationally) against 21 (84%) on the west coast. On the west coast, eight species accounted for 94.6% of the total records (*n* = 1,276): spinner dolphin (33.4%) > Indo-Pacific bottlenose dolphin (18.4%) = long-beaked common dolphin (18.4%) > finless porpoise (9.4%) > Indo-Pacific humpback dolphin (9%) > blue whale (3.3%) > Risso's dolphin (1.7%) > sperm whale (1.0%). The remaining 13 species combined accounted for 2.8% of records.

Table 3

Review of cetacean study in India. Numbers in parentheses denote the maritime states as follows; (1) Gujarat; (2) Maharashtra; (3) Goa; (4) Karnataka; Kerala; (6) Tamil Nadu; (7) Pondicherry; (8) Andhra Pradesh; (9) Orissa; (10) West Bengal; (11) Lakshadweep; (12) Andaman and Nicobar Islands; and (13) Indian EEZ.

Aspects/subjects	Sources
Blue whale Anatomy (1); capture (6); carcass (6); fishery interaction (6; 8; 5); museum collection (1); oil extraction (5); organ weights (5); osteology (1); stomach contents (1); stranding (1, 2, 3, 4, 5, 6, 10); survey (11); taxonomy (1); washed ashore (1, 2, 3, 4, 5, 6, 8)	Millard (1906); Kinnear (1915); Prater (1915); McCann (1934); Poduval (1938); Moses (1940; 1947b); Devkar (1949–50); Chari (1951); Jones (1953); Rao (1961); Daniel (1963); Nagabushanam and Dhulkhed (1964); Grubh and Pereira (1965); Venkataraman and Girijavallabhan (1966); Kewalramani (1969); Dhawan (1970; 1972); Bensam <i>et al.</i> (1972); Nagabhushanam and Rao (1972); Karbhari (1973); James and Soundararajan (1979); Venkataramanujam <i>et al.</i> (1983); Marichamy <i>et al.</i> (1984); James and Mohan (1987); Nair and Jayaprakash (1987); Kulkarni <i>et al.</i> (1989); Nammalwar <i>et al.</i> (1989a); Kasim and Balasubramanian (1989); Mohan (1992); Nammalwar <i>et al.</i> (1992b); James <i>et al.</i> (1993); Krishnapillai <i>et al.</i> (1995); Lipton <i>et al.</i> (1995); Mohanraj <i>et al.</i> (1995); Baby (1996; 1999); Tiwari and Varu (2001); Jani (2002); Anoop <i>et al.</i> (2004b); Krishnapillai and Kingston (2004); Afsal <i>et al.</i> (2008).
Fin whale Carcass (4); fishery interaction (6); osteology (4); sighting (2); stomach contents (5); stranding (1, 2, 6); washed ashore (6).	Moses (1940); Grubh and Pereira (1965); Kharbari <i>et al.</i> (1966); Dhawan (1970; 1972); Karbhari (1973); Nammalwar <i>et al.</i> (1983); Kulkarni <i>et al.</i> (1989); Subramani, (1989); Purandhara and Naik (1992); Joel <i>et al.</i> (1996).
Sei whale Capture (5, 6); feeding (1, 5, 6); fishery interaction (1, 5, 6); oil extraction (6); traffic accident (6); skeleton (1); stomach contents (5, 6); stranding (1, 5, 6); washed ashore (1, 6)	Jacob and Menon (1950); Venkataraman <i>et al.</i> (1973); James and Soundararajan (1980); James and Mohan (1987); Anon. (1988a; 1988b); Venkataramanujam <i>et al.</i> (1988); Kasim and Balasubramanian (1989); Nammalwar <i>et al.</i> (1992b); Noble <i>et al.</i> (1992); Jani and Patel (1995); Balasubramanian (2000; 2001b); Gandhi and Kasinathan (2002); Nair <i>et al.</i> (2004).
Bryde's whale Stranding (2, 6); washed ashore (5)	Kinnear (1915); Mohan (1992); Baruah (2000); Jayasankar <i>et al.</i> (2008).
Common minke whale Attacking crew (6); captivity (8); fishery interaction (6, 8); rescue (6)	Silas (1964); Rao (1991); Kasinathan (2002a).
Humpback whale Fishery interaction (5); oil extraction (5); stranding (6); washed ashore (5)	Mathew (1948); Muthiah <i>et al.</i> (1988); Sathasivam (2002).
Sperm whale Captivity (6); capture (5, 6, 11); fishery interaction (5, 6, 11); museum collection (6); oil extraction (6); osteology (6); sighting (11, 12); skull (6); stomach contents (6); stranding (1, 6, 8, 11); washed ashore (4, 6, 7, 11); foetus (11)	Blandford (1888–91); Raja and Pai (1973); Bande <i>et al.</i> (1980); James and Manivasagam (1980); James and Soundararajan (1980; 1981); Kuthalingam <i>et al.</i> (1982); Nammalwar and Thanapathi (1982); Rao, 1983; Leatherwood (1986); Sivadas <i>et al.</i> (1987) Venkataramanujam <i>et al.</i> (1987); Nammalwar <i>et al.</i> (1992a; 2002a; 1989b); James and Panicker (1990a; 1990b); Tiwari and Varu (2001); Kasinathan and Gandhi (2002); Murugan and Khan (2003); Afsal and Rajagopalan (2007); present study.
Pygmy sperm whale Fishery interaction (8); parasites (5); stranding (5)	Blandford (1888–91); Gibson and Harris (1979); Leatherwood (1986).
Dwarf sperm whale Museum collection (8); stranding (5)	Blandford (1888–91); Leatherwood (1986).
Cuvier's beaked whale Fishery interaction (6); organ weights (6); skeleton (11); stomach contents (6); stranding (6, 11); washed ashore (6, 11)	Pillai <i>et al.</i> (1981); Kumaran (1989); present study.
Blainville's beaked whale Washed ashore (11)	Said Koya (unpublished records).
Irrawaddy dolphin Carcass (9); museum collection (8, 10); stranding (6, 10); survey (9); washed ashore (9)	Blandford (1888–91); Leatherwood (1986); James <i>et al.</i> (1989); Dhandapani (1992); Mohan (1994); Karunakaran (pers. comm.).
Killer whale Museum collection (12); stranding (1); survey (11)	Moses (1947a); Nagabhushanam and Rao (1972); Leatherwood <i>et al.</i> (1991).
Short-finned pilot whale Anatomy (6); captivity (6); fishery interaction (6); mass stranding (6, 10); museum collection (2); oil extraction (6); pollution (6); school composition (6); sighting (11); skeleton (6); stomach contents (6)	Blandford (1888–91); Leatherwood (1986); Alagaraswami <i>et al.</i> (1973); Nammalwar <i>et al.</i> (1989a).
False killer whale Age determination (5); biochemical composition (5); captivity (5, 6); capture (6); fishery interaction (5, 6, 12); monitoring (13); museum collection (1); sighting (6, 11); stomach contents (5, 12); stranding (5, 6, 12); taxonomy (5)	Ferguson (1903); Lydekker (1903); Silas and Pillay (1960); Sivaprakasam (1980); Thiagarajan <i>et al.</i> (1984); James (1984); Silas (1984); James (1985); Mohan <i>et al.</i> (1984); Mohan (1995; 1985a; 1994); Alling (1986); James and Mohan (1987); Rao <i>et al.</i> (1989); Leatherwood <i>et al.</i> (1991); Kasim <i>et al.</i> (1993); Nammalwar <i>et al.</i> (2002b).

Aspects/subjects	Sources
Melon-headed whale Fishery interaction (6); museum specimen (6, 8, 12); sighting (8)	Blandford (1888–91); Townsend (1935); Leatherwood (1986); Leatherwood <i>et al.</i> (1991); Karuppiiah <i>et al.</i> (1998).
Indo-Pacific humpback dolphin Age determination (5); captivity (5); carcass (9); fishery interaction (1, 2, 5, 6, 8); foetus (5, 6); mass mortality (6); museum collection (1, 5, 8); organ weights (6); poaching (6); pollution (6); rescue (6); skeleton (1); skull (5); sighting (1, 3, 5, 8); stomach contents (4, 6); stranding (1, 3, 6, 9); taxonomy (5); washed ashore (2, 6)	Blandford (1888–91); Sinclair (1894); Lydekker (1903; 1908); Joglekar <i>et al.</i> (1975); Mohan (1982; 1983; 1995; 1985a; 1985b); Leatherwood (1986); Anon. (1988b); Krishnapillai and Kasinathan (1988); James <i>et al.</i> (1989); Kumaran (1989); Krishnapillai <i>et al.</i> (1991); Arumugam <i>et al.</i> (1995; 1992); Tanabe <i>et al.</i> (1996; 1993); Kasim <i>et al.</i> (1994); Jayaprakash <i>et al.</i> (1995); Lipton <i>et al.</i> (1995); Jadhav and Rao (1998); Parsons (1998); Balasubramanian <i>et al.</i> (2000); Jani (2004); Sutaria and Jefferson (2004); Gandhi (2005); Anoop <i>et al.</i> (2008); present study.
Rough-toothed dolphin Fishery interaction (12); museum collection (12); washed ashore (4)	Blandford (1888–91); Leatherwood (1986); Afsal <i>et al.</i> (2008).
Risso's dolphin Aboriginal hunting (11); anatomy (6); captivity (6); capture (6); fishery interaction (5, 6, 11); sighting (6); stomach contents (6); stranding (6)	Burton (1941); Rajagopalan <i>et al.</i> (1984); Alling (1986); Thiagarajan <i>et al.</i> (1999); Balasubramanian and Easterson (2000); Thiagarajan and Krishnapillai (2000); present study.
Indo-Pacific bottlenose dolphin Aboriginal hunting (11); age determination (5); anatomy (6, 8); captivity (6); commercial exploitation (8); fish bait (8); fishery interaction (5, 6, 8, 11); foetus (5); human consumption (8); museum collection (5, 8); organ weights (6); osteology (6); pollution (6); rescue (6); sighting (6); stomach contents (4, 5, 6); stranding (5, 6); taxonomy (5); washed ashore (5, 6, 10); xenobalanus (6)	Blandford (1888–91); Ferguson (1903); Lydekker (1903; 1905; 1908); Burton (1941); Mohan (1982; 1995; 1985a); Silas <i>et al.</i> (1984); Natarajan and Rajaguru (1985); Rajaguru and Natarajan (1985); Leatherwood (1986); James and Mohan (1987); Krishnapillai and Kasinathan (1987; 1988); Rao (1998); Kumaran (1989); Kannan (1990); Rajaguru and Shantha (1992); Rao and Rao (1993); Rao and Venkataramana (1994); Jayaprakash <i>et al.</i> (1995); Kar (1996); Tanabe <i>et al.</i> (1996; 1993); Lipton <i>et al.</i> (1995); Chandrakumar (1998); Venkataramana and Achayya (1998); Thiagarajan <i>et al.</i> (1999); Joel and Ebenezer (2000); Balasubramanian (2001a); Krishnapillai (2002); Mohamed <i>et al.</i> (2006); present study.
Pantropical spotted dolphin Fishery interaction (6, 8); museum collection (13); organ weights (6); sighting (11); stomach contents (6); pollution (4)	Alling (1986); Leatherwood (1986); Sekhar <i>et al.</i> (1993); present study.
Spinner dolphin Age determination (5); anatomy (6); behaviour (5); fishery interaction (1, 5, 6, 8, 11); human consumption (11); organ weights (6); pathology (1); pollution (6); sighting (5, 11); stomach contents (1, 4, 6); skull (5); washed ashore (6); xenobalanus (6)	Blandford (1888–91); Mohan (1989; 1990; 1995; 1985a; 1985b); Natarajan and Rajaguru (1985); Rajaguru and Natarajan (1985); Alling (1986); Leatherwood (1986); James and Mohan (1987); Anon. (1988c); Kumaran (1989); Krishnapillai <i>et al.</i> (1989); Rajaguru and Shantha (1992); Rao and Rao (1992); Tanabe <i>et al.</i> (1996; 1993); Rao and Chandrashekar (1994); Velayutham <i>et al.</i> (1994); Jayaprakash <i>et al.</i> (1995); Lipton <i>et al.</i> (1995); Kizhakudan <i>et al.</i> (1998); Joel and Ebenezer (2000); Balasubramanian and Selvarani (2001); Krishnapillai (2002); Kasinathan <i>et al.</i> (2005); Anoop <i>et al.</i> (2008); Yousuf <i>et al.</i> (2010); present study.
Striped dolphin Fishery interaction (6); organ weights (6); sighting (11); stranding (1)	Kumaran (2003); Rodriguez (pers. comm.); Said Koya (pers. comm.).
Long-beaked common dolphin Age determination (5); capture (6); feeding (5); fishery interaction (2, 3, 5, 6, 8, 12); human consumption (2); parasites (6); sighting (5, 8); skull (5); stomach contents (2, 4, 6); stranding (1, 2); survey (12); washed ashore (6)	Blandford (1888–91); Balan (1961); Nagabhushanam and Rao (1969; 1972); Hamsa and Nammalwar (1978); Daniel <i>et al.</i> (1979); Sivaprakasam (1980); Silas <i>et al.</i> (1984); Mohan (1989; 1990; 1995; 1985a; 1985b); Leatherwood (1986); Krishnapillai and Kasinathan (1987); Karbhari <i>et al.</i> (1985); Pillai and Chandrangathan (1990); Jayaprakash <i>et al.</i> (1995); Krishnapillai and Lipton (1996); Jadhav and Rao (1998); Rao (1998); Thathayya and Achayya (1998); Jani (2004); Anoop <i>et al.</i> (2008).
Finless porpoise Age determination (5); capture (3); carcass (9); commercial exploitation (3); distribution (5); embryo (4); foetus (3); fishery interaction (1, 2, 3, 4, 5, 6); museum collection (2, 5); parasites (3); stomach contents (1, 4); taxonomy (5); washed ashore (4, 6); xenobalanus (4)	Blandford (1888–91); Lydekker (1908); Dawson (1959); Devaraj and Bennet (1974); Balan (1976); Thomas (1983); Hafeezullah (1984); Mohan (1995; 1985a); Leatherwood (1986); Anon. 1988a; James <i>et al.</i> (1989); Ganapathy (1992); Kumaran and Subramanian (1993); Nammalwar <i>et al.</i> (1994); Jayaprakash <i>et al.</i> (1995); Muthiah (1995); Bose (2000); Kizhakudan and Kizhakudan (2001); Kasinathan (2002b); Bose and Palanichamy (2003); Josekutty (2003); Anoop <i>et al.</i> (2004a); Anoop <i>et al.</i> (2008); present study.

On the east coast, spinner dolphins were still relatively well represented in the literature, but less frequently than on the west. On the east coast, twelve species accounted for 91.5% of records ($n = 819$): spinner dolphins (21.9%) > Indo-Pacific humpback dolphin (19.0%) > Indo-Pacific bottlenose dolphin (17.0%) > sperm whale (7.8%) > finless porpoise (6.2%) > blue whale (5.3%) > false killer whale (4.1%) > long-beaked common dolphin (3.7%) > Risso's dolphin (2.5%) > Irrawaddy dolphin (1.6%), fin whale (1.2%) = common minke whale (1.2%). The remaining nine species contributed 7.4%. The relative contribution of

unidentified baleen whales was 1.8% and 0.8% for the west and east coast respectively.

Species composition on both coasts is dominated by pantropical species, and is comparable to results from other regional studies (Anderson, 2005; Ilangakoon, 1997; Leatherwood *et al.*, 1984; Leatherwood and Reeves, 1989). The data reviewed here can only give the most crude measure of relative abundance, and so such differences, for example the occurrence of more species of beaked whales in Maldives than India (Anderson, 2005), are not unexpected. Even within the Indian EEZ, some species (such as pygmy

and dwarf sperm whales, rough-toothed dolphin, killer whales and Blainville's beaked whale) are hard to see or may occur relatively far offshore, making them less likely to strand or to be caught in coastal fisheries. They are therefore likely to be under-represented in this review. As a considerable amount of the information here comes from fishery interactions, the distribution and nature of the fishing gear used plays a major role in influencing this review. For instance, finless porpoise records are more frequent on the west coast, probably owing to the relatively high use of shore-seines in Karnataka. Shore-seine is more detrimental to finless porpoise than any other gear on the west coast of India, although as pointed out in earlier studies (Jefferson and Curry, 1994) gillnets do also take some finless porpoise (Bose, 2000; Kasinathan, 2002b; Kumaran and Subramaniam, 1993; Mohan, 1995; Nammalwar *et al.*, 1994). The apparent distributional gap for finless porpoise along the east coast probably reflects the limited extent of shore-seine operations on that coast. In contrast, the apparently greater diversity of species on the east coast might be attributed to the presence of large scale gillnet operations in the southeast of India. In that area there are as many as 520 small fishing hamlets involved in gillnet fishing (Anon., 2005a) and therefore the probability of accidentally netting different species is relatively high.

Nevertheless, the data reviewed here do reflect some genuine trends. For example, the Irrawaddy dolphin is distributed all along the east coast of India on the Bay of Bengal side with not a single record from the west coast on the Arabian Sea side. Also, sighting surveys in the Indian EEZ revealed the spinner dolphin as being the most abundant species in both the Arabian Sea and Bay of Bengal (Anon., 2007).

Based on body length data and others factors (such as the presence of foetuses, lactating mothers and un-weaned calves) it is likely that the following ten species use Indian waters as their calving/nursing grounds: blue whale, sperm whale, finless porpoise, short-finned pilot whale, spinner dolphin, pantropical spotted dolphin, Risso's dolphin, Irrawaddy dolphin, Indo-Pacific humpback dolphin and Indo-Pacific bottlenose dolphin. Accidental capture in fishing gear and other strandings of smaller sized blue whales (600, 630cm), sperm whales (366, 371cm) and Cuvier's beaked whale (234cm) support this view.

Producing an inventory

Indian states have the responsibility of implementing the Indian Wildlife Act of 1972. Historical records and recent sightings confirm that the distributional range for many cetacean species transcend the political boundaries of maritime states. Exploitation of some species may be strictly monitored or protected in a particular state but not in the adjacent state. The differences in implementation of the Wildlife Act between maritime states could be attributed to differences in their priorities. Many of the conservation programmes require a state level inventory of the floral and faunal compositions before taking specific actions. Earlier attempts at preparing an inventory of marine mammals in India were restricted in scope and never went beyond brief compilations (James and Soundarajan, 1979; Moses, 1947b). In the present study an attempt has been made to summarise the total 2,059 records

to propose an inventory by state. Inventory of cetaceans by state is a prerequisite for evolving regional action plans as there is no uniform approach towards conservation of cetaceans in India.

Publications in English (publications in regional languages are excluded) on the marine cetaceans from different states were considered when making this inventory. The numbers of publications for each state are plotted against the cumulative number of species to understand the relationship between the research efforts and species diversity (Fig. 2). The total number of publications for the Arabian Sea was 103 and the number of species recorded was 21. The number of publications from Bay of Bengal was 127 with 24 species. Assessment of published records by maritime states has clearly brought out the relationship between effort and expansion of species inventory (Figs 2a and 2b). Pondicherry recorded a single species, the sperm whale and hence is not represented in Fig. 2b. Earlier studies in most of the states were either on coastal species or on large whales. With the increased use of gillnets in the last 40 years and the development of multiday fishing there is an increase in offshore and deep water species composition (Table 1) and in the number of records.

The inventory of marine cetaceans by maritime states of India based on confirmed reports is presented in Table 4.

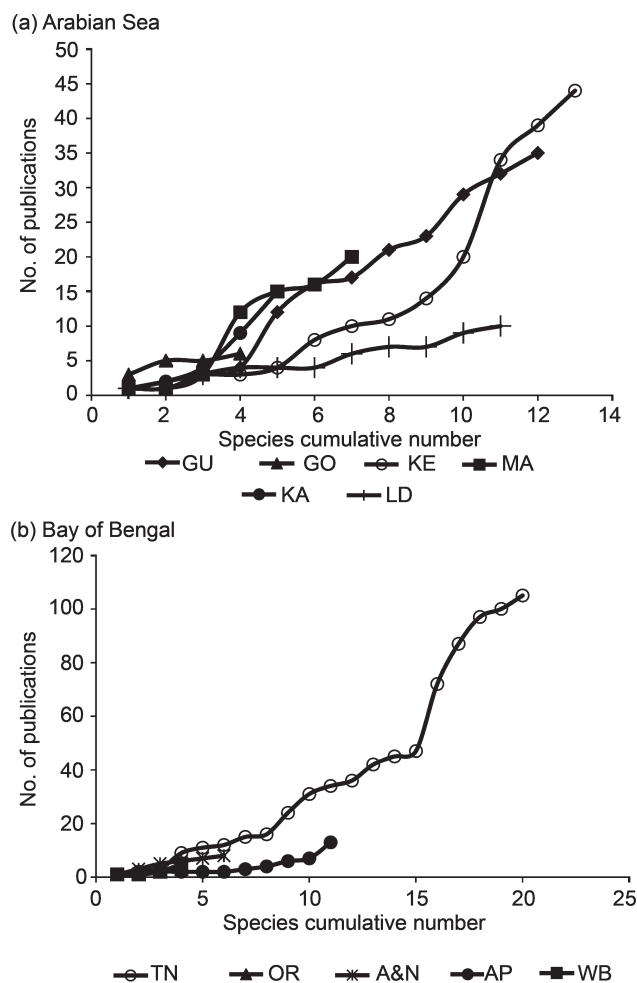


Fig. 2. Cumulative number of species for each maritime state (names mentioned in the text) is plotted against the number of publications from the respective state. (a) Arabian Sea and (b) Bay of Bengal.

Table 4

Inventory of cetaceans by maritime states in India based on the published and confirmed records. IUCN status are given in parentheses: Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC) and Data Deficient (DD).

Species	Maritime states												Indian EEZ
	GU	MA	GO	KA	KE	TN	PO	AP	OR	WB	LD	A&N	
Blue whale (EN)	•	•	•	•	•	•	–	•	–	•	•	–	–
Fin whale (EN)	•	•	•	•	•	•	–	–	–	–	–	–	–
Sei whale (EN)	•	–	–	–	•	•	–	–	–	–	–	–	–
Sperm whale (VU)	•	–	–	•	•	•	•	•	–	–	•	•	–
Irrawaddy dolphin (VU)	–	–	–	–	–	•	–	•	•	•	–	–	–
Finless porpoise (VU)	•	•	•	•	•	•	–	–	•	–	–	–	–
Indo-Pacific hump-backed dolphin (NT)	•	•	•	•	•	•	–	•	•	–	–	–	–
Cuvier's beaked whale (LC)	–	–	–	–	–	•	–	–	–	–	•	–	–
Common minke whale (LC)	–	–	–	–	–	•	–	•	–	–	–	–	–
Humpback whale (LC)	–	–	–	–	•	•	–	–	–	–	–	–	–
Melon-headed whale (LC)	–	–	–	–	–	•	–	•	–	–	–	•	–
Pantropical spotted dolphin (LC)	–	–	–	•	–	•	–	•	–	–	•	–	•
Striped dolphin (LC)	•	–	–	–	–	•	–	–	–	–	•	–	–
Rough-toothed dolphin (LC)	–	–	–	•	–	–	–	–	–	–	–	•	–
Risso's dolphin (LC)	–	–	–	–	•	•	–	–	–	–	•	–	–
Bryde's whale (DD)	–	–	–	–	•	•	–	–	–	–	–	–	–
Pygmy sperm whale (DD)	–	–	–	–	•	–	–	•	–	–	–	–	–
Dwarf sperm whale (DD)	–	–	–	–	•	–	–	•	–	–	–	–	–
Blainville's beaked whale (DD)	–	–	–	–	–	–	–	–	–	–	•	–	–
Short-finned pilot whale (DD)	–	•	–	–	–	•	–	–	–	•	•	–	–
Killer whale (DD)	•	–	–	–	–	–	–	–	–	–	•	•	–
False killer whale (DD)	•	–	–	–	•	•	–	–	–	–	•	•	•
Indo-Pacific bottlenose dolphin (DD)	–	–	–	•	•	•	–	•	–	•	•	–	–
Spinner dolphin (DD)	•	–	–	•	•	•	–	•	–	–	•	–	–
Long-beaked common dolphin (DD)	•	•	•	•	•	•	–	•	–	–	•	•	–
Total number of species	11	6	5	10	15	20	1	12	3	4	13	6	2+

Apparent gaps in species distribution are mainly due to lack of research effort, and there is much scope for improvement. The number of species recorded in a maritime state increases with the amount of research effort and subsequent publications. However, for the state of Tamil Nadu the possibility of adding new species is relatively low because already its present inventory is close to the number of known species from the northern Indian Ocean. Inventories alone are inadequate for conservation.

However, based on 47 publications and the number of species recorded (14 including dugong), a 'hot spot' for the study of marine mammals is the Gulf of Mannar, an area within Tamil Nadu state on the southeast coast between India and Sri Lanka. The number of species reported for the Gulf of Mannar is higher than any other maritime state except Kerala (14). The depth gradation is very pronounced within a limited area providing habitat for many coastal, offshore and deep water species. Furthermore this area has been declared a national 'Marine Protected Area'. Another contributing factor to the high species richness here may be the consistent effort in the region to collect data over many years, and its density of gillnet operations is among the highest in the country (Anonymous, 2005b).

Areas of research interest on Indian cetaceans

Relatively little cetacean research was published in the 19th and early 20th centuries. Most of the publications reviewed here (87%) are from after 1950. Since that date, the major contribution towards cetacean research in India has been from fishery biologists (Kumaran, 2002). The scope of their publications was generally limited to a few measurements and some photographs or figures. Although the quality of

such publications is not high, they provide much needed information on the distribution of several species along the Indian coast. Most publications are in local journals, but there have been some publications from Indian authors in international journals dedicated to marine mammal research such as *Investigations on Cetacea* (Kuthalingam *et al.*, 1982; Venkataramanujam *et al.*, 1988; 1983; 1987), *Marine Mammal Science* (Natarajan and Rajaguru, 1985), *Fishery Bulletin* (Rajaguru and Shantha, 1992), *Aquatic Mammals* (Sutaria and Jefferson, 2004) and the *Journal of Cetacean Research and Management* (Afsal *et al.*, 2008). Besides this there have been few other international publications on Indian cetaceans (Anoop *et al.*, 2008; Jayasankar *et al.*, 2008; Karuppiyah *et al.*, 2005; Tanabe *et al.*, 1996; Tanabe *et al.*, 1993; Yousuf *et al.*, 2008). When classified according to the IWC recommended list of keywords, it can be seen that research on cetaceans in India has focussed on the following nine major areas: behaviour (4.7%); environment (4.7%); exploitation (26.2%); feeding (4.7%); health (7.3%); population assessment (9.5%); stock identity (9.5%); techniques (7.3%); and reproduction (4.7%). Other subject matters contributed to 21.4%. With 'exploitation' being the topic discussed most frequently in the literature, it is worth reiterating the necessity for more detailed studies on cetaceans in Indian waters.

The number of publications and the number of species recorded are greater on the east coast than on the west coast of India. However, the west coast scores better than the east coast when it comes to the diversity of research topics studied. This may be a more meaningful measure of the value of information for management purposes than simply the total number of species recorded.

Threats

Fishery interaction

Fishery interaction is a major threat that needs immediate attention. In India, 19 species (75% of the national total) have been recorded as accidentally taken in different gears. Different species of dolphins, porpoise and small whales form a large proportion of the bycatch. The major fishing gears in India are trawl (44%) > seines (19.2%) > gillnets (18.4%) > bag nets (11%) comprising together 92.6% of the total gears (Anon., 2005a). The numbers of cetacean species recorded as entangled in these four gears are 3, 4, 14 and 1 respectively. Twelve species of cetaceans are reported as fishery bycatch without mentioning the actual gear involved. The impacts of other gear on cetaceans needs to be documented. As many as 98% of the trawls operated in India are benthic, which may be less lethal to cetaceans than pelagic trawls (Fertl and Leatherwood, 1997). Indeed only three species of cetacean are recorded as entangled in trawls in India. However, gillnets are a major threat to cetaceans. Gillnets are a popular gear with many indigenous innovations. Low operating costs and the ability to operate from different vessel types make it a favourite choice among fishermen. Gillnets support the livelihoods of the poorest fisherman, who have no access to more expensive crafts and gears. Regulating mesh sizes, let alone restricting or banning gillnets altogether, would be difficult to implement or monitor in India.

Even though 50.2% of all records in the present study are from fishery interactions, there has been little regular monitoring or mitigation studies. The few studies on the impact of fisheries on cetaceans have been from the southwest coast (Jayaprakash *et al.*, 1995; Mohan, 1985a; Pillai and Chandrangathan, 1990; Silas *et al.*, 1984), the southeast coast (Kumaran, 1989) and recently by Yousuf *et al.* (2008) from three different landing centres (one on the west coast and two on the east coast). Apart from this there are no reliable data on the species or quantity of cetaceans landed, or on the extent of utilisation of cetacean meat as baits in hook and line shark fisheries.

Domestic consumption

A few species, notably finless porpoise, have a niche market along the west coast of India. For instance observations at three different locations (Goa, Malpe in Karnataka and Trivandrum in Kerala) revealed that there is an open market for cetacean meat (Dawson, 1959; Thomas, 1983; present study). At Malpe a conservative estimate is that 2,000 cetaceans are caught per year for human consumption (present study). There is also a market for juvenile dolphins on the west coast. A dedicated study on the species composition and numbers taken for domestic consumption would bring information on consumer choice and utilisation of dolphin meat.

Pollution

The number of cetacean species studied for pollutants, and the diversity of the pollutants studied in Indian waters are reasonable when compared to other aspects of cetacean research. Tissues of spinner dolphin, pantropical spotted dolphin, long-beaked common dolphin, Indo-Pacific humpback dolphin, Indo-Pacific bottlenose dolphin, short-

finned pilot whale, Risso's dolphin and finless porpoise were studied for pollutants such as DDTs⁵, HCHs⁶, enantiomers of α -HCH, chlordane compounds, HCB⁷, PCBs⁸ and for trace metals such as Mn, Ni, Cu, Zn, Pb, Al, Cr, Fe, Co, Cd, Hg (Alagarswami *et al.*, 1973; Karuppiiah *et al.*, 2005; Prudente *et al.*, 1997; Tanabe *et al.*, 1996; Tanabe *et al.*, 1993; Velayuthum *et al.*, 1994; unpublished records). The results obtained to date are comparable to those from any developing country with no specific elevation to any particular group of chemicals. However, continuous monitoring is recommended for different pollutants for those cetaceans that are near the top of the food chain.

Lack of quality information

In India, recently, cetaceans are of interest to the media. Successful networking between the different media and the scientific community could prove useful in collecting much biological information on stranded animals when they are relatively fresh. With almost 440 television channels and hundreds of regional and national newspapers in several languages in India, most stranding events should be covered. While such reports do record many strandings, they may not recover all available information, and in particular specific identification may be unreliable. Nevertheless, such reports are frequently incorporated into regional reviews. As time passes, the secondary documents become the source of information as the older literature becomes untraceable. When the originals are not consulted it is difficult to ascertain the species identity or related information. In the case of original misidentification, the secondary sources help to establish the initial reports more firmly. A classic example is the report of a southern right whale from the northwest coast of India in 1944. Moses (1947a) originally reported this stranding, which has been included in subsequent reviews (Bensam and Menon, 1996; de Silva, 1987; James and Mohan, 1987; James and Soundarajan, 1979; Mohan, 1999; Leatherwood, 1986; Menon, 2003; Moses, 1947b; Sathasivam, 2000; 2004). This despite the fact that the identification error of Moses (1947a) was corrected, as a blue whale, by Devkar (1949–50) and the skeleton has been displayed for the public in the Baroda Museum for the past 60 years. Incidents like this continue even today. For instance a dedicated website for marine mammals of India⁹, has listed Risso's and bottlenose dolphins as finless porpoises without verifying the original source (Burton, 1941). There is no quality control to verify the publications and regrettably the Government of India's reports on issues concerning marine mammals are prepared with equal negligence. The report submitted by the Indian government to the CMS in 2008 had many errors and inconsistencies and underrepresents the ongoing research on marine mammals in India (Kumarran, 2009). The habit of citing work without verifying the original sources is a source of misinformation and thus a potential threat to cetacean conservation in India. Since joining the IWC in 1981 only one representative from India has produced peer reviewed publications on cetaceans. The

⁵ Dichlorodiphenyltrichloroethanes.

⁶ Hexachlorocyclohexanes.

⁷ Hexachlorobenzene.

⁸ Polychlorinated biphenyls.

⁹ <http://www.marinemammals.in/marine-mammal-sightings-strandings>.

need for quality research is indispensable to conserve cetaceans in Indian waters as well as to fulfil India's obligations to international treaties. This calls for sensitisation of different government agencies at both national and state levels.

CONCLUSIONS

Historical data can provide valuable insights into the abundance and diversity of cetaceans. For example, it is possible to estimate the geographical extent of a particular species within Indian waters; to aid in identifying major threats; and to highlight the quality of research required for developing and implementing effective conservation and management plans. However, this requires a certain standard of reporting, with accurate species identification being of particular importance.

The status of current knowledge of different species of cetaceans based on this study might be categorised as: (1) species where data are adequate (blue whale, sperm whale, finless porpoise, spinner, bottlenose and humpback dolphins); (2) species where data are restricted to a few geographic locations (Cuvier's beaked whale, short-finned pilot whale, striped, spotted and Irrawaddy dolphins); (3) species for which data collection is being initiated (sei whale, false killer whale, common and Risso's dolphins); (4) species for which data are sparse (melon-headed whale, humpback, minke, fin and Bryde's whales); and (5) species with less than five records in the last 50 years and therefore considered difficult to see (Blainville's beaked whale, pygmy and dwarf sperm whales, killer whale and rough toothed dolphin).

In the last few years there has been steady progress in systematic data collection on different species and this will reassign the scale for different species. Cetacean research in India in the last few years has qualitatively improved after the initiation of a long term study on marine mammals of India in 2002 (Anoop *et al.*, 2008; Jayasankar *et al.*, 2008; Kumarran, 2009; Yousuf *et al.*, 2008). Conventional approaches to the study of cetaceans in India rely heavily on the funds and infrastructure with less emphasis on data quality. National priorities for biodiversity studies cannot be adequately addressed by merely importing or modifying research methodologies from different countries. A good database on the available information is indispensable for developing suitable action plans for India.

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Obtaining distributional information on Indian Ocean cetaceans: suggestions based on an Indian network experience

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ABSTRACT

The understanding of the occurrence and distribution of cetaceans in the Indian region is largely based on information that has been incidentally obtained from strandings and bycatches. An attempt was made to compile such data systematically. The resultant database has been made widely accessible by hosting it on the internet. To improve the quality of information collected, identification aids were published on the same website. A stranding booklet was also created, mainly for the use of individuals and organisations with limited access to the internet. The 'spare capacity' of individuals and organisations was used to gather information and also to prepare the website and booklets, so that little or no expense was incurred. Recommendations are made regarding the collection of distributional data from the Indian Ocean.

KEYWORDS: INDIAN OCEAN; STRANDINGS; CONSERVATION; MONITORING

INTRODUCTION

Little is known about the distribution or populations of marine cetaceans occurring in Indian waters. India has a coastline of 7,500km, an exclusive economic zone (EEZ) of 2.3 million km² and millions of citizens rely on marine resources for their livelihoods and nutrition. Remarkably few sightings surveys have been conducted in Indian waters (Afsal *et al.*, 2008; Alling, 1986) and nearly all the information that is available has come from just a few hundred records of strandings and fisheries bycatch (James and Soundarajan, 1980; Lal Mohan, 1994; Leatherwood, 1986; Moses, 1940; 1947; Pillay, 1926; Sathasivam, 2000; 2004; Yousuf *et al.*, 2008). There is no regular national data collection scheme and the information accumulated over the past one and a half centuries can be considered scanty. The information that is available relating to the cetaceans of India is almost entirely based on incidental observations and a large number of the specimens have not been identified to the species level.

THE VALUE OF INCIDENTAL INFORMATION

The number of cetaceans stranded, cast ashore and incidentally caught along the Indian coast annually is believed to be great. Given the experiences of other countries it was thought that much information of value could be obtained from records of such specimens. For example, in Australia numerous strandings have been documented, giving considerable insights into species composition, demographics and population variability (e.g. Evans *et al.*, 2005; Kemper *et al.*, 2005). Closer by, much has been learnt from relatively modest recording programmes in the Maldives and Oman (Anderson *et al.*, 1999; Collins *et al.*, 2002).

In India, even a basic record of stranding location, date and species would be very useful. Additional information on sex, whether juvenile or adult, condition and obvious causes,

if any, of stranding or death might also be collected relatively easily. If these data were collected systematically, then over time the resulting database would be sufficiently large to provide a useful reflection of the status of cetaceans in the Indian seas. The species diversity, demographic constitution, spatial distributional patterns, temporal variations including migrations, causes of mortality and population trends might all be inferred in due course. These are essential for understanding the conservation requirements of these animals. A database was developed guided by the following criteria:

- (1) easily available to all interested parties;
- (2) would be a collaborative effort by those who made the observations;
- (3) created in conjunction with efforts to increase awareness about cetacean identification, diversity, abundance and habitats. This would ensure that the data collected were of the best scientific quality possible. It would also reduce the proportion of unidentified records;
- (4) provide as much detail as available, including photographs.

With assistance from the Whale and Dolphin Conservation Society (WDCS, UK), the Indian Marine Mammal Conservation Network (IMMCN) was established in 2008, creating a website (<http://www.marinemammals.in>) which incorporated the database described above.

SPARE CAPACITY

Marine mammal science is typically expensive and laborious to pursue. This hurdle can be overcome by using 'spare capacity' to collect information, at little or no expense. Essentially, spare capacity refers to the opportunities, manpower and facilities available to individuals and existing organisations through their infrastructure and regular

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activities. This idea has been described more fully elsewhere (Sathasivam and Natarajan, In press); in the present context the spare capacity available for studying cetaceans is referred to.

It is intended that the IMMCN will grow through the spare capacity and voluntary efforts of those individuals and organisations in India involved with the marine environment. Many already possess diverse data on marine mammals (cetaceans and the dugong) and some could gather more in the course of their work and contribute it to the community at large, particularly to an open-access data storage and distribution system such as the IMMCN. These individuals and groups include members of fishing communities, defence and law enforcement agencies, the media, naturalists and conservationists. They are well placed to acquire data on marine mammals in the course of their daily activities.

One of the important aspects of the IMMCN is that it is web-based. The internet is widely accessible and India has a very large and rapidly growing online population (<http://www.internetworldstats.com/stats3.htm#asia>). Not only does the IMMCN rely on spare capacity for gathering data, it also used it in creating its own website: many of the website's pages were created through the voluntary effort of cetacean enthusiasts.

However, reaching out to communities who do not have internet access is a challenge. With this in mind, a printable stranding booklet has been created for distribution to such groups through organisations and individuals who work with them (also available from 'Dealing with a Stranding' in the website). It is anticipated that these organisations and individuals have a key role. Voluntary effort, or spare capacity, was again used in translating the stranding booklet. India is a multilingual country and there are many languages used along the coast. A particular cetacean species has a different name in each language. Thus the booklet needs to be produced in each of these languages. Members of the IMMCN have translated the booklet into Tamil and Gujarati, two of the most widely used languages of the coastline. Another member has undertaken to translate it into Bengali.

RECOMMENDATIONS

There are many outstanding questions relating to the taxonomic diversity, distribution and migratory movements of cetaceans within the Indian Ocean, as highlighted by papers in this issue of the *Journal of Cetacean Research and Management*. Even as more rigorous scientific surveys are undertaken, the collection of incidental data still has a significant role, particularly when performed at minimal expense. The following guidance should be given to all national and local efforts to collect distributional information on cetaceans in the Indian Ocean.

(1) The internet can be used not only to receive and display records, but also to disseminate information. This will permit easy information exchange in the region. An electronic mail discussion group linking cetologists across the region would serve as a single point where the answers for all technical questions could be obtained. The IMMCN has such a forum; the *marinemammalsofindia* Yahoo group.

- (2) The value of national and local networks will depend to a large extent on the reliability of the data they accumulate. Accurate species identification is critical. The provision of identification aids as on the website and in the stranding booklet of the IMMCN; the ability to store all available information, including photos, on the database; and the periodic scientific scrutiny of all records are all important.
- (3) Low-cost solutions are required because of the limited availability of financial resources. The use of spare capacity, such as 'platforms of opportunity' for offshore surveys is encouraged (Perera and Ilankoon, 2009; Rowat, 2009). The regular ferry services to the Lakshadweep and Andaman Islands are examples of such platforms. In the same vein, when necropsies are performed regularly on stranded cetaceans, samples could be sent, for instance for molecular analyses, to existing facilities in India or a nation in the region rather than creating new institutions or sending the samples farther away.
- (4) Innovative solutions should be sought for any problems encountered rather than following the usual protocols.

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A review of cetacean research and conservation in Sri Lanka

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ABSTRACT

Sri Lanka is a developing island nation in the northern Indian Ocean. Travellers and historians have documented whales in the waters around the island as far back as the 14th century but the first scientific records of live cetaceans from vessel-based research observations were documented only in the early 1980s. Sri Lanka's waters have high cetacean species richness with 27 species recorded to date and year-round abundance. Small cetaceans are however increasingly threatened due to the developing fisheries industry, with bycatch being a major cause for concern. Other identified threats include increasing shipping traffic and unregulated marine tourism. Cetaceans are protected by national legislation but implementation of the relevant laws and conservation measures is hampered by resource constraints. The prevailing gaps in knowledge are also due to a lack of resources to carry out dedicated long-term research on cetaceans in a developing country with more immediate human development priorities. Therefore strengthened law enforcement and finding adequate resources for sustained systematic research that can inform management decisions are priorities in Sri Lanka.

KEYWORDS: CONSERVATION; INDIAN OCEAN; INCIDENTAL CATCHES; SPERM WHALE; BLUE WHALE; BLAINVILLE'S BEAKED WHALE; INDO-PACIFIC HUMPBAC DOLPHIN; SPINNER DOLPHIN; COMMON BOTTLENOSE DOLPHIN; RISSO'S DOLPHIN; PANTROPICAL SPOTTED DOLPHIN; FRASER'S DOLPHIN; ROUGH-TOOTHED DOLPHIN; SHORT-FINNED PILOT WHALE; FALSE KILLER WHALE; PYGMY KILLER WHALE; KILLER WHALE; MELON-HEADED WHALE; COMMON DOLPHIN; CUVIER'S BEAKED WHALE; BLAINVILLE'S BEAKED WHALE; GINKGO-TOOTHED BEAKED WHALE; LONGMAN'S BEAKED WHALE; SOUTHERN BOTTLENOSE WHALE; PYGMY SPERM WHALE; DWARF SPERM WHALE; FIN WHALE; COMMON MINKE WHALE; HUMPBAC WHALE; BRYDE'S WHALE

INTRODUCTION

Sri Lanka (5°–9°N, 79°–81°E) is a developing island nation in the northern Indian Ocean (Fig. 1) with a long tradition of fisheries around her shores. Travellers and historians have referred to whales around Sri Lanka (previously referred to as Serendib, Taprobane or Ceylon) as far back as the 14th century (Tennant, 1859). Records of stranded whales and museum specimens were first reported from the 1850s (Blyth, 1859; Deraniyagala, 1945; 1960; Fernando, 1912; Kelaart, 1852) and interactions between cetaceans and fisheries from the 1880s (Lantz and Gunasekera, 1955; Nevill, 1887). Scientific records of live cetaceans were not documented until as recently as the early 1980s and present knowledge remains limited due to a lack of dedicated research.

After the International Whaling Commission (IWC) established the Indian Ocean Sanctuary in 1979, cetaceans and cetacean research in Sri Lanka became an area of focus both nationally and internationally (Ilangakoon, 2002; Leatherwood and Reeves, 1989). Further impetus was added with the convening of the first Symposium on Indian Ocean Marine Mammals, held in Colombo in 1983. In the early 1980s, the World Wildlife Fund sponsored 'Tulip Expedition' studied sperm whales (*Physeter macrocephalus*) in the waters around Sri Lanka and brought the occurrence of large numbers of sperm whales and blue whales (*Balaenoptera musculus*) close to land in northeastern waters to the attention of cetacean researchers around the world (Alling *et al.*, 1991; Whitehead, 1989; Whitehead *et al.*, 1983). Consequently, the first national marine mammal research programme in Sri Lanka was initiated by the National Aquatic Resources Research and Development Agency (NARA) in 1984. The initial focus of that programme was on large whales, but early efforts indicated that Sri Lanka was a 'hotspot' in terms of diversity and abundance of cetaceans in general. Soon the

scope of the programme expanded to include small cetaceans, as the threat posed by incidental bycatch in fishing gear was recognised early in the project. With this awareness, a further multi-pronged national research programme was initiated in 1985 with funding from the United Nations Environment Programme (UNEP). These national efforts continued for the next decade and since the mid-1990s individual researchers and international Non-Governmental Organisation (NGO) funded projects have continued sporadic research in Sri Lankan waters. Much of what is known about cetaceans around Sri Lanka today is a result of these varied projects and research efforts (Ilangakoon, 1989; 1997; 2002; 2006c; 2009; Ilangakoon *et al.*, 2000a; Ilangakoon and Perera, 2009; Ilangakoon *et al.*, 2000b; Leatherwood and Reeves, 1989; Ocean Alliance, 2003).

This paper summarises the current state of knowledge on cetaceans in Sri Lankan waters, focuses attention on current and potential threats, and highlights future research and conservation priorities.

RESULTS AND DISCUSSION

Three decades of research, even though sporadic and discontinuous, has resulted in the collection of some valuable information on cetaceans around Sri Lanka. It has also resulted in a small but growing national consciousness about an important aspect of marine biodiversity that was largely unknown before. The present state of knowledge can be examined in relation to what is known about cetaceans in these waters, the threats they face, legal aspects, conservation, research, information gaps and future priorities.

Species diversity and relative abundance

The waters off Sri Lanka are inhabited by a rich diversity of cetaceans, with apparent year-round abundance (Ilangakoon,

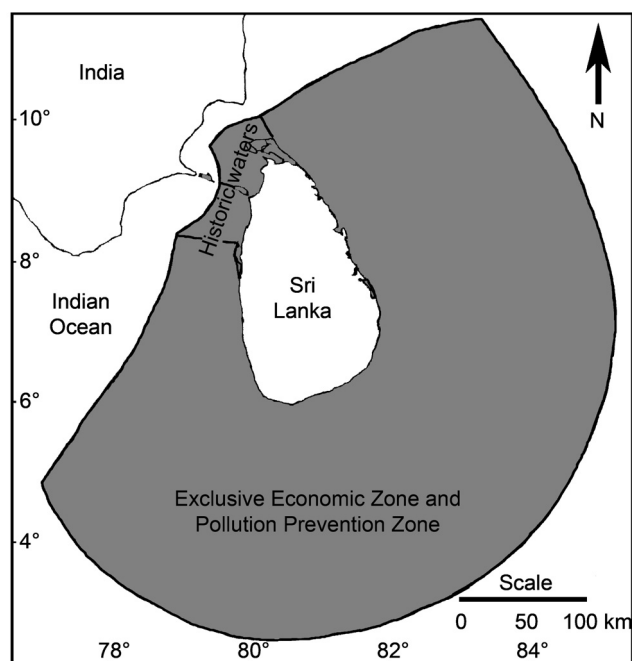


Fig. 1. Location map of Sri Lanka and surrounding waters.

1997; 2002; 2006a; 2006c; Ilangakoon *et al.*, 2000b; Leatherwood and Reeves, 1989). Based on current taxonomy 27 species of cetaceans under the two sub-orders Mysticeti and Odontoceti and placed within the six families of *Balaenopteridae*, *Physeteridae*, *Kogiidae*, *Ziphiidae*, *Delphinidae* and *Phocoenidae* have been recorded from the

waters around the island (Table 1). This species list is based on specimens obtained from strandings on the coastline (Deraniyagala, 1945; Deraniyagala, 1948; Deraniyagala, 1960; 1965; Ilangakoon, 2002; 2006c; Leatherwood and Reeves, 1989; Pearson, 1931), specimens from the fisheries bycatch and direct take (Dayaratne and Joseph, 1993; Ilangakoon, 1989; 1997; 2002; Ilangakoon *et al.*, 2000a; Ilangakoon *et al.*, 2000b; Leatherwood, 1990; Leatherwood and Reeves, 1989; Prematunga *et al.*, 1985) and sightings from offshore surveys (Afsal *et al.*, 2008; Alling, 1986; Alling *et al.*, 1991; Ballance and Pitman, 1998; Ilangakoon, 2002; 2005; 2006a; 2009; Ilangakoon *et al.*, 2000a; Leatherwood *et al.*, 1984; Leatherwood and Reeves, 1989; Ocean Alliance, 2003). It is likely that this species list is still incomplete, as dedicated research has been limited and new species continue to be added. One such example is the addition of Blainville's beaked whale (*Mesoplodon densirostris*) in 2002, based on a specimen identified in fisheries bycatch (Ilangakoon, 2002; 2003).

The continental shelf around Sri Lanka, except in the north and northwest, is relatively narrow, with deep waters being found quite close to the shore around most of the island's coastline (Wijeyananda, 1997). Cetaceans are distributed all around the island. Although no specific abundance estimates have yet been made for any species, bycatch studies (Dayaratne and Joseph, 1993; Ilangakoon, 1989; 1997; Ilangakoon *et al.*, 2000b; Leatherwood and Reeves, 1989) and limited vessel surveys (Afsal *et al.*, 2008; Bröker and Ilangakoon, 2008; Ilangakoon, 2002; 2005; 2006a; 2006c; 2009; Ilangakoon and Perera, 2009) demonstrate that the

Table 1
Cetacean species recorded in Sri Lankan waters.

Species	Based on			Key references
	Si	St	Ca	
Blue whale (<i>Balaenoptera musculus</i>)	X	X	–	Deraniyagala (1948); Leatherwood and Reeves (1989); Ilangakoon (2002)
Fin whale* (<i>Balaenoptera physalus</i>)	–	?	X	Deraniyagala (1965); Leatherwood and Reeves (1989)
Bryde's whale* (<i>Balaenoptera brydei/edeni</i>)	X	X	–	Leatherwood and Reeves (1989); Ilangakoon (2002); Herath (2007)
Minke whale (<i>Balaenoptera acutorostrata</i>)	X	X	–	Deraniyagala (1963); Leatherwood and Reeves (1989); Ilangakoon (2002)
Humpback whale (<i>Megaptera novaeangliae</i>)	X	X	–	Deraniyagala (1965); Leatherwood and Reeves (1989); Ilangakoon (2002)
Sperm whale (<i>Physeter macrocephalus</i>)	X	X	X	Deraniyagala (1965); Leatherwood and Reeves (1989); Ilangakoon (2002)
Pygmy sperm whale (<i>Kogia breviceps</i>)	–	X	X	Pearson (1931); Leatherwood and Reeves (1989); Ilangakoon (2002)
Dwarf sperm whale (<i>Kogia sima</i>)	X	X	X	Leatherwood and Reeves (1989); Ilangakoon (2002; 2006b)
Spinner dolphin (<i>Stenella longirostris</i>)	X	X	X	Phillips (1935); Leatherwood and Reeves (1989); Ilangakoon (2002)
Pantropical spotted dolphin (<i>Stenella attenuata</i>)	X	–	X	Alling (1986); Leatherwood and Reeves (1989); Ilangakoon (2002)
Striped dolphin (<i>Stenella coerulescens</i>)	X	–	X	Alling (1986); Leatherwood and Reeves (1989); Ilangakoon (2002)
Common bottlenose dolphin (<i>Tursiops truncatus</i>)	X	X	X	Phillips (1935); Leatherwood and Reeves (1989); Ilangakoon (2002)
Indo-Pacific hump-backed dolphin (<i>Sousa chinensis</i>)	X	X	X	Deraniyagala (1945); Ilangakoon (2005; 2006b)
Rough-toothed dolphin (<i>Steno bredanensis</i>)	X	–	X	Leatherwood and Reeves (1989); Ilangakoon (2002)
Common dolphin* (<i>Delphinus capensis</i>)	–	–	X	Alling (1986); Leatherwood and Reeves (1989); Ilangakoon (2002)
Fraser's dolphin (<i>Lagenodelphis hosei</i>)	X	–	X	Leatherwood and Reeves (1989); Ilangakoon (2002)
Risso's dolphin (<i>Grampus griseus</i>)	X	–	X	Alling (1986); Leatherwood and Reeves (1989); Ilangakoon (2002)
Short-finned pilot whale (<i>Globicephala macrorhynchus</i>)	X	X	X	Alling (1986); Leatherwood and Reeves (1989); Ilangakoon (2002)
Melon-headed whale (<i>Peponocephala electra</i>)	X	–	X	Leatherwood and Reeves (1989); Ilangakoon (2002; 2005; 2006b)
Pygmy killer whale (<i>Feresa attenuata</i>)	X	–	X	Leatherwood and Reeves (1989); Ilangakoon (2002; 2009)
False killer whale (<i>Pseudorca crassidens</i>)	X	X	X	Pearson (1931); Leatherwood and Reeves (1989); Ilangakoon (2002; 2009)
Killer whale (<i>Orcinus orca</i>)	X	–	X	Ilangakoon <i>et al.</i> (1992); Leatherwood and Reeves (1989); Ilangakoon <i>et al.</i> (2010)
Cuvier's beaked whale (<i>Ziphius cavirostris</i>)	X	X	X	Deraniyagala (1965); Alling (1986)
Ginkgo-toothed beaked whale (<i>Mesoplodon ginkgodens</i>)	–	X	–	Deraniyagala (1965); Moore and Gilmore (1965)
Blainville's beaked whale (<i>Mesoplodon densirostris</i>)	–	X	X	Ilangakoon (2003; 2006a)
Longman's beaked whale (<i>Indopacetus pacificus</i>)	X	X	X	Pitman <i>et al.</i> (1999); Anderson <i>et al.</i> (2006); Afsal <i>et al.</i> (2009)
Finless porpoise* (<i>Neophocaena phocaenoides</i>)	?	–	X	Phillips (1935); Leatherwood and Reeves (1989)

Notes: Si = sightings; St = strandings; and Ca = catch.

Species in relation to which there are uncertainties, revisions and clarifications in the main text are marked with an * in this table.

spinner dolphin (*Stenella longirostris*) is by far the most common species around the island. This species appears to be evenly distributed throughout both coastal and offshore waters. Other commonly encountered species of small cetaceans include the common bottlenose dolphin (*Tursiops truncatus*) and Risso's dolphin (*Grampus griseus*) (Alling, 1986; Ilangakoon, 1989; 1997; 2006a; 2006c; Ilangakoon and Perera, 2009; Ilangakoon *et al.*, 2000b; Kruse *et al.*, 1991).

A small population of Indo-Pacific humpback dolphins (*Sousa chinensis*) was identified in nearshore waters centered on the Puttalam lagoon in the northwest of Sri Lanka as recently as 2004 (Bröker and Ilangakoon, 2008; Ilangakoon, 2005; 2006a; 2006c). Although a museum specimen of a skull of this species from Mannar further to the north (Blanford, 1891) and a probable sighting in Dutch Bay during an aerial survey in the early 1980s (Leatherwood *et al.*, 1984) existed, it remained unconfirmed until regular sightings were made during cetacean surveys in 2004/05. Other small delphinids recorded as sightings (Alling, 1986; Ilangakoon, 2002; Leatherwood and Reeves, 1989; Ocean Alliance, 2003) and/or bycatch (Dayaratne and Joseph, 1993; Ilangakoon, 1989; 1997; 2002; Ilangakoon *et al.*, 2000b; Leatherwood and Reeves, 1989; Prematunga *et al.*, 1985) from around Sri Lanka include pan-tropical spotted dolphin (*S. attenuata*), striped dolphin (*S. coeruleoalba*), rough-toothed dolphin (*Steno bredanensis*), Fraser's dolphin (*Lagenodelphis hosei*) and common dolphin (*Delphinus capensis*). The original records of bycaught specimens of common dolphin were thought to be *D. delphis* are listed as such in the literature, based on knowledge available at the time (Dayaratne and Joseph, 1993; Ilangakoon, 1997; 2002; Leatherwood and Reeves, 1989). However, following the review of Jefferson and Van Waerebeek, (2002) it is more likely that these are *D. capensis tropicalis*.

Five species commonly referred to as 'Blackfish' have been recorded in Sri Lanka's waters, but none appears to be common. Short-finned pilot whale (*Globicephala macrorhynchus*), false killer whale (*Pseudorca crassidens*), pygmy killer whale (*Feresa attenuata*), melon-headed whale (*Peponocephala electra*) and killer whale (*Orcinus orca*) have been recorded as bycatch around the island (Ilangakoon, 1997; 2002; Ilangakoon *et al.*, 2000b; Ilangakoon *et al.*, 1992; Leatherwood *et al.*, 1991; Leatherwood and Reeves, 1989). Most sightings of these species around Sri Lanka have been in continental shelf waters that are not very deep (Bröker and Ilangakoon, 2008; Ilangakoon, 2002; 2005; 2006a; 2009; Ilangakoon *et al.*, 2010) though these are all species that are thought to be usually more common in pelagic waters.

Four species of Ziphiid have been recorded in strandings and bycatch (Dayaratne and Joseph, 1993; Deraniyagala, 1965; Ilangakoon, 2002; 2003; Leatherwood and Reeves, 1989) but sightings (Alling, 1986) are rare. The four species recorded are Cuvier's beaked whale (*Ziphius cavirostris*), Blainville's beaked whale (*M. densirostris*), ginkgo-toothed beaked whale (*M. ginkgodens*) and Longman's beaked whale (*Indopacetus pacificus*). Specimens of the latter species had earlier been referred to as southern bottlenose whales (*Hyperoodon planifrons*) (Alling, 1986; Dayaratne and Joseph, 1993; Ilangakoon, 2002). However, following the studies of Pitman *et al.* (1999) and Dalebout *et al.* (2003),

Anderson *et al.* (2006) referred the Sri Lankan specimens to Longman's beaked whale. Subsequently there has been a confirmed sighting of this species reported from southeast of Sri Lanka by Afsal *et al.* (2009).

Both the pygmy sperm whale (*Kogia breviceps*) and dwarf sperm whale (*K. sima*) have been recorded in low numbers (Bröker and Ilangakoon, 2008; Chantrapornsyl *et al.*, 1991; Deraniyagala, 1960; Ilangakoon, 1989; 1997; 2002; 2005; 2006a; 2006c; Ilangakoon *et al.*, 2000b; Leatherwood and Reeves, 1989; Pearson, 1931) around Sri Lanka.

Among the larger cetaceans, the sperm whale is one of the most commonly encountered and widely distributed in Sri Lankan waters. In the 1980s sperm whales were recorded as being abundant in the waters off the northeast coast, especially in association with the Trincomalee canyon, where very deep water occurs close to the coast (Gordon, 1991; Leatherwood *et al.*, 1984; Whitehead *et al.*, 1983). Subsequent surveys off the south, southeast, west and northwest of Sri Lanka have also regularly sighted this species (Ilangakoon, 2002; 2006a; 2009; Ilangakoon *et al.*, 2000b; Leatherwood and Reeves, 1989; Ocean Alliance, 2003). Sperm whale strandings are also documented from all coastal areas (Deraniyagala, 1948; 1960; Ilangakoon, 2002; 2006b).

Five species of large *Balaenopterid* whales have been recorded around Sri Lanka with blue whales and Bryde's whales being the most common and widely distributed. Blue whales were first sighted in abundance in the northeastern waters near Trincomalee canyon (Alling *et al.*, 1982; Leatherwood *et al.*, 1984; Whitehead *et al.*, 1983) during the 'Tulip Expedition' in the early 1980s. These early records were followed by sightings off the south, southeast, west and northwest (Ilangakoon, 2002; 2006a; 2009; Ilangakoon *et al.*, 2000b; Leatherwood and Reeves, 1989; Ocean Alliance, 2003) indicating widespread occurrence around the island. Blue whale strandings are also documented from all coastal areas other than the northern coastline (Deraniyagala, 1948; Deraniyagala, 1960; Ilangakoon, 2002; 2006b).

Bryde's whales have been frequently sighted all around the island by most surveys undertaken thus far (Ilangakoon, 2002; 2009; Ilangakoon and Perera, 2009; Leatherwood *et al.*, 1984; Leatherwood and Reeves, 1989; Ocean Alliance, 2003) though strandings of this species are rare (Ilangakoon, 2006b). The taxonomic status of this species in Sri Lankan waters is uncertain. Mitochondrial DNA analysis of tissue samples from a Bryde's whale killed off the west coast by a ship strike in 2003 (Herath, 2007) suggested that it was a specimen of *B. brydei*. It is possible that *B. edeni* also occurs but this remains undetermined at present.

The other baleen whales recorded are fin whale (*B. physalus*), minke whale (*B. acutorostrata*) and humpback whale (*Megaptera novaeangliae*). There is considerable uncertainty regarding the occurrence of the fin whale in the tropical northern Indian Ocean, with no recent sightings or strandings. Since occurrence in Sri Lanka is based mainly on old and poorly documented stranding records (Deraniyagala, 1948) and just one more recent net entanglement (Leatherwood and Reeves, 1989) there is a possibility that these may have been misidentifications. Minke whales appear to occur mainly in the shallower northwestern waters of the Gulf of Mannar, based on recorded strandings (Deraniyagala, 1963) and sightings

(Bröker and Ilangakoon, 2008; Ilangakoon, 2006a). Humpback whales, while not common in Sri Lankan waters, have stranded sporadically on the west coast (Deraniyagala, 1948; Ilangakoon, 2002; Leatherwood and Reeves, 1989; Reeves *et al.*, 1991) and their songs have been recorded in northwestern waters (Leatherwood and Reeves, 1989; Whitehead, 1985). These animals are probably part of the Arabian Sea population but their stock affinities are as yet undetermined.

The only species of porpoise recorded from Sri Lanka is the finless porpoise (*Neophocaena phocaenoides*). Phillips (1935) reported sightings of this species off the east coast but no details were given and there have been no reported sightings since then. One specimen in the Harvard Museum of Comparative Zoology was reported in earlier literature (Ilangakoon, 2002; Leatherwood and Reeves, 1989) as having been caught by a Smithsonian Carangid Survey team on the Wadge Bank (Indian waters), but it is catalogued in the Museum collection as coming from Kuru Nagar, Jaffna in northern Sri Lanka (Charles Anderson, pers. comm.). The collector of the specimen has confirmed (Tyson Roberts, pers. comm.) to Charles Anderson that the fresh dead specimen was purchased by him at a fish landing site in Jaffna and handed over to the Museum of Comparative Zoology.

Threats

Cetaceans throughout the world's oceans face a multitude of threats due to increasing human activities, and those around Sri Lanka are no exception. The primary threat to small cetaceans around Sri Lanka is the fishing industry. Interactions between cetaceans and fisheries were first mentioned in the literature in 1887 (Nevill, 1887) but were documented in more detail in the 1950s (Lantz and Gunasekera, 1955). Although the island has a long history of artisanal fishing, traditional nets were made of natural fibers and posed little threat to cetaceans, which could usually break through unharmed if accidentally entangled. Development of modern fisheries began in the late 1940s and with this came the adoption of synthetic fibre gillnets. These gillnets are now widely used, and accidental bycatch has become a major problem, causing the mortality of thousands of small cetaceans each year (Dayaratne and Joseph, 1993; Ilangakoon, 2002; Leatherwood and Reeves, 1989).

Although direct hunting is not as widespread as bycatch in Sri Lanka, the use of a hand-held harpoon to kill small cetaceans has been documented off the south coast (Ilangakoon, 1989; 1997; 2002; Ilangakoon *et al.*, 2000b; Leatherwood and Reeves, 1989). Within the past two decades this practice has spread to other areas on the west and southwest coast and the numbers of small cetaceans being killed annually in this manner continue to increase (Ilangakoon, 2002; 2007; Ilangakoon *et al.*, 2000b).

At present, fisheries cause both targeted and accidental mortality of cetaceans, and both forms of take are indiscriminate in relation to species, sex and size, with rare species, pregnant and lactating females and young animals being taken among others (Ilangakoon, 1989; 2007; Ilangakoon *et al.*, 2000a; Kruse *et al.*, 1991). The availability of dolphin flesh originally derived from accidental bycatch, has led to a newly acquired taste for this non-traditional

source of protein, for some parts of the human population (Breiwick and Tsunoda, 1987; Ilangakoon, 1989; 2002; 2007; Ilangakoon *et al.*, 2000a). This demand-driven market for dolphin flesh is now fed by a growing direct take (Ilangakoon, 2006c; 2007).

Some cetacean catch studies indicate that spinner dolphins comprise more than 50% of the total recorded catch in Sri Lanka (Dayaratne and Joseph, 1993; Ilangakoon, 1989; 1997; 2007; Ilangakoon *et al.*, 2000b). This high rate of bycatch is possibly a result of the association of this species with the tuna that are targeted by fishermen (Ilangakoon, 2006a). The spinner dolphin's natural behaviour of frequently bow-riding with boats also makes it an easy target for direct take using hand-harpoons (Ilangakoon, 1989; 2002; Ilangakoon *et al.*, 2000b). Spinner dolphins could therefore be at particular risk in Sri Lanka's waters, but as no population estimates are available it is difficult to assess the impact.

Sri Lanka is located on a major international shipping route across the Indian Ocean. Increased shipping traffic is a threat that affects all marine mammals, but appears to be more of a direct threat to large whales in the waters around the island. Recent stranding records show evidence of several large whales being killed by ship strikes (Herath, 2007; Ilangakoon, 2006b; 2006c), with some dead animals being pushed along by container vessels into Colombo harbour. Increased shipping traffic also increases the risk of marine pollution, both acoustic and chemical, that can be harmful to cetaceans (Norris, 1994; Sousa-Lima and Clark, 2008; Wise *et al.*, 2009).

Habitat degradation due to destructive fishing practices and pollution of coastal waters from land-based and marine-based sources also poses a threat to cetaceans in Sri Lanka. This may be particularly severe for those species that are restricted to coastal waters. Based on current knowledge, the range of the Indo-Pacific humpback dolphin in Sri Lanka is restricted to a small, nearshore area, off the northwest of the island, including the Puttalam lagoon, which is extensively used for human activities (Bröker and Ilangakoon, 2008; Ilangakoon, 2006a; 2007). This area is also currently earmarked for tourism development. Disturbance and pollution could become a threat to the long-term viability of this population. Anthropogenic impacts on other coastal species have not yet been studied, documented or assessed.

A recent and growing activity around Sri Lanka is marine tourism, notably whale and dolphin watching off the southern coast (Ilangakoon, 2009; Ilangakoon and Perera, 2009). This may become a threat to cetaceans if unregulated. Although cetaceans are legally protected in Sri Lanka, there are no specific regulations in place to control or monitor whalewatching. With only a few seasons of such activities having taken place from 2007 onwards, problems in the form of harassment of large whales have already been documented (Ilangakoon and Perera, 2009). Even if regulations were framed to control such activities under the existing law, enforcement would be difficult due to constraints faced by the authorities. These constraints include the lack of trained personnel and basic equipment, such as boats for monitoring activities at sea. Elsewhere in the world, where whale and dolphin watching is a well-developed part of the tourism industry, adverse impacts have become evident, especially

on species and populations of small cetaceans inhabiting coastal waters (Constantine *et al.*, 2004; Lusseau, 2003) and some large whales (Au and Green, 2001; Gordon *et al.*, 1992; McCauley and Cato, 2001). Such impacts have taken place even where strict regulations are in place (Garrod and Fennell, 2004) and this is now a cause for concern in Sri Lanka.

Legal status and conservation

All cetaceans are protected under national legislation in Sri Lanka. They are afforded blanket protection as a group, under the Fauna and Flora Protection Ordinance, as amended in 1993. Cetaceans are also protected under the Fisheries Act of 1996. While this legislation is in theory adequate to provide protection for all species of whales and dolphins, implementation and enforcement of these laws are negligible at present. As a result, small cetaceans continue to be landed as bycatch and direct take, while the flesh from these animals is openly sold for human consumption, in violation of existing laws (Ilangakoon, 2002; 2006c). Under both sets of legislation it is not only a punishable offence to kill or harm cetaceans, but it is also an offence to sell or have possession of any part of such an animal. Being protected under two sets of legislation also causes some confusion and loopholes in enforcement, because the penalties differ under each legislative instrument (Ilangakoon, 2006c).

Sri Lanka has an extensive network of terrestrial protected areas, but Marine Protected Areas (MPAs) have not been given priority in the protected area system of the country (Ilangakoon, 2006c). Presently there are only six MPAs around the island, four of which were created with the priority aim of protecting coral reefs, while the other two were designated for fisheries management (Perera and De Vos, 2007). Cetacean occurrence and distribution has only been assessed in one of these MPAs, and that too, long after its boundaries were demarcated (Bröker and Ilangakoon, 2008; Ilangakoon, 2006a; 2007). No protected area has yet been created for the express purpose of protecting cetaceans, or important cetacean habitat. Some cetacean species, such as the Indo-Pacific humpback dolphin that is dependent on shallow nearshore waters, could benefit from well-managed protected areas declared specifically for their protection. However, even in the existing Marine Protected Areas (MPAs), enforcement and management are almost non-existent, for reasons including lack of resources and trained personnel (Ilangakoon, 2006c).

Research gaps and constraints

There has been little dedicated, long-term research on cetaceans in Sri Lanka. During the past three decades, several short-term research projects and studies have been conducted when external funds were available and data have also been collected using platforms of opportunity when possible. Therefore, research on cetaceans has been sporadic and discontinuous making results obtained from these surveys difficult to compare. Such data are not conducive to deciphering cetacean life histories, long-term population trends or impacts of human activities. Land-based studies, such as those on fisheries bycatch and direct take, have been more extensive and thorough than boat-based surveys on live animals. This is mainly due to a lack of resources for at-sea

research surveys, which are expensive and often unaffordable for small developing countries like Sri Lanka with more immediate human development priorities. The work already undertaken has helped develop baseline data including a national species list, while temporal and spatial distribution patterns of some of the more common species are only now being unravelled through on-going work. Little however is known about the distribution of other species, migration patterns, population trends or species/populations at particular risk. Even the ecological needs of many of the coastal small cetaceans are currently not clearly understood in Sri Lanka, making it difficult to assess the impacts of human development activities.

Likewise, no molecular biological studies to determine stock affinities or population structures have ever been carried out, with species identifications having been primarily based on morphological characteristics. These research gaps have also resulted in taxonomic uncertainties, especially in relation to some of the large baleen whales. For example, although Bryde's type whales are common around Sri Lanka, the recent splitting of the species (Wada *et al.*, 2003) has created uncertainty as to which species occur(s) around the island. Likewise, there is uncertainty about the movements and population affinities of blue whales. While feeding aggregations of this species including mother-calf pairs have been recorded off the north-east (Alling *et al.*, 1991) and south (Ilangakoon, 2009) coasts, at least some animals are present in Sri Lankan waters throughout the year, raising the possibility of a resident population (Ilangakoon, 2002; 2006c; Leatherwood and Reeves, 1989).

In terms of spatial coverage, Sri Lanka's northern waters have been totally neglected in relation to cetacean research, due to the civil unrest and terrorism which prevailed in the area for the past 25 years. The uncertain security situation made the area inaccessible to researchers. While almost nothing is known about cetacean occurrence and distribution in these northern waters, the cessation of hostilities in 2009 presents opportunities for future research activities.

Research in the past three decades resulted in several publications specifically on cetaceans in Sri Lanka (Ilangakoon, 2002; Leatherwood and Reeves, 1989) and a number of scientific papers, reports and articles. These however, have not been adequate to raise awareness among management authorities, law enforcement personnel, tourism authorities or the general public within the country. There is still a large gap in awareness about cetaceans in the waters around the island, their ecological needs and conservation status, due to a dearth of information and non-scientific literature on the subject.

CONCLUSION AND RECOMMENDATIONS

There is a diversity of cetacean species, inhabiting both coastal and offshore waters around Sri Lanka. This understanding is however based on limited research. There is a need to expand the research base, and to cover more areas, including the north and offshore waters. Likewise, it is desirable that long-term and consistent research activities are initiated in order to assess population trends, ecological needs and the conservation status of cetacean populations in these waters. While it is important to carry out research on all aspects of cetaceans in Sri Lanka's waters, priority needs

to be given to management and conservation-oriented research. Information that is crucial for management purposes includes population trends and immediate and growing threats. More detailed, long-term studies on species and behavioural aspects should be undertaken, along with continuous monitoring of all cetacean related human activities, as and when resources become available.

Sri Lanka has good potential for the development of non-consumptive activities like commercial whale and dolphin watching. At present cetaceans remain a potentially important but underutilised resource that could, through careful management, become economically beneficial to the country. Such activities can benefit underprivileged coastal communities that presently view small cetaceans only as a source of food or supplementary income. Benefits of activities like whale and dolphin watching would be an incentive for these local communities to realise the value of live animals in their waters, as opposed to the exploitation that takes place at present. In developing these activities, baseline data and continuous monitoring are important for long-term sustainability.

It is also important to raise awareness regarding cetaceans and cetacean conservation within the country. Data from scientific studies should therefore be used to create awareness among management authorities as well as the general public. It is only through this kind of heightened awareness and understanding at a local level, especially among coastal communities, that long-term conservation and rational management goals can be achieved.

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Cetacean sightings and acoustic detections in the offshore waters of Sri Lanka: March–June 2003

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ABSTRACT

The Indian Ocean Sanctuary was established in 1979 in an effort to allow exploited stocks of whales to recover from whaling and to facilitate benign research. Further information is required to establish comprehensive management and conservation measures for species within these waters. The current study took place in the offshore waters of Sri Lanka in early 2003. During three research cruises conducted between 29 March and 17 June 2003 the *R/V Odyssey* covered a total track line of 4,480 km around the island resulting in 52 confirmed group sightings of 11 species from three cetacean families. As the tracklines were designed to locate sperm whales (*Physeter macrocephalus*) for tissue sampling, they accounted for the greatest number of sightings. Only two species of balaenopterids, the blue whale (*Balaenoptera musculus*) and the Bryde's whale (*Balaenoptera edeni*), were recorded with the blue whale being the most frequently sighted species. Spinner dolphins (*Stenella longirostris*) were the most dominant species in terms of numbers. Some small odontocetes such as the common bottlenose dolphin (*Tursiops truncatus*), striped dolphin (*Stenella coeruleoalba*) and Fraser's dolphin (*Lagenodelphis hosei*) were observed in mixed-species groups, while one group of melon-headed whales (*Peponocephala electra*) was seen associating with a group of sperm whales. Risso's dolphins (*Grampus griseus*) were frequently sighted throughout the research cruise, with one unusual record of a large mating group. Many sightings were made in the vicinity of the numerous submarine canyons around Sri Lanka's coastline highlighting their potential role in enhancing productivity in the offshore waters. It is concluded that Sri Lankan offshore waters hold a rich, but little surveyed cetacean fauna that warrants further studies and implementation of conservation measures to protect these populations.

KEYWORDS: INDIAN OCEAN; BLUE WHALE; SPERM WHALE; FALSE KILLER WHALE; PANTROPICAL SPOTTED DOLPHIN; SPINNER DOLPHIN; BRYDE'S WHALE; BOTTLENOSE DOLPHIN; STRIPED DOLPHIN; FRASER'S DOLPHIN; RISSO'S DOLPHIN; MELON-HEADED WHALE; MONITORING; SURVEY-COMBINED; CONSERVATION; INCIDENTAL CATCHES

INTRODUCTION

Sri Lanka lies in the heart of the Indian Ocean Sanctuary (area north of 55°S), which was proposed by the Seychelles in its first year as a member of the International Whaling Commission (IWC) in 1979 (Leatherwood and Donovan, 1991). Sri Lanka is not a member of the IWC, but marine mammals within its 200-mile Exclusive Economic Zone (EEZ) are in theory protected under national legislation – the Fauna and Flora Protection Ordinance of 1993, as well as the Fisheries and Aquatic Resources Act of 1996. However, little is known about the composition, abundance and zoogeography of cetaceans off Sri Lanka, providing a poor basis for informed conservation efforts.

The physical characteristics of the coast of Sri Lanka, which include the presence of numerous deep canyons adjacent to the coast, help create a heterogeneous environment, which provides habitats for a variety of cetacean species. While references to the whales in Sri Lankan waters date as far back as the 2nd Century, records of stranded whales were first reported in the scientific literature in 1859 (Blyth, 1859; Fernando, 1912). The *Tulip* expedition, which spent three field seasons in the waters of Sri Lanka between the spring of 1982 and the spring of 1985 has thus far been the only comprehensive cetacean research programme in the waters of Sri Lanka (Alling, 1986). Although the study was focused on the tracking and documenting of sperm whale (*Physeter macrocephalus*)

populations (Gordon, 1991), other species such as blue whales (*Balaenoptera musculus*) (Alling *et al.*, 1991) and odontocetes such as spinner dolphins (*Stenella longirostris*), spotted dolphins (*S. attenuata*), striped dolphins (*S. coeruleoalba*), Risso's dolphins (*Grampus griseus*), bottlenose dolphins (*Tursiops truncatus*), pygmy killer whales (*Feresa attenuata*), dwarf sperm whales (*Kogia sima*), rough toothed dolphins (*Steno bredanensis*), false killer whales (*Pseudorca crassidens*) and Cuvier's beaked whales (*Ziphius cavirostris*) were documented either as live or bycaught specimens (Alling, 1986). The research conducted in Sri Lanka throughout the last thirty years concludes that a total of 27 species of cetacean occur in Sri Lankan waters (Bröker and Ilangakoon, 2008; Ilangakoon, 1989; 1997; 2002; 2006a; 2006c; Ilangakoon *et al.*, 2000a; Ilangakoon and Perera, 2009; Ilangakoon *et al.*, 2000b; Leatherwood and Reeves, 1989).

As a part of a five-year global programme the 'Voyage of the *Odyssey*', collected baseline data on the distribution and concentrations of chemical contaminants in the world's oceans. Ocean Alliance's research vessel *Odyssey* entered Sri Lankan waters in the spring of 2003. While the above goals were achieved by collecting tissue samples from sperm whales, the research was designed to obtain broader information on the species composition and distribution of all other cetaceans sighted. This paper presents sighting and acoustic data of cetaceans in Sri Lankan waters made from

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on board the *Odyssey* during the months of March–June 2003 with the aim of contributing additional data on cetaceans in this little surveyed area with increasing human encroachment.

MATERIALS AND METHODS

The sighting surveys were conducted from March–June 2003 onboard the *R/V Odyssey*, a 28m ketch equipped for open ocean cetacean research. As the main aim of the cruise was to locate sperm whales, the vessel primarily followed depth contours greater than 500m and thus sightings of other cetaceans are biased to this preferred sperm whale habitat. In addition, the whole coastline was not surveyed due to security restrictions.

Visual effort

Observation watches were performed during daylight hours (0600–1845hrs) from an observation platform situated 4.6m above water level. Using their naked eye and a pair of 7 × 40 binoculars two observers would make observations 180° forward of the boat out to the horizon at 7.5km. Vessel speeds were maintained at 4–6 knots. All sightings and other relevant data collected on the cetaceans were recorded in *logger 2000 v. 2.05* (developed by the International Fund for Animal Welfare – IFAW). In addition GPS position, local time and GMT, vessel course and speed, information on sea surface temperature and weather relating to sightings ability (sea state, swell and meteorological data) and navigational data were collected half hourly. Visual observations made within 2km of the *Odyssey's* track line were approached to make positive species identifications, collect photo-identification data and estimate group size.

Acoustic effort

Acoustic detections were made using a two-hydrophone array towed at 100m from the stern via Kevlar-shielded cables. The hydrophone elements were separated by 3m and held together by a stabilising plastic mesh. Effective listening range was 2–20km depending on weather, sea conditions, vocalising species and whether the vessel was motoring or sailing. The output signal was connected to a pair of headphones and stereo speakers located in the pilothouse and monitored by the helmsperson 24 hours a day.

Two kinds of acoustic stations were conducted during the research. Every half hour and on the odd hour a 'slow to listen' was carried out, which involved slowing the boat to idle speed with the autopilot on standby and listening for 5–10 minutes on the headphones connected to the hydrophone. On the even hour an 'acoustic stop' was conducted that involved switching off the boat's engine, putting the boat in neutral gear, and listening in a similar manner with the hydrophone sunk to an average depth of 30m from the surface. Any acoustic contacts were then recorded.

Sperm whale acoustic detections

Once sperm whales were acoustically detected the boat was manoeuvred in an effort to track the clicks using the 'bearing/time' display in the software *Rainbow Click* (RBC) v. 1.03.00 (IFAW). The output signal was also interfaced with a PC desktop computer with a stereo 16-bit sound card

and RS232 data input. Input data was automatically processed in real-time using RBC, which is specifically written for the analysis of sperm whale clicks. RBC uses the time of arrival of clicks at the hydrophone to generate a bearing to the sound source.

RESULTS

During the three research legs conducted between 29 March and 17 June 2003, representative of the inter-monsoon and southwest monsoon periods, the *R/V Odyssey* covered a total track line of 4,480 km around Sri Lanka (Fig. 1). The first leg, lasting 6 days from 29 March through 3 April, followed the south coast of Sri Lanka along the 1,000m contour line to 6°36'N 82°03'E and returned to Colombo via the 2,000m depth contour (Fig. 1).

The second leg lasted from April 15 to April 30. After heading northwest into the Gulf of Mannar to 8°25'N 79°30'E, the *Odyssey* zigzagged southwards to 6°05'N 78°32'E, prior to travelling east along the 4,000m contour line. Next the *Odyssey* headed north along the east coast to 7°20'N 82°06'E before turning south and returning to Colombo via the 4,000m contour line (Fig. 1).

The final research leg of 7 days was conducted in three phases due to bad weather conditions resulting from the onset of the southwest monsoon. During this leg the *Odyssey* surveyed the Gulf of Mannar on the west coast (Fig. 1).

Visual effort

A total of 76 marine mammal group sightings of an estimated 1,943 individuals were made during the study period (Table 1, Fig. 2), 68% of which were identified to the species level. Among the 11 species identified, three were whales and eight were small cetaceans (Table 1). The most commonly sighted was the sperm whale, which accounted for 13% of all sightings (Fig. 2). However, as the track lines were primarily designed to locate this species this dominance of sperm whales is likely biased. Blue whales and Bryde's whales were the other large whale species recorded in the area (Table 1). Of the small cetaceans, Risso's dolphins were recorded most often (6 sightings) while the spinner dolphin was the most abundant in terms of number of individuals ($n = 605$). 32% of all sightings were of unidentified species, which included whales, dolphins and one beaked whale (Table 1).

Acoustic effort

1,106 acoustic stations were conducted during the 624 hours of acoustic effort (Fig. 3). Cetaceans were detected 58% ($n = 640$) of the time. The majority belonged to unidentified delphinids ($n = 514$; 46%) with the rest belonging to sperm whales ($n = 126$; 11%). The similarity in tonal and click sounds of the delphinid species rendered it difficult to acoustically identify the various species detected. As expected, blue whales were not detected using towed hydrophones since flow noise masks their low frequency signals and thus acoustic detections were biased towards odontocetes that vocalise at higher frequencies.

DISCUSSION

A total of 11 species were positively identified during this study. This represents 41% of all cetacean species ever

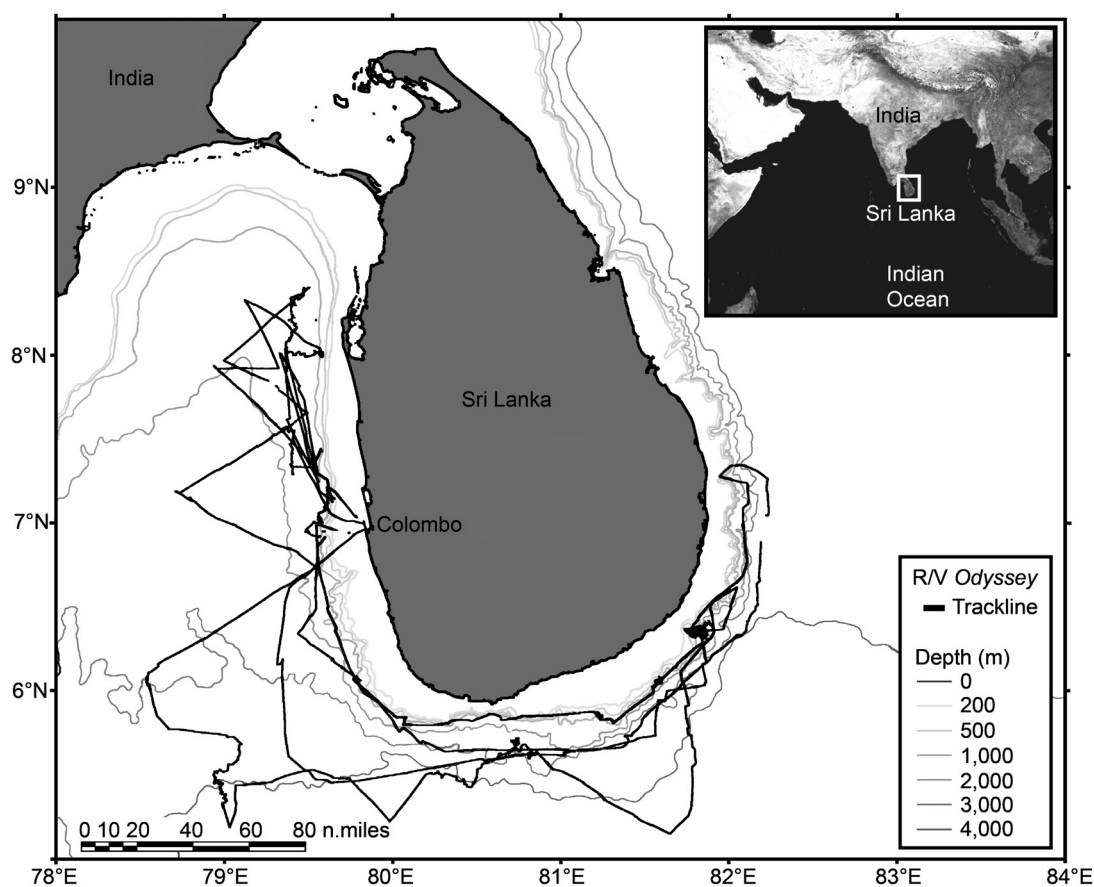


Fig. 1. Cruise track of the R/V *Odyssey* between 29 March and 17 June 2003 (black line).

recorded around the island (Ilankoon, 2002). Of those not recorded many, such as the Ginkgo toothed beaked whale (*Mesoplodon ginkgodens*), common dolphin (*Delphinus delphis*) and finless porpoise (*Neophocaena phocaenoides*) are considered rare (Ilankoon, 2002) while the records of fin whales (*Balaenoptera physalus*) within the Northern Indian Ocean (NIO) are currently being challenged (Dr R.L. Brownell Jr., pers. comm.).

Table 1

Visual sightings recorded during the three legs from 29 March to 17 June 2003.

Species (common name)	No. of sightings	Approx. no. of individuals
Family Balaenopteridae		
Blue whale	9	12
Bryde's whale	3	4
Unidentified balaenopterid	8	6
Family Physeteridae		
Sperm whale	10	128
Family Delphinidae		
Bottlenose dolphin	2	33
False killer whale	2	5
Fraser's dolphin	5	205
Melon-headed whale	3	180
Pantropical spotted dolphin	5	253
Risso's dolphin	6	153
Spinner dolphin	4	605
Striped dolphin	3	90
Unidentified delphinid	15	268
Family Ziphiidae		
Unidentified ziphiid	1	1

Family Balaenopteridae

Blue whale (Balaenoptera musculus)

This species is currently classified into three subspecies; *B. m. musculus* (northern hemisphere blue whale), *B. m. intermedia* (Antarctic or 'true' blue whale) and *B. m. brevicauda* (pygmy blue whale). The blue whale recorded around Sri Lanka is reportedly the pygmy blue whale (Alling *et al.*, 1991) albeit Brownell and Donahue (1994) proposed that the Northern Indian Ocean (NIO) populations be recognised as a separate subspecies, *B. m. indica*. These populations, like those of the NIO humpback whales reportedly have a restricted range and breed six months out of phase with the pygmy blue whales in the Southern Indian Ocean (Mikhalev, 2000), highlighting the conservation implications and significance of these subdivisions.

A juvenile blue whale was recorded off the west coast with other observations off the south east coast in close proximity to the Basses Submarine Canyon (Swan, 1983) (Fig. 2). Worldwide, aggregations of blue whales appear to be associated with areas of high productivity, particularly submarine canyons (Croll *et al.*, 2005; Rennie *et al.*, 2009). Observations of faecal matter during the present surveys also indicate that Sri Lanka represents a feeding ground for this species (Alling *et al.*, 1991; Branch *et al.*, 2007). Records show that blue whales are commonly documented around the island (Afsal *et al.*, 2008; Alling *et al.*, 1991; Ballance and Pitman, 1998; Branch *et al.*, 2007; Bröker and Ilankoon, 2008; de Silva, 1987; Ilankoon, 2002; 2006a), despite the limited sightings made during the

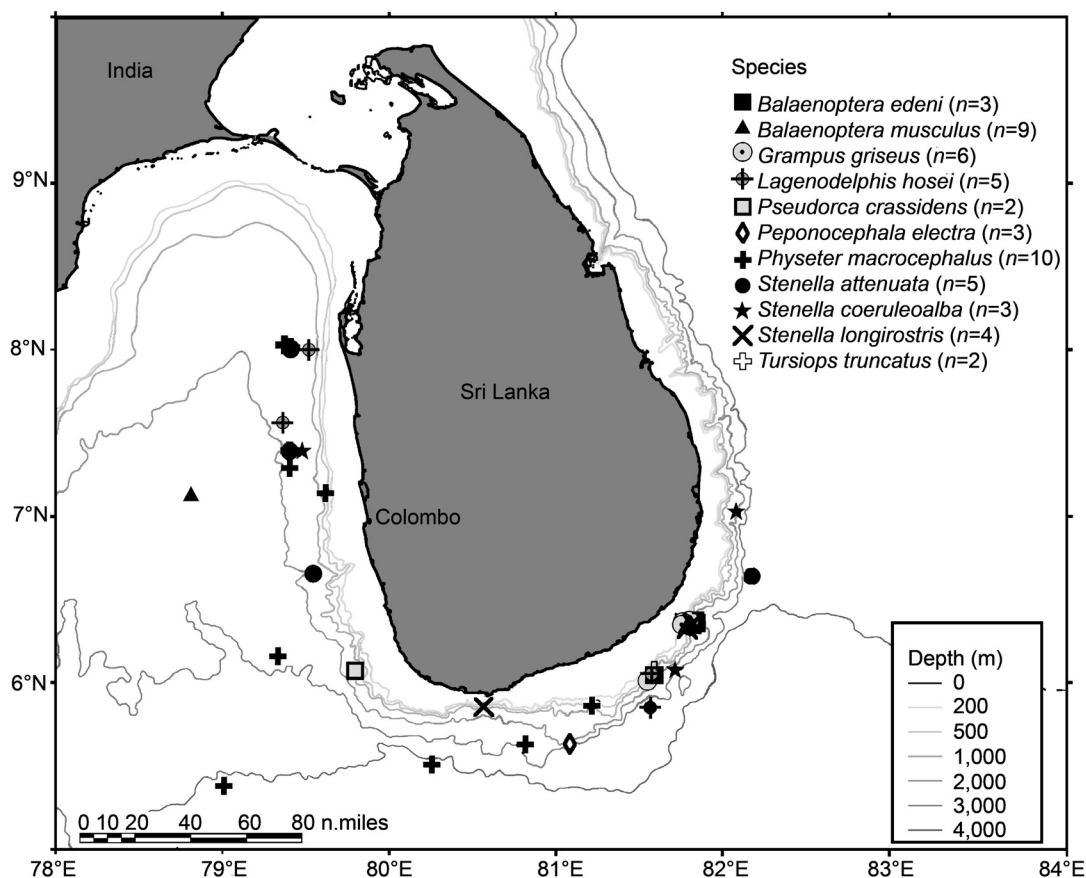


Fig. 2. Visual sightings recorded during the study period.

present study. In the past, sightings and stranding records of this species have been consistently made throughout the year (Deraniyagala, 1932; 1948; 1965; Fernando, 1912; Ilangakoon, 2002; 2006b) suggesting that the blue whales inhabiting these waters either do not undertake regular seasonal migrations, or maintain a population in this area throughout the year lending support to the theory of a NIO stock (Mikhalev, 1996; Yochem and Leatherwood, 1985).

Bryde's whale (Balaenoptera edeni)

Bryde's whales were the only other balaenopterid species observed during the surveys. All three sightings were made off the southeast coast close to the Basses Submarine Canyon (Swan, 1983) (Fig. 2). This species has been documented by all surveys undertaken around the island since the 1980s (Ballance and Pitman, 1998; Ilangakoon, 2002; 2009; Ilangakoon and Perera, 2009; Leatherwood *et al.*, 1984; Leatherwood and Reeves, 1989). However, strandings of this species have been low relative to other balaenopterids recorded in these waters (de Silva, 1987; Ilangakoon, 2006b). Evidence of Bryde's whales feeding – in the form of faecal matter – was observed several times.

Family *Physeteridae*

Sperm whale (Physeter macrocephalus)

During the Sri Lankan research leg, a total of ten sperm whale groups were sighted, comprising 128 individuals (Table 1; Fig. 2). The groups mostly consisted of sub-adults with few calves and adults being recorded. As the primary

objective of this cruise was to locate this species for tissue sampling, this high sighting rate highlights the bias in the data set. However, in general, they are commonly recorded and widely distributed in Sri Lankan waters (Afsal *et al.*, 2008; Ballance and Pitman, 1998; Bröker and Ilangakoon, 2008; de Silva, 1987; Gordon, 1987; 1991; Ilangakoon, 2002; 2006a).

The largest single group, numbering 23 individuals, was observed off the southern coast, almost directly south of Dondra head, the southern most point of the country. This sighting coincides with the Dondra Submarine Canyon (Swan, 1983) that may play a role in enhancing the productivity of this region. About 40 sperm whales were also recorded in close proximity to one another off the northwest coast, an area popular with whalers during the months of August to December in the 1840s (Wray and Martin, 1983). A dedicated survey by Bröker and Ilangakoon (2008) within the Bar Reef Marine Sanctuary also indicated the presence of this species during the inter-monsoonal period of August–September. The frequent sightings of large groups including calves in the waters off the northeast coast by Gordon (1987) may indicate that Sri Lankan waters are an important calving ground for this species.

Sperm whales were the only species acoustically identifiable to species level (Fig. 3). While the majority of acoustic detections were of 'unidentified delphinids' acoustic identification to the species level was difficult because of the similarity in the sounds produced. Therefore it is evident that there is a bias in the acoustic data towards large, easily identifiable (acoustically and visually) species.

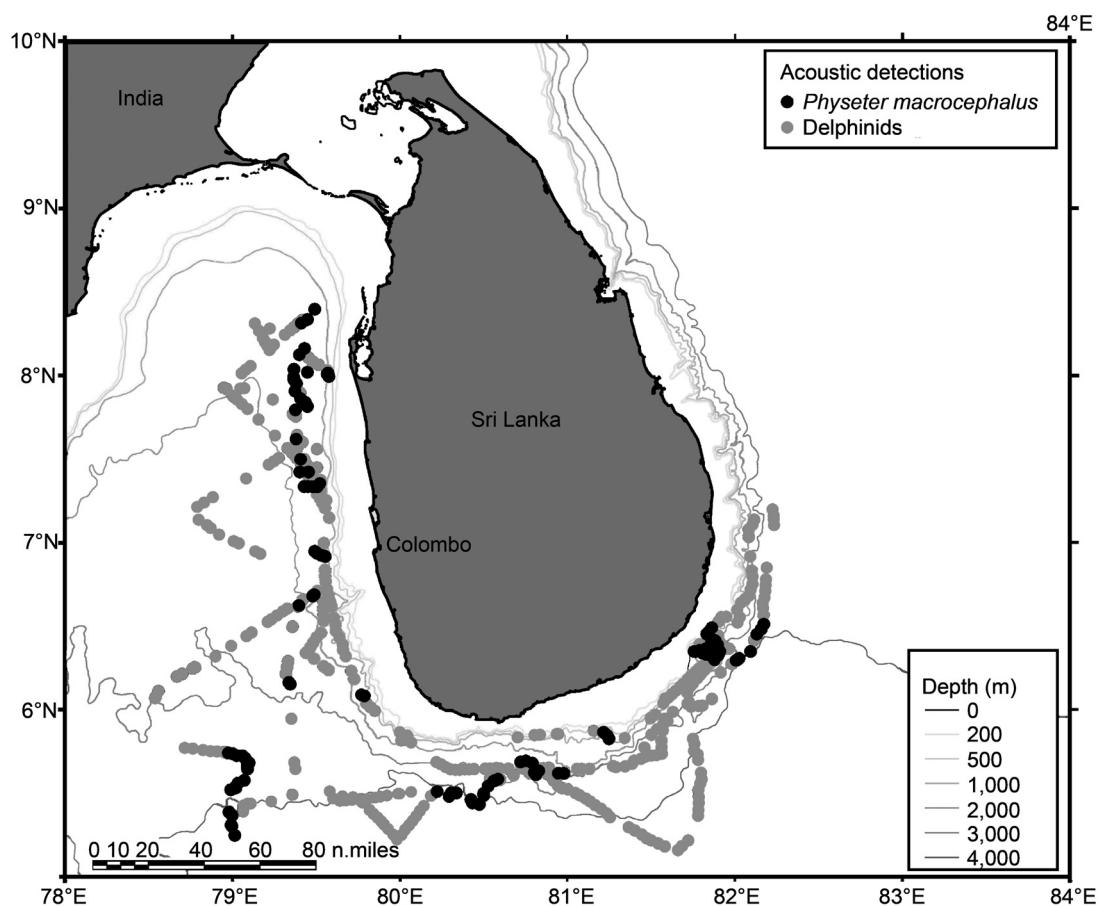


Fig. 3. Acoustic detections along *Odyssey's* track line. Sperm whales (black) and unidentified delphinids (grey).

Family Delphinidae

Bottlenose dolphin (Tursiops truncatus)

Bottlenose dolphins were sighted on two occasions, off the west coast (Table 1; Fig. 2) and in the vicinity of the Basses Submarine Canyon in waters 1,000–1,800m deep. Their large sizes coupled with the depths at which they were recorded suggest that these groups belong to the offshore form of bottlenose dolphin. The small group recorded on the west coast of the country was seen travelling with a group of approximately 100 striped dolphins. Mixed-species groups such as this have been documented in the Western Indian Ocean and other parts of the world (Ballance and Pitman, 1998; Jefferson *et al.*, 2008). A group of 30 bottlenose dolphins was sighted on the southeast coast, a somewhat uncommon sighting as most are found in groups of 20 individuals or less (Jefferson *et al.*, 2008). This species is considered common around the island as evidenced by the frequent sightings and catch data from around the coastline (Alling, 1986; 1988; Bröker and Ilangakoon, 2008; de Silva, 1987; Ilangakoon, 1997; 2002; Ilangakoon *et al.*, 2000a; Ilangakoon *et al.*, 2000b).

False killer whale (Pseudorca crassidens)

Only two of the five species of 'blackfish' recorded from Sri Lankan waters were observed during this research cruise. Although false killer whales are considered highly social and often seen in groups of more than ten individuals (Jefferson *et al.*, 2008), only two sightings of small group sizes were made during this cruise (Table 1; Fig. 2). One record was made at a depth of 1,200m off the west coast of the island which is

not unusual as they are known to spend time in relatively deep, offshore waters (Jefferson *et al.*, 2008). This species has been recorded as live observations, strandings and in bycatch from around the island in the past (de Silva, 1987; Deraniyagala, 1960; Ilangakoon, 1997; 2002; Ilangakoon *et al.*, 2000b; Leatherwood *et al.*, 1991; Leatherwood and Reeves, 1989).

Fraser's dolphin (Lagenodelphis hosei)

Five groups of Fraser's dolphins were recorded representing 205 individuals (Table 1). They were generally observed at depths exceeding 1,000m, further reinforcing the observation that they are primarily an oceanic species (Ilangakoon, 2002; Jefferson *et al.*, 2008; Leatherwood *et al.*, 1992). The majority of records from Sri Lankan waters are provided through bycatch data collected between 1985–1994 by Leatherwood and Reeves (1989), Ilangakoon (1989; 1997), Ilangakoon *et al.* (1992) and Dayaratne and Joseph (1993). Ballance and Pitman (1998) also observed this species on the west coast of Sri Lanka while one unconfirmed sighting of this species was made in the Trincomalee area, on the east coast (Alling, 1986). On two occasions, schools of Fraser's dolphins were associated with other species, specifically Risso's and Pantropical spotted dolphins. Such associations have previously been documented by Leatherwood *et al.* (1992) and Perrin *et al.*, (1994). In the Maldives and elsewhere they have also been documented associating with short-finned pilot whales (*Globicephala macrorhynchus*) and melon-headed whales (Anderson, 2005; Leatherwood *et al.*, 1992; Perrin *et al.*, 1994).

Melon-headed whale (Peponocephala electra)

One group was sighted on the west coast of the country while the other was observed off the southern coast (Fig. 2). The latter group had an estimated 165 individuals, within which ten were classified as calves. This species is known to be highly social and generally found in very deep waters (Jefferson *et al.*, 2008), as confirmed by the data collected through this survey in waters 1,800 and 4,500m deep. Historical catch records indicate that melon-headed whales were present within the Palk Strait area (Blanford, 1891). Other areas where catch data indicate their presence include the west, southwest, south and northeast coasts (Dayaratne and Joseph, 1993; Ilangakoon, 2002; Ilangakoon *et al.*, 1992; Leatherwood *et al.*, 1991). Only one other confirmed sighting record is available from within the Bar Reef Marine Sanctuary on the northwest coast (Bröker and Ilangakoon, 2008) and one unconfirmed sighting from the east coast (Alling, 1986). During these surveys one group of melon-headed whale was seen associating with sperm whales – to our knowledge, a previously unrecorded sighting.

Pantropical spotted dolphin (Stenella attenuata)

Pantropical spotted dolphins are found extensively in all oceans and are primarily oceanic animals that prefer offshore waters. During these surveys they were observed in depths between 1,500–3,200m on the west, northwest and southeast of the country (Fig. 2). In the past, this species has been observed off the northwest coast off Puttalam, the southwest and the east coasts by Leatherwood *et al.* (1984) and Alling (1986). Past catch records indicate that they also appear around the northeast, southwest and southern coasts (Dayaratne and Joseph, 1993; de Silva, 1987; Ilangakoon, 1997). In terms of numbers of individuals sighted, this species ranked second ($n = 253$).

Risso's dolphin (Grampus griseus)

Six groups of Risso's dolphins were sighted with group sizes ranging from 8–50 individuals. Past catch and sightings data indicate that this species is common and widespread around Sri Lanka (Afsal *et al.*, 2008; Alling, 1986; 1988; de Silva, 1987; Ilangakoon, 1997), however it was only documented off the southeast coast during these surveys. Risso's dolphins were generally recorded at depths between 800–2,000m confirming their preference for waters seaward of the continental shelf, steep bottom topography (Baumgartner, 1997; Kruse *et al.*, 1999) and deep oceanic waters (Alling, 1986; Ilangakoon, 2002). While most records were of traveling or bow-riding Risso's dolphins, one unusual record was also made of a large group of mating individuals. Additionally, in one instance, this species was seen closely associating with a large group of Fraser's dolphins as previously reported (Leatherwood *et al.*, 1992; Perrin *et al.*, 1994).

Spinner dolphin (Stenella longirostris)

The largest group of dolphins sighted during these surveys comprised of an estimated 500 spinner dolphins. According to Ballance and Pitman (1998) spinner dolphins were the most abundant species, in terms of numbers sighted, in the western Indian Ocean. Afsal *et al.* (2008) noted that this species was the most abundant in terms of number of

individuals in their surveys within the Indian EEZ and contiguous seas. In addition, catch records (Dayaratne and Joseph, 1993; de Silva, 1987; Ilangakoon, 1989; 1997; Ilangakoon *et al.*, 2000a; Ilangakoon *et al.*, 2000b; Leatherwood and Reeves, 1989) and sightings surveys (Afsal *et al.*, 2008; de Silva, 1987; Ilangakoon, 2002; 2005; 2006a; 2006c) show that this species is the most common cetacean in Sri Lankan waters. The presence of large active groups (Afsal *et al.*, 2008) provides evidence of their highly gregarious nature, which has been documented in the past (Ilangakoon, 2002). Three of the four groups recorded were observed in the Basses area, with one group comprising of two juveniles and five calves (Fig. 2). Alling (1986) previously documented the presence of calves during this same period. The final sighting was made along the southern coast adjoining Dondra Head, in the vicinity of a deep-water submarine canyon.

Striped dolphin (Stenella coeruleoalba)

Striped dolphins were sighted on three occasions during this study. They were consistently recorded in deep oceanic waters (1,450–4,500m) confirming their preference for these offshore habitats (Alling, 1986; Jefferson *et al.*, 2008). The largest group comprising of 50 individuals was sighted off the west coast of the country where it was sighted in a mixed group with bottlenose dolphins. A further group was observed in the Basses Canyon area on the southeast coast, with a final group on the east coast adjoining Batticaloa, the northernmost extent of this research cruise (Fig. 2). The submarine canyons located in these areas may play a role in enhancing productivity, which in turn attracts cetaceans.

Alling (1986) documented the occasional presence of calves off Sri Lanka in surveys conducted in February–April, however no calves were sighted during these surveys. Other catch (Alling, 1988; Dayaratne and Joseph, 1993; de Silva, 1987; Ilangakoon, 1997; 2002) and sighting data (Alling, 1986; Ballance and Pitman, 1998; de Silva, 1987) highlight the prevalence of this offshore species around the coast of Sri Lanka.

Conservation implications

The data gathered during the Sri Lankan research leg add support to the view that Sri Lanka is an area of high cetacean diversity, within the Indian Ocean Sanctuary (Afsal *et al.*, 2008). The narrow and very steep continental shelf/slope resulting in deep waters close to the shore and the presence of submarine canyons around the coastline (Swan, 1983) probably contributes to enhancing the productivity of the waters that attract and support the feeding requirements of the numerous species distributed around the island. This has been shown to be the case in other parts of the world (Croll *et al.*, 2005; Hooker *et al.*, 1999; Rennie *et al.*, 2009). Additionally, other physical processes such as the monsoonal regime with seasonally reversing currents that lead to water exchange between the Bay of Bengal and the Arabian Sea drive the seasonal upwelling observed in these waters that may influence the marine mammal populations by enhancing productivity. Historical records have consistently alluded to the presence of a variety of cetacean species around Sri Lanka. However, they lack comprehensive records of

population sizes due to the scarcity and logistical challenges of line transect surveys off Sri Lanka. In the absence of such data, it is not possible to evaluate the conservation status of each species.

It is nevertheless relevant to briefly identify and discuss some of the threats to the cetaceans surrounding the island. Noise pollution caused by ship traffic and seismic activity within the habitat of the whales is a cause for concern particularly because the life of the whale is largely dependent on acoustic transmission underwater (Gordon and Tyack, 2001). With the end of the civil war Sri Lanka is being opened up for oil and gas exploration. The combination of a rich cetacean fauna and increased levels of anthropogenic activity in the marine habitats of Sri Lanka call for in depth studies of abundance and habitat use of cetacean species to mitigate human encroachment responsibly. Elevated background noise levels caused by manmade noise may interfere with or prevent marine mammals from detecting sounds that are otherwise important to their survival (Richardson *et al.*, 1995).

The level of consistent shipping noise recorded from the commercial shipping lanes on the south coast, is extremely high as evidenced by the difficulties faced in tracking sperm whales acoustically in this area. The southern areas particularly around the Dondra and Basses Canyons seemingly act as important habitats for three large whale species; sperm whales, Bryde's whales and blue whales. Thus these levels of noise may lead to a reduced carrying capacity of large whales in the area due to increased masking levels, and a subsequent increase in ship strikes. The high cetacean biodiversity on the south coast of Sri Lanka is unique and calls for an array of mitigation measures if the marine life in such vital areas is to be effectively protected.

While commercial whaling has not been documented around the island, a small scale dolphin fishery using handheld harpoons is known to occur (Ilankoon, 1989; 1997; 2002; Ilankoon *et al.*, 2000b; Leatherwood and Reeves, 1989) with concerns about its increase (Ilankoon *et al.*, 2000b). Leatherwood (1994) estimated that during a two-year period spanning 1984–86 between 8,042 and 11,821 dolphins were caught annually. Bycatch levels are also high. In 1987 Alling (1988) reported that an estimated 38,000 odontocetes were entangled annually in gillnets deployed within 30 miles (48km) of the shoreline from 26'–60' vessels. More recently, Dayaratne and Joseph (1993) estimated that 5,000 small cetaceans are entangled in gillnets around the island every year.

The incidental entrapment and entanglement of cetaceans in tended and untended nets was, and continues to be of serious concern (Wallace, 1984). The modernisation of fishing gear, technical advances and a steady increase in the number of vessels harvesting fish are cited as the primary causes of such mortality. Specifically, the replacement of cotton or jute nets with synthetic monofilament gillnets by the United Nation's Food and Agriculture Organisation (FAO) in the 1950s marked the beginning of an increased take of target commercial fish and non-target marine animals, cetaceans, birds and turtles (Wallace, 1984).

The populations of cetaceans off the coast of Sri Lanka are also potentially threatened by marine pollution in the

form of organic and inorganic chemicals. Fertilisers and other such pollutants carried in the many waterways around the island that extend from the inland areas to the coastal waters, may result in reproductive failure and immune system breakdown in the marine life inhabiting Sri Lanka's waters. Current knowledge of the Bay of Bengal indicates that existing levels of toxic contaminants particularly that of PCBs and DDT, are high enough to cause severe health risks to animals through suppressed immune system complications (Prudente *et al.*, 1997; Simmonds *et al.*, 1999). More comprehensive research on the extent of pollution in the waters around Sri Lanka using sperm whales as indicator species was the primary focus of the 'Voyage of the *Odyssey*'. The results of these analyses are presented in Wise (2009) and forthcoming publications.

In conclusion, it appears that certain areas around Sri Lanka's vast coastline house a large number of species in considerable numbers. These habitats may provide good breeding, calving and/or feeding grounds for a number of the whale and dolphin species recorded. One such area is located on the southeast coast in the vicinity of the Basses Canyon. This area, which lies between Dondra and Sangamankande Point, is subject to both monsoons and is known for possessing the strongest coastal currents documented around the island (Swan, 1983). The physical attributes of this region may provide deep, cold nutrient rich water that can support sufficient krill to feed the cetaceans that aggregate here. However, the presence of heavy shipping (Kaluza *et al.*, 2010) in the adjoining shipping lanes is a potential cause for concern for the cetaceans in these waters with recent strandings showing evidence of whales being killed as a result of ship strikes (Ilankoon, 2006c). Further research assessing the importance of these waters and the effects of these varying threats is needed to develop comprehensive management plans for the effective conservation of these species.

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The need for taxonomic investigations on Northern Indian Ocean blue whales (*Balaenoptera musculus*): implications of year-round occurrence off Sri Lanka and India

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ABSTRACT

The blue whale (*Balaenoptera musculus*) is one of the most common cetaceans in the waters around Sri Lanka and in a worldwide context one of the highest low-latitude sighting rates for this species has been recorded in these waters. As genetic analyses, acoustic studies and even long-term sighting surveys for blue whales in these waters are limited, the taxonomic status and population affinities of these animals are not definitively known at present. Sighting records of this species were examined from the waters around Sri Lanka and stranding records from the coasts of both Sri Lanka and India in terms of seasonality of occurrence and it was found that the species is clearly present in these waters throughout the year. This, together with secondary data on certain morphological characteristics and behavioural anomalies, indicates that these waters are ecologically important to blue whales in the Northern Indian Ocean and questions are raised regarding the subspecific identity and population affinities of the animals in the region. It is not clear if they belong to either of the two subspecies currently recognised for the Southern Ocean and Indian Ocean region: their apparently non-migratory nature is akin to the pygmy blue whale *B.m. breviceauda*, while some morphological and behavioural characteristics are indicative of Antarctic blue whales of the subspecies *B.m. intermedia*. This raises the possibility of an entirely different or intermediate subspecies and the need to re-examine *B.m. indica* as a third subspecies in the Northern Indian Ocean. As clarifying their taxonomic status is important in the context of conservation and management, multi-disciplinary studies are urgently needed.

KEYWORDS: BLUE WHALE; NORTHERN INDIAN OCEAN; TAXONOMY; SUBSPECIES; NORTHERN HEMISPHERE

INTRODUCTION

The blue whale (*Balaenoptera musculus*) is the most common large mysticete in the waters around Sri Lanka (5°55'–9°50'N; 79°42'–81°53'E), in the Northern Indian Ocean (Ilangakoon, 2002; 2006b; Leatherwood and Reeves, 1989). Sighting rates for this species are high in these waters in comparison to other low-latitude regions of the world (Branch *et al.*, 2007). These animals are unique in that their northward movement is limited by a land barrier, namely the landmass of Asia. Primary productivity in the waters around Sri Lanka and India, as in other parts of the Northern Indian Ocean, is driven mainly by monsoon-related upwelling (Vinayachandran *et al.*, 2003; Vinayachandran and Mathew, 2003). While the ecology of the blue whale in this region is not yet clearly understood, it has been suggested that there is a resident population (Ballance and Pitman, 1998; Gordon *et al.*, 1986; Ilangakoon, 2002; 2006b; Leatherwood and Reeves, 1989) with a geographical distribution that does not overlap with those of Southern Indian Ocean populations (Branch *et al.*, 2007; Mikhalev, 2000). The breeding cycle of the Northern Indian Ocean blue whale is also out of phase with those in the Southern Indian Ocean (Mikhalev, 2000), indicating that there is no interbreeding with other populations.

Although blue whales are the largest mammals on the planet and were extensively hunted until the middle of the 20th century, little is known about their distribution and migration patterns in the Northern Indian Ocean (Branch *et al.*, 2007). The two currently recognised subspecies of blue whale in the Southern Ocean and Indian Ocean region

are the Antarctic blue whale (*Balaenoptera musculus intermedia*) and the pygmy blue whale (*B.m. breviceauda*). The Antarctic blue whale is believed to remain south of 55°S in the austral summer, while pygmy blue whales generally remain north of 54°S (Ichihara, 1966; Kato *et al.*, 1995). These two subspecies are not easy to distinguish in the field though Antarctic blue whales attain a greater total length (>30m as against 24.1m) and have a proportionately longer tail region compared with pygmy blue whales (Ichihara, 1966; Mackintosh and Wheeler, 1929). Other morphological characteristics distinguishing the two subspecies include a 'torpedo' body shape in the Antarctic blue whale as opposed to a 'tadpole' shape with a proportionately larger head in the pygmy blue whale and differences in the relative position of the central groove of the blowhole, which usually ends with the anterior margin of the nostrils in the Antarctic blue whale but extends beyond the nostrils in the pygmy blue whale (Kato *et al.*, 2001). *Balaenoptera indica* was suggested in the middle of the 19th century (Blyth, 1859) as a separate species occurring in the Northern Indian Ocean but is not widely recognised because its distinguishing features are unclear (Rice, 1998). It is currently not definitively known if the blue whales in the Northern Indian Ocean, including those around Sri Lanka and India (Fig. 1), belong to either of the two accepted subspecies.

Through an examination of sighting records from around Sri Lanka over the past three decades, combined with historical and recent stranding data from India and Sri Lanka, the ecological importance of these waters to blue whales was evaluated and questions regarding their affinity to the

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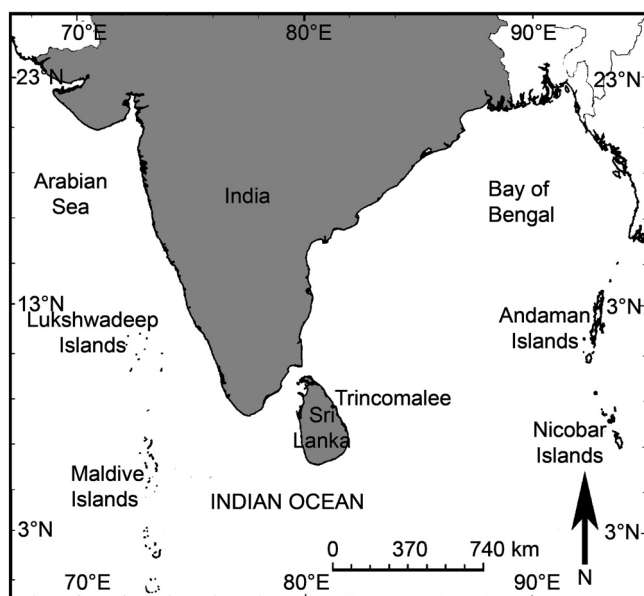


Fig. 1. Study location.

currently accepted subspecies were addressed. Limited morphological and behavioural observations were used as supporting secondary data and the possibility that the species described earlier as *B. indica* is actually a third distinct Northern Indian Ocean, subspecies of blue whale, that would merit the name *Balaenoptera musculus indica* by the rules of nomenclature was considered. Attention is drawn to research limitations in this region and the need for taxonomic evaluation of blue whales in the Northern Indian Ocean in order to close the current gaps in knowledge, which could have long-term conservation and management implications.

METHODS

All published records of blue whale strandings that occurred on the coasts of Sri Lanka and India between 1894 and 2004 were initially listed separately for the two countries by extracting them from compilations of cetacean stranding records for the two countries by Ilangakoon (2002; 2006b) and Sathasivam (2004). Subsequently these records were collated with data from more recent publications (Afsal and Rajagopalan, 2007; Baby, 1999; Jayasankar *et al.*, 2006; Krishnan *et al.*, 2004) and one comprehensive list was developed for closer examination. Strandings of this species occurring after 2004 but not yet reported in the literature were included in this analysis if the specimens had been examined personally by one of the present authors and authenticated as being blue whales.

Published blue whale sightings data are currently available in any quantifiable manner only for Sri Lanka and not for Indian waters. Therefore, all sighting records from published sources for which a clear date of sighting and area of sighting were available (Branch *et al.*, 2007; Ilangakoon, 2002; 2006a; Leatherwood and Reeves, 1989) were compiled separately from the strandings data. Unpublished but reliable sightings from cetacean survey reports (Ocean Alliance, 2003) and unpublished data from project reports of recent surveys undertaken by the first author (Ilangakoon, 2009; Ilangakoon and Perera, 2008; 2009) in Sri Lankan waters

Table 1
Blue whale sighting records from Sri Lanka.

Month/year	Area	No. of animals	Source
March 1985	Northeast	2	Leatherwood and Reeves (1989)
March 1985	Northeast	1	Leatherwood and Reeves (1989)
March 1985	Northeast	1	Leatherwood and Reeves (1989)
May 1985	Southwest	1	Leatherwood and Reeves (1989)
May 1985	Southwest	1	Leatherwood and Reeves (1989)
December 1985	Southwest	1	Leatherwood and Reeves (1989)
December 1985	South	1	Leatherwood and Reeves (1989)
December 1985	South	1	Leatherwood and Reeves (1989)
December 1985	South	1	Leatherwood and Reeves (1989)
February 1987	Northeast	1	Branch <i>et al.</i> (2007)
February 1987	Northeast	1	Branch <i>et al.</i> (2007)
February 1987	Northeast	3	Branch <i>et al.</i> (2007)
February 1987	Northeast	1	Branch <i>et al.</i> (2007)
February 1987	Northeast	1	Branch <i>et al.</i> (2007)
March 1987	Northeast	1	Branch <i>et al.</i> (2007)
March 1987	Northeast	1	Branch <i>et al.</i> (2007)
March 1987	Northeast	1	Branch <i>et al.</i> (2007)
March 1987	Northeast	1	Branch <i>et al.</i> (2007)
March 1987	Northeast	1	Branch <i>et al.</i> (2007)
May 1994	West	1	Ilangakoon (2002)
July 1994	West	2	Ilangakoon (2002)
August 1994	West	1	Ilangakoon (2002)
August 1994	West	1	Ilangakoon (2002)
April 2003	Southeast	2	Ocean Alliance (2003)
April 2003	West	1	Ocean Alliance (2003)
April 2003	Southeast	1	Ocean Alliance (2003)
April 2003	Southeast	1	Ocean Alliance (2003)
April 2003	Southeast	1	Ocean Alliance (2003)
April 2003	Southeast	1	Ocean Alliance (2003)
April 2003	Southeast	2	Ocean Alliance (2003)
June 2003	West	1	Ocean Alliance (2003)
October 2003	West	7	Branch <i>et al.</i> (2007)
August 2004	Northwest	2	Ilangakoon (2006a)
September 2008	South	4	C. Jayatilleke, pers.comm/pics
November 2008	South	1	Ilangakoon and Perera (2009)
November 2008	South	9	Ilangakoon (2009)
November 2008	South	2	Ilangakoon (2009)
November 2008	South	1	Ilangakoon (2009)
December 2008	South	1	Ilangakoon and Perera (2009)
January 2009	South	1	Ilangakoon (2009)
February 2009	South	4	Ilangakoon and Perera (2009)
February 2009	South	1	Ilangakoon (2009)
February 2009	South	2	Ilangakoon (2009)
February 2009	South	7	Ilangakoon (2009)
February 2009	South	5	Ilangakoon (2009)
March 2009	South	1	Ilangakoon and Perera (2009)
April 2009	South	2	Ilangakoon and Perera (2009)
April 2009	South	1	Ilangakoon and Perera (2009)
April 2009	South	3	Ilangakoon and Perera (2009)
April 2009	South	1	Ilangakoon and Perera (2009)

were included. All Sri Lankan sources are listed in Table 1. As these data are from several different surveys, the methodology is not standardised either in relation to observer effort or in terms of temporal and spatial coverage. Some of the published data used are from opportunistic observations made during oceanographic surveys where a single marine mammal observer was on board. While none of the surveys were undertaken purely for the purpose of observing blue whales, the majority were cetacean surveys.

Morphological data and behavioural observations on blue whales around Sri Lanka from published material (Alling *et al.*, 1991) as well as from recently concluded and yet unpublished surveys undertaken by the first author off southern Sri Lanka in the 2008/2009 field season

(Ilangakoon, 2009; Ilangakoon and Perera, 2009) were also examined as secondary or supplementary data. Given the general dearth of survey effort in the area, these recent and yet unpublished observations, though not quantifiable, were used to add important new perspectives to the analysis.

Strandings were examined in terms of stranding events and not in terms of the number of animals. Sightings were also primarily examined in terms of the number of separate sightings, but data on the number of animals in each sighting as well as observed behaviour were also investigated. Stranding data from India and Sri Lanka were examined by month of stranding. Sightings data from Sri Lanka were similarly examined in terms of time of year to determine when blue whales are present.

RESULTS

Seasonality of sightings and strandings are reported here through examination of primary data. Additionally, morphological characteristics and behavioural observations are considered as secondary data that support the primary data.

Seasonality of sightings and strandings

Data are available for 40 blue whale strandings on the coasts of Sri Lanka (17) and India (23) between 1894 and the present. Two older records from Sri Lanka were excluded as they did not include the stranding month. Sightings are detailed in Table 1 and summarised in Fig. 4. Accordingly, 38 records from the two countries were examined by month of stranding. The most significant factor to emerge is that blue whale strandings have occurred along the coasts of the two countries in all months of the year (Fig. 2). Overall numbers for the two countries peaked in May, but in general strandings are randomly distributed throughout the year. There are months for which strandings have been reported only from one country and not the other, but as the two countries are located very close to each other, the distinction was not considered to be significant. Most strandings have been of single animals, with a single record of two animals (a female and a calf) stranding at the same location on the west coast of Sri Lanka in 1984 (Ilangakoon, 2002).

A total of 51 sightings was available from Sri Lanka (Table 1). There are sightings in every month of the year (Fig. 3), with a clear peak from February–April and a smaller peak in November–December. Smaller numbers of sightings were recorded between May and October.

The majority (67%) of sightings were of single animals,

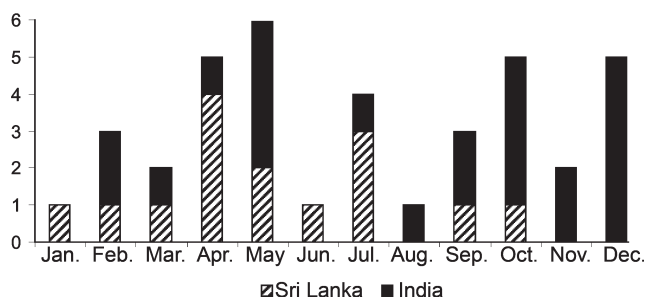


Fig. 2. Blue whale strandings in Sri Lanka and India from 1894 to the present.

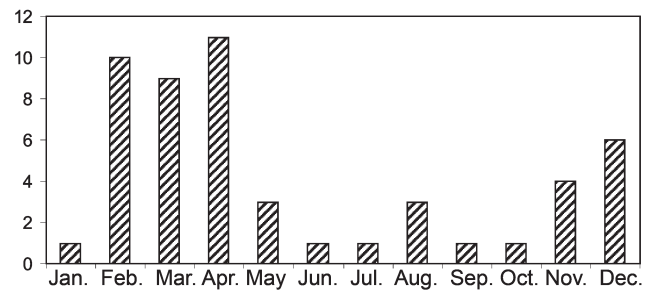


Fig. 3. Blue whale sighting events from Sri Lanka.

while 16% were of two animals together (Fig. 4). Smaller percentages of sightings were recorded for groups consisting of 3, 4, 5, 7 and 9 animals in close proximity to each other and moving in a coordinated fashion, indicating that they were part of a single unit. Most cow-calf pairs observed were among those groups.

Morphology

Kato *et al.* (2001) described three blowhole types that can be used to distinguish pygmy blue whales from Antarctic blue whales in the field: Type A, where the anterior tip of the central groove extends beyond the anterior tip of the nostril; Type B, where the anterior tip of the central groove ends at the anterior tip of the nostril and Type C, where the anterior tip of the central groove is inside the anterior tip of the nostril. During the 2008–09 field season the majority of sightings were of Type A blowholes, but at least two blue whales with a Type B blowhole were observed off southern Sri Lanka and one with a Type C blowhole was observed (Ilangakoon, unpublished data).

Several of the stranded animals from both Sri Lanka and India were close to the maximum recorded length of pygmy blue whales, 24m (Table 2), while two animals from India exceeded that length, at 26m and 28.2m respectively. The largest animal (28.2m) stranded during the austral summer (Table 2).

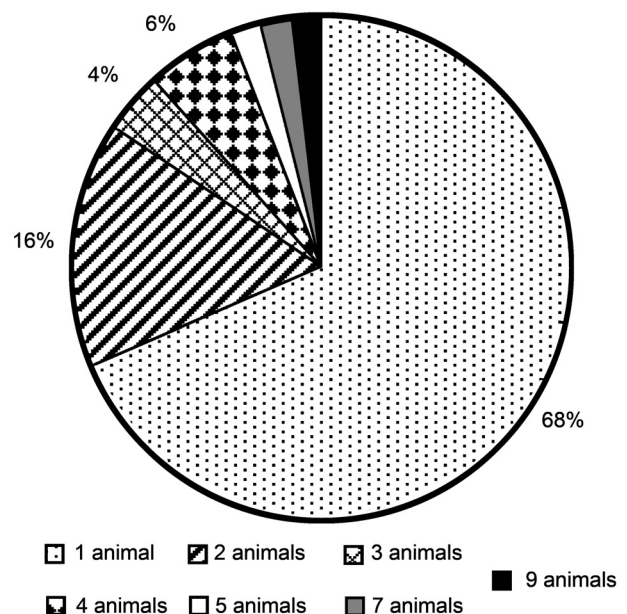


Fig. 4. Group sizes of blue whales sighted off Sri Lanka.

Table 2
Strandings of blue whales exceeding 22m in total length.

Month/year	Length (m)	Sex	Location	Source
Nov. 1927	28.2	N/A	Cochin, India.	Moses (1947)
Mar. 1939	23.7	N/A	Kathiawar, India	Moses (1947)
May 1951	22.2	N/A	Bombay, India	Chari (1951)
Dec. 1960	23.4	N/A	Gujarat, India	James and Soundararajan (1979)
May 1993	26.0	N/A	Cochin, India	James <i>et al.</i> (1993)
Jul. 1999	23.8	F	Weligama, Sri Lanka	Ilangakoon (2006)
Jun. 2009	23.3	M	Chilaw, Sri Lanka	Ilangakoon (unpublished data)

Behavioural observations

Alling *et al.* (1991) reported feeding activity in northeastern waters of Sri Lanka. Re-sighting of individually identified animals off Trincomalee in consecutive years was reported by both Leatherwood (1985) and Alling *et al.* (1991). Ilangakoon (2002) reported frequent sightings of blue whales in continental shelf waters during the south-west monsoon off the west coast of Sri Lanka in 1994. Blue whales were also observed feeding along the edge of the continental shelf between November and April during recent cetacean surveys off the south coast in the 2008–09 field season (Ilangakoon, 2009; Ilangakoon and Perera, 2009).

Feeding behavioural patterns observed in southern Sri Lanka include frequent fluke-up dives lasting 7–18 minutes, with whales resurfacing repeatedly in the same area, and subsurface skimming with occasional surface lunging. Alling *et al.* (1991) reported whales diving and resurfacing in pairs; the same synchronised diving behaviour was observed off the south coast in the 2008–09 field season (Ilangakoon, 2009; Ilangakoon and Perera, 2009), in three separate sightings. These pairs consisted of animals of similar size, as opposed to cow-calf pairs, as also observed by Alling *et al.* (1991) in the northeast.

In southern Sri Lanka the most frequently observed surfacing pattern for undisturbed adult blue whales was the appearance of the head followed by rounding of the back, showing the dorsal fin and dorsal keel with the tail stock arched and frequent lifting of the flukes 'fluking up' before submerging. The diving behaviour of mother-calf pairs off the south coast was similar in all sightings, with calves diving in synchrony with the accompanying adult, but while the adults usually raised their flukes at the onset of a dive, none of the calves raised their flukes above the surface but only displayed an arched tail stock. The dives of these cow-calf pairs were generally short in duration, lasting from 3 to 9 minutes.

Alling *et al.* (1991) noted that the blue whales seen in Sri Lanka often lifted their flukes above the water before they dived, allowing fluke photographs to be taken for identification purposes. In observations during the 2008–09 field season adult blue whales off the south coast raised their flukes out of the water on approximately 70% of dives. Only when diving hurriedly due to disturbances caused by whale watching boats did they dive without fluking up.

Acoustic recordings made in the Indian Ocean have enabled the identification of three distinct blue whale call

types (Alling *et al.*, 1991; Ljungblad *et al.*, 1998; McCauley *et al.*, 2001) attributed to pygmy blue whales because they have only been recorded north of 60°S. One of these call types was first recorded in 1984 off northeast Sri Lanka (Alling *et al.*, 1991) and subsequently the same type of call was recorded near Diego Garcia, south of the equator (McDonald *et al.*, 2006; Stafford *et al.*, 2005). However, these calls are distinct from pygmy blue whale calls recorded off Madagascar and Australia (Branch *et al.*, 2007).

Cow-calf pairs were observed off the northeastern coast of Sri Lanka in both 1983 and 1984 in February–March (Alling *et al.*, 1991). Likewise, in the 2008–09 field season cow-calf pairs were encountered off the south coast on two occasions, in November and February. A sighting on 11 November 2008 was of particular interest as two cow-calf pairs were sighted in close proximity to each other among a feeding aggregation of nine individuals (Ilangakoon, 2009). Additionally, there is a single record of a female and calf stranding together on the west coast of Sri Lanka in February 1984 (Ilangakoon, 2002).

A blue whale was observed breaching repeatedly off southern Sri Lanka and photographed from a distance by whalewatchers on 10 March 2009 (Fig. 5).

DISCUSSION

This analysis demonstrates that blue whales are present in the Northern Indian Ocean waters around Sri Lanka and India during all months of the year. While strandings in both countries are distributed throughout the year, the peaks in sightings in certain months may not reflect the actual abundance of blue whales in different months of the year, but rather the sea conditions suitable for surveys to be carried out and opportunistic observations to be made. The small numbers of sightings from May to October are certainly the result of the south-west monsoon, which prevails during this period and makes cetacean surveys off the west and south coasts of Sri Lanka nearly impossible from May to August and difficult due to unpredictable seas in September–October. Therefore, although the peaks and troughs in sightings may not be indicative of the actual abundance of animals present, they show that blue whales were present in the waters around Sri Lanka during periods when survey effort was minimal.

The general view of blue whale migration is that Antarctic blue whales remain in waters south of 55°S in the austral summer and venture northwards into temperate waters, e.g. around southern Africa, in winter, while pygmy blue whales do not migrate to Antarctic waters but generally remain north of 54°S at all times (Ichihara, 1966; Kato *et al.*, 1995). Accordingly, it has been assumed that blue whales in the Northern Indian Ocean are all pygmy blue whales (Alling *et al.*, 1991; Mikhalev, 2000; Yochem and Leatherwood, 1985) although their taxonomic status is as yet uncertain due to the extremely limited number and nature of taxonomic studies there.

Some authors have suggested that blue whales in the Northern Indian Ocean undertake a roughly east-west migration, taking advantage of monsoon upwellings around Somalia and Arabia, from May to October, dispersing eastwards and southwards towards the Maldives and Sri



Fig. 5. Breaching blue whale off southern Sri Lanka.

Lanka from November to April (Anderson, 2005; Anderson *et al.*, 1999). Previous surveys limited to the water off northeast Sri Lanka found blue whales to be rare around Sri Lanka between May and October (Alling *et al.*, 1991; Leatherwood *et al.*, 1984). Based on these reports and the seasonal presence of blue whales in the waters around the Maldives, it was suggested that the animals passing the Maldives from November to April were the same as those that appeared off the northeast coast of Sri Lanka from December to April (Anderson, 2005). Several authors have suspected that at least a part of the blue whale population in the tropical Northern Indian Ocean may remain year-round in high-productivity areas including the waters off Sri Lanka (Branch *et al.*, 2007; Ilangakoon, 2002; 2006b). Subsequent studies off the Sri Lankan west and south coasts (Branch *et al.*, 2007; Ilangakoon, 2006a; 2009; Ilangakoon and Perera, 2009; Ocean Alliance, 2003) have confirmed that blue whales are present in Sri Lankan waters at all times of the year. The east-west movement theory does not fit neatly with these findings or with the present analysis, which takes into account both live sightings and strandings. It fails to explain the high sighting rates or how and why blue whales are present around Sri Lanka and India throughout the year. Branch *et al.* (2007) suggested that the classic theory of migration patterns for blue whales may be in need of revision and we agree with this suggestion insofar as it applies to the Northern Indian Ocean population.

Based on the currently examined data an alternative hypothesis is that the blue whales in this part of the Northern Indian Ocean undertake extremely localised movements within a small but highly productive, monsoon-driven feeding area. While blue whale ecology in the Northern Indian Ocean is poorly understood, a few feeding areas have been identified in the Indian Ocean, including off Sri Lanka in the past two decades (Alling *et al.*, 1991; Gill, 2002; Ilangakoon, 2009). Sri Lanka has a relatively narrow continental shelf (Wijeyananda, 1997) and, being located just south of the Indian Subcontinent, with no landmass to its south, is affected by both the south-west and north-east monsoons (Shankar *et al.*, 2002; Vinayachandran *et al.*, 2003). The north-east monsoon affects the northeast coast of Sri Lanka and adjacent waters from November to March, the time when blue whales are abundant in the waters around Trincomalee, as reported by Alling *et al.* (1991), who suggested that these waters are an important feeding ground. The outfall of Sri Lanka's largest river, the Mahaweli, is

located in Trincomalee and deposits the largest volume of nutrient-rich waters at this time of the year, enhancing productivity in the area. Re-sightings of individually identified animals in consecutive years also indicate site fidelity to these productive feeding grounds. Vinayachandran and Yamagata (1998) suggested that a thermal dome forms east of Sri Lanka from May to July, modifying the upper ocean thermal structure and maintaining cooler water temperatures within it. As a result, cooler, nutrient-rich water is brought to the surface by open-ocean upwelling within this dome. Though no blue whale sightings have been reported from the northeastern waters during this period (Alling *et al.*, 1991), two strandings have occurred in May (Ilangakoon, 2006b) and it is possible that the whales move further offshore at this time in order to take advantage of the open-ocean upwellings created by the thermal dome. In doing so, they may have moved out of the area covered by the surveys in 1983 and 1984. Concurrently, the south-west monsoon creates upwelling and nutrient enrichment through river outfalls off the south and west coasts from May to September and localised upwelling occurs between the southern tip of India and Sri Lanka (Rao *et al.*, 2006). Both sightings and strandings have been recorded from the west, northwest, south and southeast coasts during the period of the south-west monsoon (Ilangakoon, 2002; 2006a; 2006b; 2009; Ilangakoon and Perera, 2009; Ocean Alliance, 2003). However, sightings and feeding off the south coast are not limited to this monsoon period but have also been recorded during the north-east monsoon (Ilangakoon, 2009; Ilangakoon and Perera, 2009), indicating that feeding opportunities are not limited to monsoon-related upwelling.

The implications are that blue whales around Sri Lanka and India exploit seasonal upwelling-related food sources and at least a part of the population is able to find enough sustenance there throughout the year. Ballance and Pitman (1998) have also suggested that blue whales in the Western Indian Ocean and Eastern Tropical Pacific track localised areas of high productivity to take advantage of feeding opportunities in low latitudes. Based on the data presented here it is suggested that in the Northern Indian Ocean similar feeding opportunities allow blue whales to remain in low-latitude waters around Sri Lanka throughout the year. Based on work in other low-latitude areas, it has also been suggested that certain populations of blue whales, along with other baleen whales, remain in such waters throughout the year (Bannister, 2002; Hucke-Gaete *et al.*, 2004; Mikhalev,

1997). Remaining throughout the year in areas with adequate food is also reported for Antarctic blue whales, as catch data and acoustic recordings have shown that some blue whales over-winter in Antarctic waters instead of migrating north (Harmer, 1931; Hinton, 1915; Risting, 1928; Sirovic *et al.*, 2004).

Given the above, questions arise about the taxonomic status and stock affinities of these animals. However, owing to the lack of historical data for these waters, it is not known if this year-round presence has been a constant phenomenon over the ages. If the animals have been non-migratory over long periods of time, it is even possible that they are of an entirely different subspecies from the two currently recognised for the Southern Ocean and Indian Oceans. Mikhalev (2000) concluded that the Northern Indian Ocean blue whale population is isolated and suggested further studies to determine the extent of this isolation, which is in agreement with this study. Further, a different species, *B. indica* (Blyth, 1859), described in the mid 19th century from the Northern Indian Ocean, though currently not accepted as a species, warrants re-evaluation as a possible subspecies, *B. m. indica*.

Uncertainty regarding the taxonomic status of these Northern Indian Ocean blue whales is compounded by the limited morphological observations on blue whales available from Sri Lanka and India. According to Kato *et al.* (2001), the Type B blowhole is most common in Antarctic blue whales, while Type A is peculiar to pygmy blue whales and Type C is occasionally seen in pygmy blue whales. Contrary to what may be expected, two animals sighted off southern Sri Lanka in 2008–09 had Type B blowholes. Likewise, it is accepted that the pygmy blue whale does not exceed 24.1 m in total length, while Antarctic blue whales can attain lengths of over 30 m (Branch *et al.*, 2007; Rice, 1998; Sears and Perrin, 2009). Some of the stranded animals in Sri Lanka and India were very large, with a stranding of the largest animals during early austral summer, when, according to the classic migration theory, Antarctic blue whales should be feeding in Antarctic waters. However, it has already been noted that there is uncertainty regarding the accuracy of length measurements in the earlier strandings as it is not known how the measurements were made.

Behavioural observations add weight to the possibility that the blue whales around Sri Lanka are different from blue whales found elsewhere. Surfacing patterns of undisturbed adult blue whales observed off southern Sri Lanka are different from surfacing patterns typical of pygmy blue whales, wherein the dorsal fin and keel are not always seen in the surfacing sequence (Kato *et al.*, 2001). In Sri Lanka the dorsal fin and arched tail stock were always seen and often the flukes were also seen before submergence. This is a surfacing pattern more commonly seen in the Antarctic blue whale. The frequent fluking behaviour reported from the northwest and south of Sri Lanka during different studies is not typical of blue whales described from elsewhere in the world. Similar percentages (73%) have been recorded only from the Maldives (Anderson, 2005), which is also in the Northern Indian Ocean and in close proximity to the present study area. Blue whales are generally reported to fluke up on only 18% of dives (Sears and Perrin, 2009), but in Sri Lanka this behaviour is observed on a much higher

percentage (70%) of dives. Fluking up is a behavioural characteristic that may simply represent prevailing motivation, such as feeding, and hence these observations are invoked here only as secondary data that indicate an unusual form of behaviour.

Acoustic data suggest some sort of north-south movement of animals between Sri Lanka and Diego Garcia, south of the equator and it is therefore possible that only a part of the blue whale population in the Northern Indian Ocean around Sri Lanka and India remains there throughout the year, while some animals may undertake longer migrations. This also leads to questions regarding blue whale breeding areas in the Indian Ocean because little is known about where either of the presently accepted subspecies calve or mate (Mackintosh, 1966; Stafford *et al.*, 2004). Though it has been assumed that Antarctic blue whales migrate to temperate mating and calving areas in the winter (Branch *et al.*, 2007), the actual areas where they breed in the Indian Ocean have yet to be identified (Sears and Perrin, 2009). Likewise, little is known about the breeding areas of the pygmy blue whale in the Indian Ocean. While cow-calf pairs were observed between November and February off southern Sri Lanka, similar sightings have been recorded south of Madagascar in December (Best *et al.*, 2003). Mikhalev (2000) recorded late prenatal stage fetuses and those in the early stages of development in catches from the Arabian Sea in November–December and concluded that Northern Indian Ocean blue whales have a breeding cycle six months out of phase with populations in the south. All the sightings of cow-calf pairs off Sri Lanka in different years, despite limited survey effort and the single stranding of a cow-calf pair, raise questions as to whether the waters around Sri Lanka could be a blue whale breeding area in addition to being a feeding area. Within the past decade, a blue whale feeding and nursing ground was discovered near Chile in the Pacific Ocean (Hucke-Gaete *et al.*, 2004) and the waters near Sri Lanka may be similarly important in the Indian Ocean.

It has been noted that vigorous surface activity such as raising the body high out of the water, porpoising forward and even occasionally breaching is possibly a part of blue whale mating behaviour (Sears and Perrin, 2009) and the repeated breaching behaviour of a blue whale off southern Sri Lanka in March 2009 is of interest in this respect. It has also been reported previously that lactating pygmy blue whale females with large calves are observed in the same regions where mating occurred (Mikhalev, 2000), strengthening the possibility that the waters around Sri Lanka are of importance to Northern Indian Ocean blue whales for breeding purposes. Breeding around Sri Lanka or somewhere near it could also explain blue whales' year-round presence there. It is possible that calving females remain throughout the year while other animals of the same population migrate southwards seasonally towards Diego Garcia, but not far enough to mingle with other reproductive groups.

All the foregoing indicates that the waters around Sri Lanka and India are ecologically important to blue whales and leads to the question as to whether these blue whales in the Northern Indian Ocean belong to either of the presently recognised subspecies or are of an entirely different subspecies. It is indeed curious that they display movement patterns similar to those of pygmy blue whales, certain morphological

characteristics similar to those of Antarctic blue whales and some anomalous behavioural characteristics. Another possibility, however, is that animals from two different subspecies use these waters without intermingling, as has been reported from areas in the Eastern Tropical Pacific near Chile and Peru (Berzin, 1978; Donovan, 1984; Ichihara, 1981), where blue whales are also found year-round (Palacios, 1999; Reilly and Thayer, 1990), as in the vicinity of Sri Lanka.

The present data clearly raise more questions than provide answers in relation to the taxonomic affinities of the Northern Indian Ocean blue whales. Taxonomic investigations on the blue whales around Sri Lanka and India are urgently needed. This is particularly important as populations of both the Antarctic blue whale and, to a lesser extent, the pygmy blue whale are considerably depleted due to whaling in the past (Branch *et al.*, 2004) and are recovering only slowly. The IUCN Red List of threatened species (IUCN, 1996) lists the Antarctic blue whale as 'Endangered', while the pygmy blue whale is currently listed as 'Data Deficient' due to its uncertain status. Accordingly genetic studies on Northern Indian Ocean animals should be considered a matter of priority in order to compare their genetic affinities with animals from other regions and to resolve their taxonomic status. Photo-identification could also add valuable information in relation to movement patterns and habitat use in the long-term. Likewise, little is known about what blue whales actually feed on in this area. Examination of faeces and plankton hauls in the vicinity of feeding animals should provide valuable information on feeding habits. Multi-disciplinary studies are therefore needed. Such knowledge could have implications for the conservation, long-term management and maintenance of genetic diversity of blue whales in the Northern Indian Ocean.

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Seasonal distribution, movements and taxonomic status of blue whales (*Balaenoptera musculus*) in the northern Indian Ocean

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ABSTRACT

There is a distinct population of blue whales, *Balaenoptera musculus*, in the northern Indian Ocean. The taxonomic status of these animals has long been uncertain, with debate over whether this population represents a distinct subspecies, and if so which name should apply. They have most frequently been assigned to *B. musculus brevicauda*, but are currently considered to be *B. m. indica*. The movements of these blue whales within the northern Indian Ocean are poorly understood. This paper reviews catches ($n = 1,288$), sightings ($n = 448$, with a minimum of 783 animals), strandings ($n = 64$) and acoustic detections ($n = 6$ locations); uses ocean colour data to estimate seasonality of primary productivity in different areas of the northern Indian Ocean; and develops a migration hypothesis. It is suggested that most of these whales feed in the Arabian Sea off the coasts of Somalia and the Arabian peninsula during the period of intense upwelling associated with the southwest monsoon (from about May to October). At the same time some blue whales also feed in the area of upwelling off the southwest coast of India and west coast of Sri Lanka. When the southwest monsoon dies down in about October–November these upwellings cease. The blue whales then disperse more widely to eke out the leaner months of the northeast monsoon (during about December to March) in other localised areas with seasonally high productivity. These include the east coast of Sri Lanka, the waters west of the Maldives, the vicinity of the Indus Canyon (at least historically), and some parts of the southern Indian Ocean. The data are consistent with the hypothesis that at least some of the blue whales that feed off the east coast of Sri Lanka in the northeast monsoon also feed in the Arabian Sea during the southwest monsoon. These whales appear to migrate eastwards past the north of Maldives and south of Sri Lanka in about December–January, returning westwards in about April–May.

KEYWORDS: BLUE WHALE; INDIAN OCEAN; STRANDINGS; SANCTUARIES; INCIDENTAL SIGHTINGS; MIGRATION

INTRODUCTION

'[Blue] whales are great travellers; a study of their distribution is largely a study of their migrations ...'
Mackintosh (1966)

There appears to be a distinct population of blue whales, *Balaenoptera musculus*, in the northern Indian Ocean (NIO) (Blyth, 1859; Branch *et al.*, 2007b; Yochem and Leatherwood, 1985). These whales hold a particular fascination for marine biologists for at least three reasons.

First, the taxonomy of these animals has long been unresolved. General understanding has been that they were probably pygmy blue whales, *Balaenoptera musculus brevicauda* (Ichihara, 1966) or of unknown taxonomic status (Alling *et al.*, 1991; Gordon *et al.*, 1986; Jefferson *et al.*, 2008; Rice, 1998; Yochem and Leatherwood, 1985). However, it is likely that they are a distinct subspecies, *B. m. indica* (Blyth, 1859). Certainly Blyth (1859) intended the name *indica* to apply to the common 'Great Rorqual' of the northern Indian Ocean. While there has been recent progress, uncertainty remains (Branch *et al.*, 2007b; LeDuc *et al.*, 2007; Perrin *et al.*, 2010; Rice, 1998), and we return to this issue in the Discussion.

Secondly, the NIO population of blue whales was subject to a short but intense period of illegal whaling by the former Soviet Union during 1963–1966. Catches were made during October–December (mostly November) as Soviet whaling fleets sailed south from Odessa for the Antarctic whaling

season. At least 1,294 blue whales were taken from the Arabian Sea (Mikhalev, 1996; Mikhalev, 2000). While catch data were reported in Russian in 1982 (Zemsky and Sazhinov, 1994) they were not reported to the International Whaling Commission (IWC) at the time, nor were they made more widely available until much later (Berzin, 2008; Brownell, 1995; Clapham and Ivashchenko, 2009; Mikhalev, 1996; Mikhalev, 2000; Yablokov, 1994). The extent of population depletion and subsequent recovery are unknown. Although Zemsky and Sazhinov (1994) suggested that 90% of the initial stock may have been removed in the 1960s, their data do not agree with that of Mikhalev (1996; 2000), and recent sightings rates are relatively high in comparison with other regions (Branch *et al.*, 2007b). Reeves *et al.* (2004) highlighted the understanding of NIO blue whale population status and trends as priorities for research.

The third reason why NIO blue whales are of particular interest is that they appear to be concentrated in tropical waters year-round. This is in contrast to most other populations of blue whales which have been thought to typically (though not invariably) migrate between higher latitude summer feeding grounds, and lower latitude winter breeding areas (Branch *et al.*, 2007b; Burtenshaw *et al.*, 2004; Mackintosh, 1966; Mackintosh and Wheeler, 1929). The NIO does not extend north to the Arctic. But so entrenched was the idea that blue whales follow this typical migration strategy, that for decades it was assumed that NIO

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blue whales must migrate seasonally either to the Southern Ocean (de Silva, 1987; Deraniyagala, 1960) or to the north Pacific (Mörzer-Bruyns, 1971; Slijper *et al.*, 1964).

It now appears that most of these whales are resident within the NIO. This understanding is based on year-round sightings (Branch *et al.*, 2007b; Yochem and Leatherwood, 1985) and strandings (Anderson *et al.*, 1999; Branch *et al.*, 2007b; Ilangakoon and Sathasivam, 2012). There also appear to be gaps in the distribution of blue whales to both the south and east (Branch *et al.*, 2007b; Kasuya and Wada, 1991; Miyashita *et al.*, 1995; Zemsky and Sazhinov, 1994). For example, Zemsky and Sazhinov (1994) noted an absence of reports by Soviet whalers of blue whales from the central latitudes of the Indian Ocean and Bay of Bengal 'even though these regions were frequently visited by our boats' and concluded 'that pygmy blue whales of the Arabian Sea ... form a local-subpopulation and their migration to the south is insignificant'. Although there is still some uncertainty (see Discussion), NIO blue whales also show distinctive biological characteristics, including: somewhat shorter length at sexual maturity (Branch and Mikhalev, 2008); breeding seasonality consistent with that of a northern hemisphere population (Mikhalev, 1996; 2000); low frequency of shark bite scars compared with southern Indian Ocean pygmy blue whales (Mikhalev, 2000); and unique 'Sri Lanka' call type (Alling and Payne, 1987; Alling *et al.*, 1991; McDonald *et al.*, 2006; Stafford *et al.*, 2011; Tolstoy and Bohnenstiehl, 2002).

Despite being largely restricted to the NIO, these blue whales do appear to undertake intra-regional migrations

(Anderson, 2005; Anderson *et al.*, 1999). These migrations are the main subject of this paper.

METHODS

Study area

This study concentrates on the Maldives, southern India and Sri Lanka, but encompasses all of the northern Indian Ocean, west of 100°E and north of 10°S (Fig. 1). This southern boundary marks the approximate position of the thermal equator and a major oceanographic front (Longhurst, 1998; Wyrtki, 1973). These boundaries also enclose all of the discrete grouping of blue whale records in the Arabian Sea and adjacent waters (Branch *et al.*, 2007a; Mikhalev, 1996). Although this area extends to 10°S, for convenience we refer to it here as the northern Indian Ocean (NIO).

The meteorology of this region is dominated by the monsoons. During the southwest (SW or boreal summer) monsoon, winds over the Arabian Sea are predominantly southwesterly or westerly, blowing from the Horn of Africa towards India. During the northeast (NE or boreal winter) monsoon winds over the Arabian Sea are predominantly northeasterly. Winds in the NE monsoon are generally much lighter than in the SW monsoon. The approximate durations of the two monsoons are:

SW: May to October; and

NE: December to March.

The early months of both monsoons are generally windier and wetter than the later months. As a result, those later months are sometimes referred to as the post-monsoons,

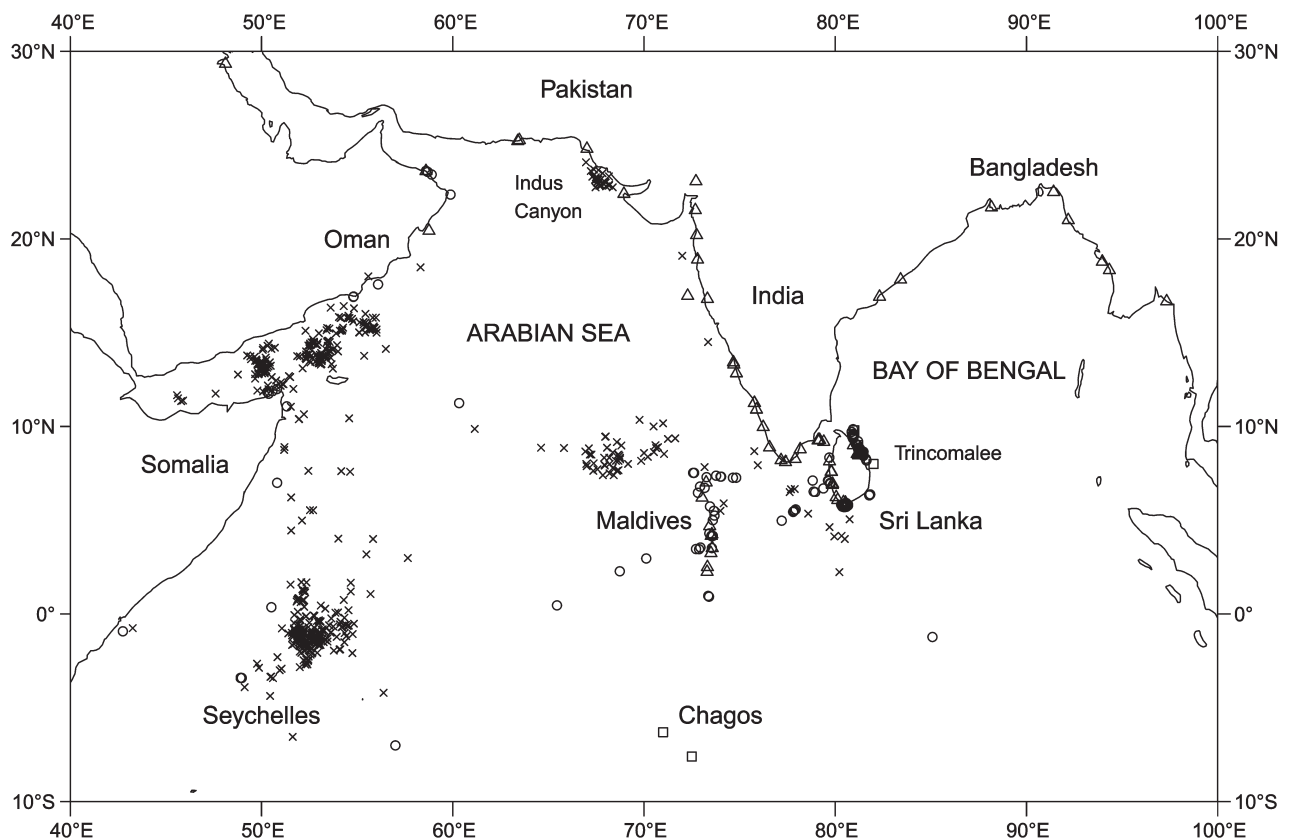


Fig. 1. Northern Indian Ocean location map, showing all known positions of blue whales catches (crosses, $n = 1,288$), sightings (circles, $n = 396$), strandings (triangles, $n = 64$) and acoustic detections (squares, $n = 6$ locations). Data from prior to 1973 are in grey; data after 1973 are in black. This figure is updated from Branch *et al.* (2007b).

although wind direction remains more-or-less constant throughout each season. April and November are inter-monsoon months, when winds are generally variable. Monsoon timings vary slightly according to latitude. Due to the Coriolis force, the NE monsoon becomes the NW monsoon south of the equator while the SW monsoon derives from the austral SE monsoon.

The oceanography of this region is strongly affected by these seasonally reversing monsoon winds (Hydrographic Office, 2007; Molinari *et al.*, 1990; Schott, 1983; Schott and McCreary, 2001; Shankar *et al.*, 2002; Swallow, 1984; Wyrtki, 1973). During the SW monsoon, the strong winds blowing across the Arabian Sea towards India force the development of a clockwise circulation and promote upwelling off the coasts of Somalia and southwest Arabia. At the eastern boundary of the Arabian Sea (i.e. along the west coast of India) this anticyclonic circulation flows southward as the West Indian Coastal Current and then eastward around the south of Sri Lanka where it joins with the Southwest (or Summer or Indian) Monsoon Current flowing into the Bay of Bengal. Within the Bay of Bengal itself, the East Indian Coastal Current flows northwards along the east (Coromandel) coast of India.

During the NE monsoon, most currents in the region reverse. The eastward flowing Southwest Monsoon Current is replaced by the westward flowing North Equatorial Current. The West Indian Coastal Current reverses, and flows northward along the southwest Indian (Malabar) coast. The East Indian Coastal Current reverses and flows southward for only a short period during the early part of the NE monsoon, being northward flowing for the remainder of the year.

In brief, throughout much of the NIO the general direction of flow in the SW monsoon is to the east, while during the NE monsoon it is to the west (although there are counter-currents south of the Equator). During the SW monsoon these currents induce significant upwellings off the coasts of Somalia, southwest Arabia and southwest India, as a result of which there are major plankton blooms in these regions at this season (Fig. 2). The upwellings, and their associated plankton blooms, die down during the NE monsoon.

Blue whale data

This study is largely based on published records of blue whale catches, sightings and strandings, most of which were previously compiled and critically scrutinised by Branch *et al.* (2007b) (see also de Silva, 1987; Leatherwood, 1986; Sathasivam, 2000). The wide-ranging study of Branch *et al.* (2007b) only briefly discussed the northern Indian Ocean, which we consider in more detail here. The Indian Ocean datasets they used (and we analyse further here) included: (a) Soviet catch data for the period 1963–66 (Mikhalev, 1996; 2000; Yablokov, 1994), which were made available by the Secretariat of the IWC; (b) published and previously unpublished records of sightings, the sources of which were summarised by Branch *et al.* (2007b: Appendix 2); (c) published and previously unpublished records of strandings, the details of which were tabulated by Branch *et al.* (2007b: Appendix 3); and (d) acoustic records, again documented by Branch *et al.* (2007b: Appendix 5).

In this study the same datasets have been used, with some

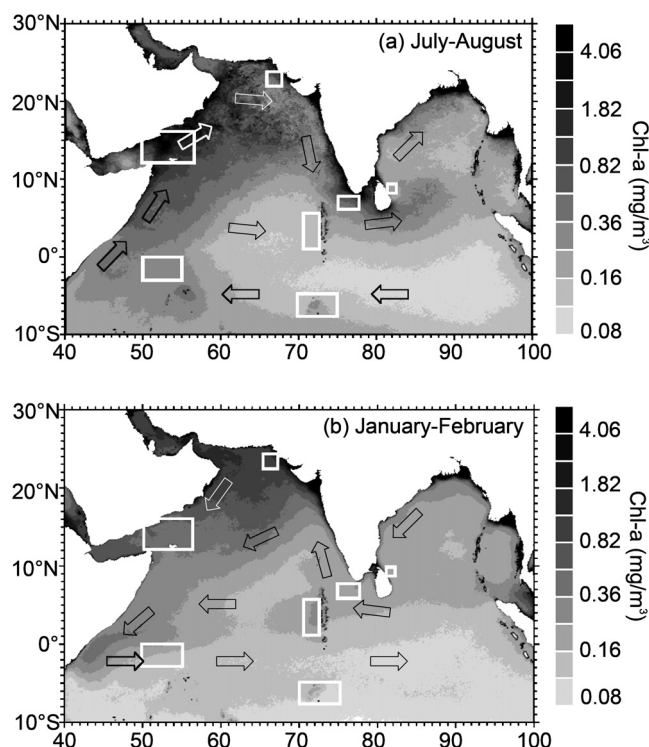


Fig. 2. Chlorophyll-a concentrations in the northern Indian Ocean (from SeaWiFS ocean colour data, see text for details). Boxes enclose areas for which seasonality of Chl-a have been estimated (see text for details). Arrows show schematic representation of major surface current directions. (a) July–August (SW monsoon). (b) January–February (NE monsoon).

additions and minor alterations (Fig. 1). Leatherwood *et al.* (1984) reported nine sightings off NE Sri Lanka in February 1983, not May as recorded by Branch *et al.* (2007b: Table A2). It should also be noted that the position of the stranding reported by Lal Mohan (1992) from ‘Paravana (12°10′N 76°30′E) near Calicut on 29-9-1988’ must be incorrect since that location is inland; here a revised position of 11°15′N 75°47′E was used, which is near Calicut. Details of ten sightings from northeastern Sri Lanka by A.D. Ilangakoon are excluded from this study; they are instead included in the review of Ilangakoon and Sathasivam (2012). Some additional information has been incorporated in this review, including the published records of sightings by Carwardine (1994) and Afsal *et al.* (2008), and of one stranding each by Jayasankar *et al.* (2006) and Gray (2009).

New and previously unreported observations have also been collected. Two sightings from NE Sri Lanka in March 2004 have been included, which were supported by photographs (Chris Paporakis, pers. comm.). One of the authors (RCA, accompanied on two days by AA) visited southern Sri Lanka in April 2007, specifically to test the hypothesis that blue whales were migrating past at that time of year. Observations were made from Dondra Head (the southernmost point of Sri Lanka) on 18 and 19 April, and from a boat at sea off Dondra on 21 and 23 April 2007. Subsequently, records of blue whale sightings off southern Sri Lanka up to April 2009 were collected. These were based on observations by two of the authors (RCA and AA, $n = 117$ encounters), together with logbook records of a commercial boat tour company (Mirissa Watersports, $n = 96$ encounters), after the crew had received training in species identification

Table 1

Sightings of blue whales on voyages between India, Sri Lanka and Maldives. SW monsoon May to October. NE monsoon December to March.

Dates	Vessel	Start	Finish	Blue whales (Sightings (individuals))		Source
				ID definite	ID uncertain	
Jan. 3–5, 2004	<i>Hebridean Spirit</i>	Colombo	Malé	0	0	RCA (unpublished data)
Jan. 11–13, 2007	<i>Hebridean Spirit</i>	Colombo	Malé	0	0	RCA (unpublished data)
Jan. 13–14, 2002	<i>Hebridean Spirit</i>	Cochin	Malé	0	0	RCA (unpublished data)
Jan. 14–16, 2007	<i>Hebridean Spirit</i>	Malé	Cochin	0	0	RCA (unpublished data)
Jan. 15–17, 2002	<i>Hebridean Spirit</i>	Maldives	Galle	0	0	RCA (unpublished data)
Jan. 16–17, 2003	<i>Hebridean Spirit</i>	Cochin	Malé	0	0	RCA (unpublished data)
Jan. 18–20, 2003	<i>Hebridean Spirit</i>	Maldives	Galle	0	0	RCA (unpublished data)
Jan. 18–21, 2007	<i>Hebridean Spirit</i>	Kannur	Galle	0	0	RCA (unpublished data)
Jan. 20–25, 1983	<i>Tulip</i>	Colombo	Colombo	0	0	Alling <i>et al.</i> (1983)
Jan. 23–24, 2003	<i>Hebridean Spirit</i>	Colombo	Vilinjani	0	0	RCA (unpublished data)
Jan. 27–28, 2002	<i>Hebridean Spirit</i>	Cochin	Malé	0	0	RCA (unpublished data)
Jan. 31, 2003	<i>Hebridean Spirit</i>	Vilinjani	Colombo	0	0	RCA (unpublished data)
Feb. 4–5, 2003	<i>Hebridean Spirit</i>	Galle	Malé	0	0	RCA (unpublished data)
Feb. 9–12, 1982	<i>Tulip</i>	Arabian Sea	Colombo	0	0	Alling <i>et al.</i> (1982)
Feb. 12–17, 1984	<i>Tulip</i>	Malé	S of Sri Lanka	0	0	Alling <i>et al.</i> (1984)
Feb. 21–23, 2007	<i>Hebridean Spirit</i>	Colombo	Malé	0	0	RCA (unpublished data)
Feb. 19–Mar. 16, 1982	<i>Tulip</i>	Colombo	Colombo	0	0	Alling <i>et al.</i> (1982)
Mar. 29–30, 2003	<i>Odyssey</i>	Colombo	S of Sri Lanka	0	0	Ocean Alliance (2003)
Apr. 2–4 2003	<i>Odyssey</i>	S of Sri Lanka	Colombo	0	0	Ocean Alliance (2003)
Apr. 19–20, 1983	<i>World Discoverer</i>	Colombo	Malé	0	0	Leatherwood <i>et al.</i> (1984)
Apr. 21, 1995	<i>Malcolm Baldrige</i>	8° Channel	Colombo	1 (1)	1 (2)	Ballance <i>et al.</i> (1996)
Apr. 26–30, 2003	<i>Odyssey</i>	S of Sri Lanka	Colombo	0	0	Ocean Alliance, (2003)
Apr. 28, 1995	<i>Malcolm Baldrige</i>	Colombo	8° Channel	0	0	Ballance <i>et al.</i> (1996)
May 14–16, 2003	<i>Odyssey</i>	Colombo	Colombo	0	0	Ocean Alliance (2003)
May 23–27, 2003	<i>Odyssey</i>	Colombo	Colombo	0	0	Ocean Alliance (2003)
Jun. 16–17, 2003	<i>Odyssey</i>	Colombo	Colombo	1	0	Ocean Alliance (2003)
Jun. 16–21, 1995	<i>Malcolm Baldrige</i>	8° Channel	Malé	8 (13)	9 (12)	Ballance <i>et al.</i> (1996)
Nov. 6–27, 1983	<i>Tulip</i>	S of Sri Lanka	Malé	0	0	Whitehead <i>et al.</i> (1983)
Dec. 4–13, 1983	<i>Tulip</i>	Malé	Malé	0	0	Whitehead <i>et al.</i> (1983)

Table 2

Sightings of blue whales during crossings from Maldives to Seychelles (Malé to Mahé). January–February is NE monsoon (NW monsoon south of the Equator); April is inter-monsoon.

Dates	Vessel	Blue whales (Sightings (individuals))		Source
		ID definite	ID uncertain	
Jan. 21–25, 2004	<i>Hebridean Spirit</i>	2 (3)	0	RCA (unpublished data)
Feb. 21–24, 2010	<i>Discovery</i>	1 (2)	1 (1)	RCA (unpublished data)
Feb. 24–28, 2007	<i>Hebridean Spirit</i>	1 (2)	0	RCA (unpublished data)
Apr. 21–24, 1983	<i>World Discoverer</i>	1 (4)	0	Leatherwood <i>et al.</i> (1984)

from the senior author. In addition, RCA has completed a number of crossings between Maldives, Sri Lanka and India, and between Maldives and Seychelles on vessels of opportunity (cruise ships) during which cetacean watches were maintained. Details are summarised in Tables 1 and 2.

In total, records of 1,288 blue whale catches, 448 sightings, 64 strandings, and acoustic detections from 6 locations in the NIO have been compiled. For 296 sightings, numbers of individuals were recorded ($n = 631$, mean = 2.1 individuals per sighting). For the remaining 152 sightings, numbers of individuals were not available. Thus for all 448 sightings a minimum of 783 (631+152) individuals were recorded (note that sightings were compiled over several decades and there are known to have been some re-sightings, so this does not imply anything about population size). Only 396 sightings were recorded with location data of sufficient accuracy to be included in Figs 1 and 4.

Acoustic studies have demonstrated a unique call type for NIO blue whales. This was first recorded off Sri Lanka

(Alling and Payne, 1987; Alling *et al.*, 1991) and subsequently around the Chagos Archipelago (Tolstoy and Bohnenstiehl, 2002). Until recently such studies were of limited value for understanding seasonality of NIO blue whales. However, while this paper was in review, an analysis of two years' monitoring of blue whale calls around Chagos became available (Stafford *et al.*, 2011) and is of great relevance for this investigation.

A number of limitations in our data can be noted. In particular, it was not possible to standardise effort. Our analyses of sightings are therefore based on raw incidental data, not sightings rates. This can clearly lead to problems of interpretation. We do, however, have an understanding of seasonal variations in sea conditions (which affect sightability), and some knowledge of relative amounts of effort between subregions and seasons. For example, in both Sri Lanka and the Maldives, more sightings effort has been conducted in the NE monsoon (which is relatively calm, particularly in its later months) than in the generally much

rougher SW monsoon. Further analysis as more detailed data become available is planned to address this shortfall. It should also be noted that blue whale strandings depend, among other things, on wind and current directions, which in this region vary dramatically with the seasons.

Chlorophyll-a concentrations

Blue whales feed almost exclusively on euphausiids. Although some information is available (e.g. Brinton and Gopalakrishnan, 1973), the seasonal distribution of euphausiids in the tropical Indian Ocean is not known in sufficient detail to be of direct use in this study. We have therefore used chlorophyll-a concentrations (hereafter Chl-a) as a proxy for blue whale food. There are limitations to this approach (e.g. that Chl-a may not adequately reflect primary productivity; that deep chlorophyll maxima may not be adequately accounted for in the data used; that there will be lags between Chl-a and euphausiid abundance peaks; and that there may be spatial and temporal variability in any relationship between Chl-a and euphausiid abundance). Nevertheless, in the absence of more appropriate data, this approach does allow a first investigation of some factors influencing the seasonal distribution of blue whales in the NIO, and highlights areas for further study.

Chl-a concentrations were quantified using monthly composites of the 9-km Level 3 SeaWiFS data, from the NASA Goddard Space Flight Center (GSFC) Distributed Active Archive Center (DAAC) (McClain *et al.*, 1998). The reflectance values of the original data files were converted into chlorophyll concentrations using the empirical algorithm of O'Reilly *et al.* (1998). The dataset used is for the period September 1997 to December 2008, which represents a sequence of 136 monthly images. For the purposes of this study we have estimated the seasonal distribution of Chl-a for seven areas (Fig. 3), which are delineated in Fig. 2 and have the following boundaries:

Gulf of Aden:	12°–16°N, 50°–57°E
North of Seychelles:	0°–3°S, 50°–55°E
Indus Canyon:	22°–24°N, 66°–68°E
West of Maldives:	1°–6°N, 70.5°–72.5°E
West of Sri Lanka:	3°–12°N, 74°–80°E
NE Sri Lanka:	8°–9°N, 81°–82°E
Chagos:	5°–8°S, 70°–75°E

The choice of box boundaries was to some extent subjective, and there is undoubtedly scope for further refinement in future studies. Areas where blue whales were suspected to be feeding seasonally were investigated, not necessarily where they might be transiting. Thus, in the case of the Maldives our box was placed west of the atoll chain (where blue whales may be feeding during the NE monsoon), not over it (where the larger number of blue whale records are suspected to be of transiting animals). In the case of the western Arabian Sea, this is a vast area, and we have used the Gulf of Aden as a representative subarea, where many blue whales were caught by Soviet whalers (Fig. 1).

RESULTS

Seasonal distributions of Chl-a for seven areas within the NIO are given in Fig. 3. Both the Gulf of Aden and the

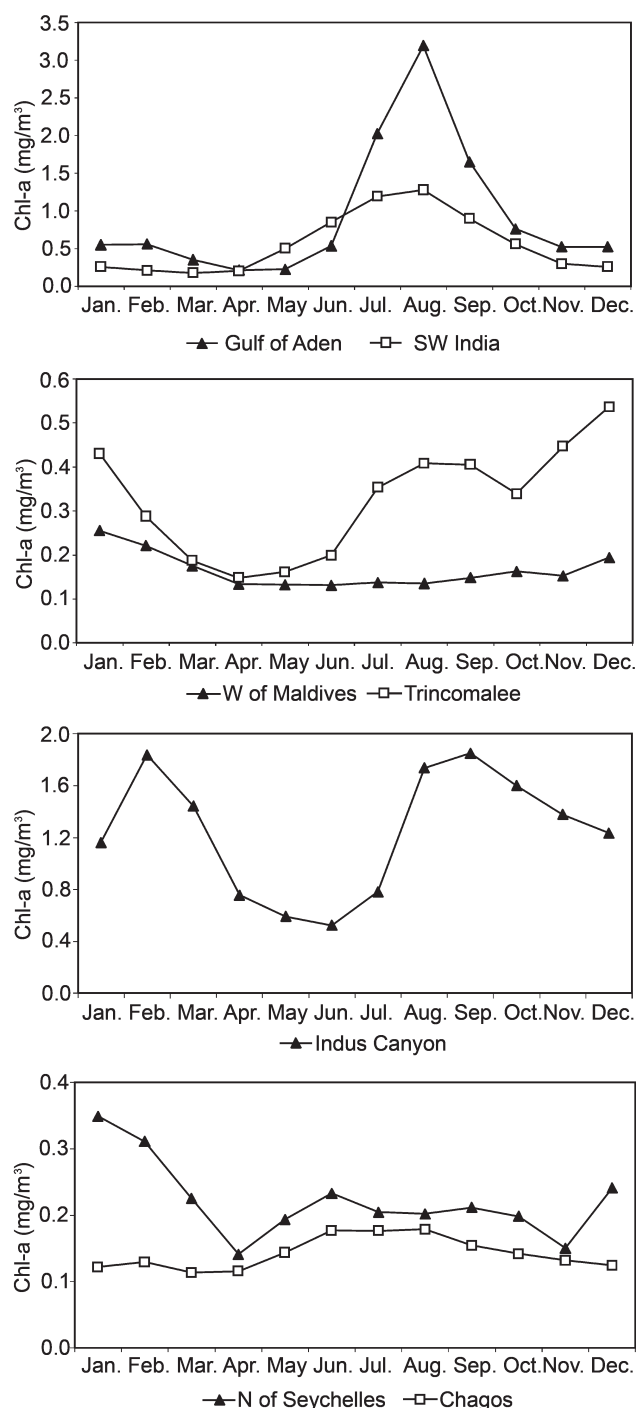


Fig. 3. Seasonal distribution of Chl-a in seven areas of the northern Indian Ocean, corresponding to boxes in Fig. 2 (from SeaWiFS data, see text for details; note different scales). SW monsoon May to October, NE monsoon December to March.

waters off SW India showed marked seasonality in Chl-a, with clear peaks from about June or July to September, i.e. during the southwest monsoon. In contrast, the area west of Maldives, which has much lower Chl-a overall, shows a peak in Chl-a during December to March, i.e. during the northeast monsoon season. Trincomalee on the east coast of Sri Lanka also shows a peak in Chl-a during the northeast monsoon season, notably during November to January. A second, lesser peak in August–September is likely associated with the increased run-off from the Mahaweli River during the latter part of the southwest monsoon. The Indus Canyon area shows distinctly bimodal seasonality, with Chl-a peaking in

February–March (northeast monsoon) and August–October (latter part of southwest monsoon). The former is possibly associated with local upwelling, the latter with increased run-off from the Indus River associated with the SW monsoon. The area north of Seychelles also shows bimodal seasonality in Chl-a, with peaks in both monsoon seasons. In the waters around the Chagos, Chl-a is low year-round, with a slight seasonal peak in June–August. These results are consistent with existing knowledge (e.g. Banse, 1968; Currie *et al.*, 1973; Darbyshire, 1967; Longhurst, 1998; Smith and Bottero, 1977; Smith, 1984; Vinayachandran *et al.*, 2003).

All available blue whale records from the NIO are mapped in Fig. 1. The same records are presented by month in Fig. 4. All Soviet catches were made during Oct–Dec, so by themselves they tell us relatively little about seasonal distribution. Most captures were actually made in November, which is the transition between the SW and NE monsoons.

Seasonality of blue whale sightings within different areas of the NIO is summarised in Fig. 5 (note that sightings are not available from all areas, so fewer areas are included in Fig. 5 than in Fig. 3). In addition, summaries of blue whale sightings made during crossings between Maldives, India and Sri Lanka are presented in Table 1. Blue whales were recorded in both June voyages, and during one of five April voyages, but not during other months. The relatively large number of crossings between mid-January and March suggest that blue whales are not common in this area at this time.

Summaries of blue whale sightings made on four crossings between Maldives and Seychelles are presented in Table 2. Blue whales were recorded west of Maldives on each of the four crossings, suggesting that they are relatively common in this area, at least during January–April. Numbers of sightings of blue whales on a standard transect off Trincomalee, Sri Lanka, completed by the RY *Tulip* during 1983–84 are summarised in Table 3 (Alling *et al.*, 1991; Whitehead, 1983).

Strandings within the NIO are clearly concentrated in the South Asian region (Fig. 1). Further west, around the Horn of Africa and on the southern Arabian coast, there is only one stranding reported. Numbers of strandings in different parts of South Asia (Pakistan and NW India; SW India and west Sri Lanka; Maldives; and Bay of Bengal) are summarised by month in Table 4, and by time period (before and after the period of Soviet whaling) in Table 5. The area including the coasts of Pakistan and NW India had the highest number of recorded strandings up to 1967, but has had no reported strandings since that time. In contrast, the Maldives (where there was almost no cetacean research conducted prior to the 1980s) had no recorded blue whale strandings prior to 1985. Seasonality of strandings by area is illustrated in Fig. 6.

DISCUSSION

Blue whales are the largest animals that have ever lived, and have particularly high prey demands, which they meet by seeking out areas of particularly high productivity (Croll *et*

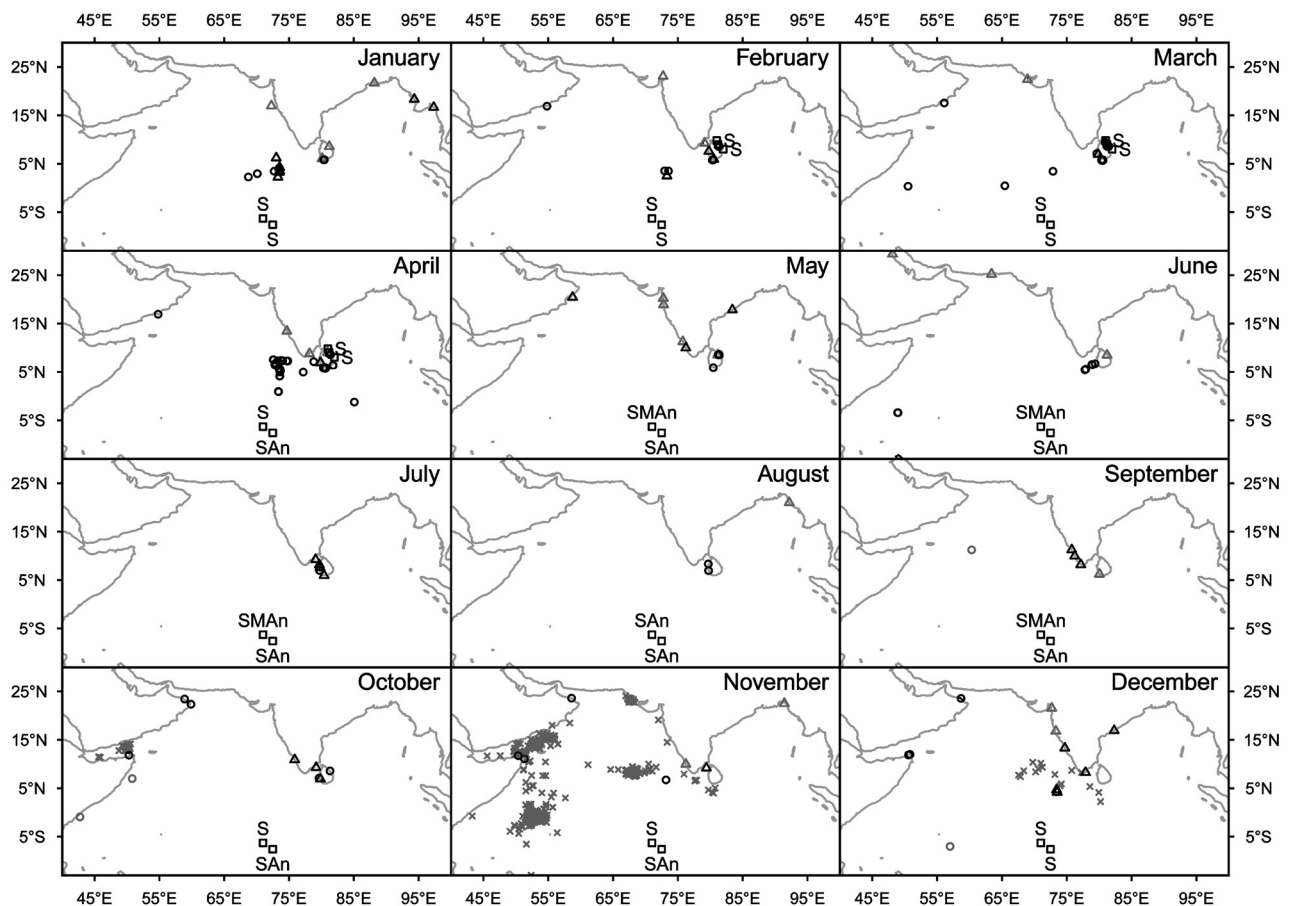


Fig. 4. Monthly distributions of blue whales in the northern Indian Ocean, showing all known positions of catches (crosses), sightings (circles), strandings (triangles) and acoustic detections (squares: S = Sri Lankan, M = Madagascan, An = Antarctic call types). Data from prior to 1973 are in grey; data after 1973 are in black. This figure is modified from Branch *et al.* (2007b). SW monsoon May to October, NE monsoon December to March.

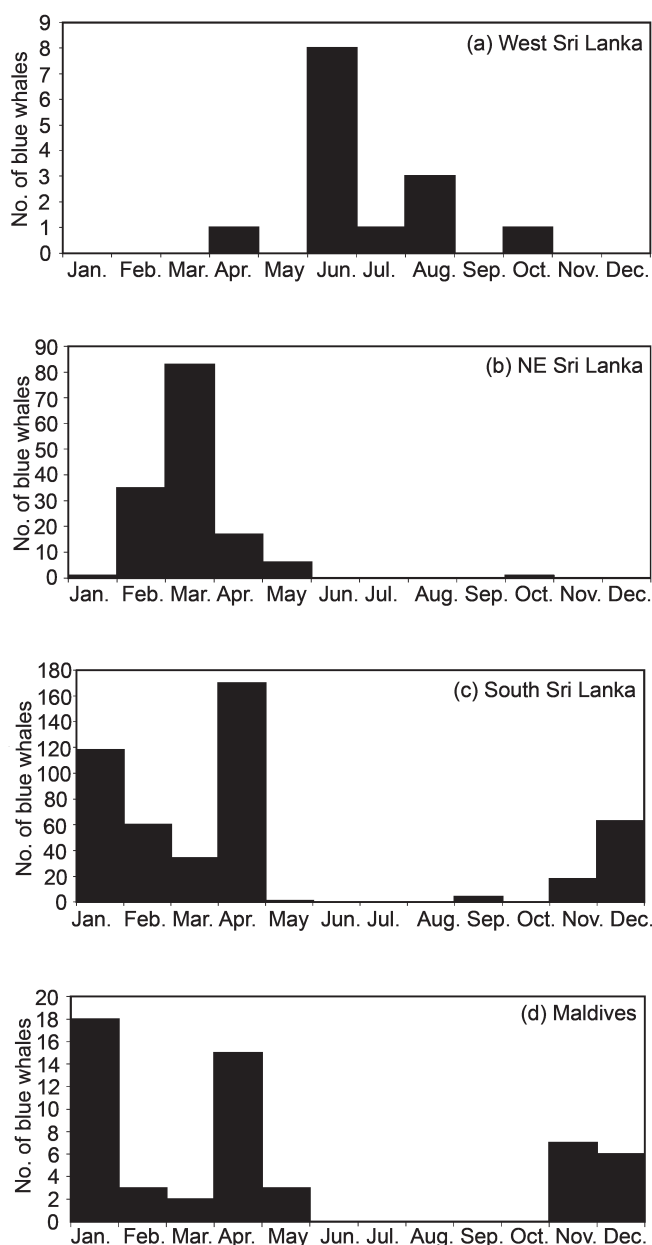


Fig. 5. Sightings of blue whales by month from four areas in the central Indian Ocean: (a) west Sri Lanka, $n = 14$ blue whales; (b) NE Sri Lanka, $n = 143$; (c) south Sri Lanka, $n = 468$; and (d) Maldives, $n = 54$. SW monsoon May to October, NE monsoon December to March.

et al., 2000). We assume that NIO blue whales are no different from other blue whales in this regard, and that they too search out areas of especially high krill (euphausiid) abundance. Since regions of high productivity within the NIO shift with the seasonally changing monsoon currents, we expect that the whales do so too. Indeed some intra-regional movements have already been proposed (Anderson, 2005; Anderson *et al.*, 1999).

Strandings of blue whales in south Asia (Maldives, India and Sri Lanka) are known to occur year-round, but peak during the NE monsoon (Anderson *et al.*, 1999). This well-defined seasonal pattern of strandings implied that there were migrations within the NIO, with many blue whales moving away from south Asia during the SW monsoon. It was suggested that the most likely destination for these whales was the western Arabian Sea (Anderson *et al.*, 1999). In that area, during the SW monsoon, intense upwelling off the

Table 3

Sightings of blue whales along standard transect off Trincomalee (NE Sri Lanka) from RV *Tulip*. SW monsoon May to October, NE monsoon December to March.

Date	No. blue whales	Source
12 Mar. 1983	7	Alling <i>et al.</i> (1991)
22 Mar. 1983	23	Alling <i>et al.</i> (1991)
24 Apr. 1983	0	Alling <i>et al.</i> (1991)
16 Oct. 1983	1	Whitehead <i>et al.</i> (1983)
2 Nov. 1983	0	Whitehead <i>et al.</i> (1983)
22 Feb. 1984	3	Alling <i>et al.</i> (1991)
11 Mar. 1984	7	Alling <i>et al.</i> (1991)

coasts of Somalia and Arabia, combined with open-ocean Ekman pumping, promote a major plankton bloom (Figs 2a and 3); in fact, this is one of the most productive seasonal upwellings in the world ocean (Longhurst, 1998).

Sightings of blue whales in the Maldives were subsequently shown to occur during November to April (Anderson, 2005). Noting that blue whales occurred off the NE coast of Sri Lanka near Trincomalee during December to April (Alling *et al.*, 1991; Leatherwood *et al.*, 1984; Leatherwood and Reeves, 1989), Anderson (2005) suggested that if at least some of these 'Sri Lankan' whales also fed in the Arabian Sea during the SW monsoon, then they must migrate via the Maldives in April. As he noted, Ballance and Pitman (1998) had previously documented the presence of numerous blue whales in the Eight Degree Channel at the northern end of the Maldives archipelago in April.

In brief, the hypothesis tested and developed here is that many blue whales in the NIO feed in the highly productive zones associated with the major SW monsoon upwellings, namely in the western Arabian Sea and off the SW coasts of India and Sri Lanka. With the change of monsoon in October–November, these upwellings stop, and within a month or so zooplankton concentrations also dissipate. The blue whales then disperse more widely in the NIO to seek out other, more localised zooplankton concentrations.

Thus it is predicted that: during the SW monsoon blue whales occur in the upwelling areas of the NW Arabian Sea and off the SW coast of India and west coast of Sri Lanka; during the NE monsoon blue whales occur in other (smaller or lesser) productive areas within the NIO; and that during intermonsoon periods, peaks in abundance of blue whales occur in intermediate areas as the whales pass between SW and NE monsoon feeding grounds. In the absence of detailed information on the seasonality of euphausiids throughout the NIO, we use satellite-derived Chl-*a* data to provide a rough proxy for blue whale forage. We note that it may take one or two months for zooplankton biomass to build up at the beginning of each upwelling season, while later in the season zooplankton grazing may keep Chl-*a* low even while production is high. Blue whale abundance may therefore lag peak Chl-*a* (Croll *et al.*, 2000).

Blue whales in the western Arabian Sea

A major prediction of this migration hypothesis is that blue whales should be found in areas of high productivity in the western Arabian Sea (including the Gulf of Aden) during the SW monsoon season. This is a wide area, and we have used

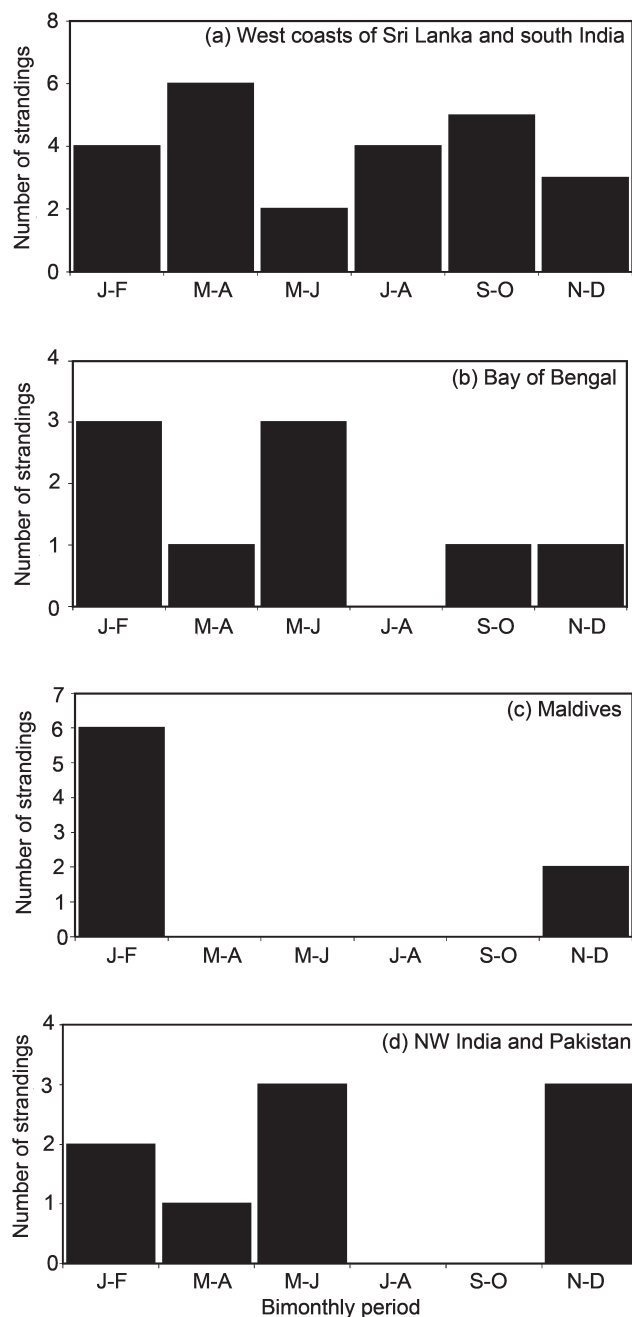


Fig. 6. Strandings of blue whales by bimonthly period from four areas in the central Indian Ocean: (a) west Sri Lanka and SW India; (b) Bay of Bengal; (c) Maldives; (d) NW India and Pakistan. SW monsoon May to October, NE monsoon December to March.

the Gulf of Aden as a representative subarea for Chl-a analysis, while recognising that finer scale analyses are desirable. Within the Gulf of Aden there is a very marked peak in Chl-a during July–September (Fig. 3). Elsewhere in the Arabian Sea, ocean colour data (which we have analysed but do not present here) show that in the Somali Basin, Chl-a increases rapidly in May as upwelling starts, and peaks during June–September. For the western Arabian Sea as a whole it is therefore likely that zooplankton (and thus potentially blue whale) abundance is high from about June–July to October or November.

Blue whales are certainly present in the western Arabian Sea from at least September to November. Nineteenth century sperm-whalers recorded blue whales on the ‘Arabian

Table 4

Strandings of blue whales by month for major regions in south Asia. (Southwest = west coasts of Sri Lanka and south India, south of 12°N. Northwest = coasts of Pakistan and west India, north of 12°N). SW monsoon May to October, NE monsoon December to March.

	Bay of Bengal	Southwest	Northwest	Maldives	Total
Jan.	3	1	1	5	10
Feb.	0	3	1	1	5
Mar.	0	1	1	0	2
Apr.	1	5	0	0	6
May	2	2	2	0	6
Jun.	1	0	2	0	3
Jul.	0	4	0	0	4
Aug.	0	0	0	0	0
Sep.	1	3	0	0	4
Oct.	0	3	0	0	3
Nov.	0	2	0	0	2
Dec.	1	1	2	2	6
Total	9	25	9	8	51

Table 5

Strandings of blue whales before and after 1967, for major regions in south Asia. (Southwest=west coasts of Sri Lanka and south India, south of 12°N. Northwest=coasts of Pakistan and west India, north of 12°N).

	Bay of Bengal	Southwest	Northwest	Maldives	Total
1967 and before	9	10	11	0	30
1968 and after	5	15	0	8	28
Total	14	25	11	8	58

grounds’ during September to November, with one vessel reporting ‘lots’ off the Somali coast at 7°N 50°49’E in October 1888 (Wray and Martin, 1983). Slijper (1962, p.337) noted ‘records made by some Dutch officers who reported, *inter alia*, that on 23rd September, 1953, 30–50 Blue Whales in groups of 3–4 were seen over an area of about ten square miles in the Indian Ocean (at 11°15’N and 60°13’E)’. The wording of this report is similar to that of Mörzer Bruyns (1971), suggesting that he may have been one of the Dutch officers concerned. Mörzer Bruyns (1971: chart 14) also recorded blue whales off the Horn of Africa and Socotra during September–November, as well as noting that he ‘encountered them [during] several southern winters well east of Socotra Island and also in the Gulf of Aden’. In the 1960s, Soviet whalers took many blue whales in the Gulf of Aden and western Arabian Sea during October–November (Figs 1 and 4; Mikhalev, 1996; 2000; Yukhov, 1969).

There is, however, little evidence for the predicted presence of blue whales in the western Arabian Sea, or indeed in most other parts of the NIO, during the period June–August. Some authors have taken this as evidence that blue whales must move out of the NIO at this time of year (e.g. de Silva, 1987; Deraniyagala, 1960; Slijper *et al.*, 1964). However, a more satisfactory explanation is that sea conditions are simply too rough during June–August for any useful cetacean surveys. Several researchers have noted the difficulties of observing cetaceans in the northwest Indian Ocean at this time of year, when the SW monsoon is at its most fierce (e.g. Ballance and Pitman, 1998; Eyre, 1995; Reeves *et al.*, 1991; Small and Small, 1991). Small and Small (1991) carried out no survey work at all off the Indian

Ocean coast of Somalia during June–September. Eyre (1995) provided data which illustrate the impact of poor observing conditions during this season. She rounded the Horn of Africa in late June 1993. During the 9-day period 26 June to 4 July inclusive, there were 8 days with an average sea state of 4 or more, and one day with an average sea state 2. During those 8 rough days, she recorded just two sightings. In contrast, on the one calmer day she recorded no less than 15 cetacean sightings. There is clearly a need for more work during the rough SW monsoon season; remote technologies such as satellite tracking and acoustic monitoring may provide the means to do so.

It is predicted that there should be relatively few blue whales in the open Arabian Sea during the NE monsoon season, when productivity is relatively low (Figs 2b and 3). There is indeed a lack of offshore sightings during January to April (Fig. 4). Sea conditions are usually relatively calm throughout much of this season, when there are reports of sperm whales for example (Ballance and Pitman, 1998; Mörzer-Bruyns, 1971; Slijper *et al.*, 1964). So one might expect at least some reported sightings of blue whales if they were present in numbers. Nevertheless, in the absence of sighting effort data, this cannot be taken as unequivocal evidence for a lack of blue whales. Furthermore, it is possible that some blue whales may loiter in coastal locations with elevated productivity during the NE monsoon season.

In contrast to some other areas within the NIO (see below), there is no evidence for blue whale seasonality in the western Arabian Sea from strandings data. Indeed, there is only a single reported stranding from the entire Arabian and NE African coasts, in Oman in May (Figs 1 and 4). The reason(s) for this dearth of strandings are unknown, but there are at least two possibilities. One is that there may be less likelihood of strandings being detected and reported on these sparsely populated coasts than on the much more densely populated coasts of the Indian subcontinent. A second possibility is that blue whale strandings along the western seaboard of the Arabian Sea may be genuinely rare. In support of this second possibility, we note that fairly comprehensive reports of strandings from Oman had until very recently failed to report a single blue whale stranding (Collins *et al.*, 2002; Gray, 2009). The hypothesis presented here predicts that blue whales are most abundant off these coasts during the SW monsoon when the prevailing winds are offshore; the likelihood of any dead whale being cast ashore must therefore be greatly reduced. In addition it seems likely that many of the blue whales in this region occur some distance offshore (Fig. 1), again reducing their chances of stranding. One reason for this may be that the inshore upwelling food chains along these coasts are dominated by copepods and myctophids rather than euphausiids (Smith *et al.*, 1998; Smith, 1984).

SW India and west of Sri Lanka

During the SW monsoon, the long-shore flow of the West Indian Coastal Current induces upwelling along the SW coast of India, promoting a major phytoplankton bloom there (Banse, 1968; Darbyshire, 1967; Longhurst, 1998). This productive water is carried southward around the west and south coasts of Sri Lanka, where it is enhanced by further upwelling (Vinayachandran *et al.*, 2003), before being

transported eastwards with the SW Monsoon Current into the Bay of Bengal (Figs 2a and 3).

It is predicted that blue whales should occur in this area of high productivity from about June to October or November and be absent or rare when productivity is low during the NE monsoon season (Fig. 3). Again, rough weather during the SW season has restricted opportunities for cetacean surveys. Nevertheless, the limited data from the west coast of Sri Lanka (Fig. 5a) do support this prediction: there are no reported sightings of blue whales during the calm NE monsoon, despite several surveys at that season (Table 1; Leatherwood and Reeves, 1989), but there have been sightings during the rough SW monsoon. Ilangakoon (2002) ‘frequently encountered’ blue whales off the west coast of Sri Lanka during May to October 1994, and there have been other reports of sightings in June (De Vos *et al.*, 2011; Asha de Vos, pers. comm.) and August (Bröker and Ilangakoon, 2008). Further offshore, in the area between Sri Lanka, India and Maldives, blue whales were recorded in June by Ballance and Pitman (1998), and in November by Soviet whalers (Fig. 4).

It is also predicted that blue whales travelling between the western Arabian Sea and the east coast of Sri Lanka (see below) should transit this area in about December and April–May. While there have been no offshore sightings in December (Table 1), there were several catches by Soviet whalers in November and December (Fig. 4). It is, however, not clear if these catches were of blue whales which had spent the SW monsoon feeding locally or whales which were in transit from the western Arabian Sea. And with only a single offshore sighting from April (Table 1 and Fig. 4), this is one area where additional survey work and/or satellite tracking will be required to test our predictions.

Despite this shortcoming, there is further support for this migration hypothesis from strandings records. Strandings on the west coasts of southern India and Sri Lanka occur more-or-less year-round (Fig. 6a, Table 4). But the peaks in strandings during April and July (Table 4) are consistent with our predictions of relatively large numbers of blue whales transiting this area in April, and feeding offshore in July. The relatively small numbers of strandings (just two) in December and early January, at a time when relatively large numbers of blue whales are predicted to be transiting the area is also to be expected, since winds and currents are offshore at this season. This is reflected in the peak of strandings downstream, in the Maldives, during December and early January (see below).

NE Sri Lanka

It has been known for many decades that blue whales occur off the east coast of Sri Lanka. Deraniyagala (1948) noted that blue whales ‘commonly occur off Ceylon’ [Sri Lanka] and that ‘the abundance of whales and their proximity to land off Trincomalee is particularly noteworthy’. Even earlier, Blyth (1859) considered the ‘great rorqual’ to be relatively common throughout the northern Indian Ocean, including Sri Lanka, and specifically noted the stranding of a whale which he apparently considered to be *B. indica* ‘in Ceylon ... near Trincomali’. However, the presence of blue whales there was largely forgotten by marine biologists, and their rediscovery in February 1983 came as something of a surprise (Whitehead, 1983; 1989).

The seasonality of these blue whales has not been well established, since most fieldwork has been conducted during the NE monsoon season (e.g. Alling *et al.*, 1991; Carwardine, 1994; Leatherwood *et al.*, 1984). However, Gunaratna *et al.* (1985) stated that blue whales were seen off Trincomalee from November to mid-May, while Alling *et al.* (1991) noted that few were recorded after April. The sightings data that we have compiled support the contention that most blue whales occur in this region during the NE monsoon season, with recorded sightings peaking during February–April (Fig. 5b). We note that this area can be quite rough at the beginning of the NE monsoon, with strong onshore winds during December–January, so the dearth of sightings in those months may not reflect genuine absence. Indeed, there is a peak in strandings in January (Table 4), which suggests that at least some blue whales are present off NE Sri Lanka at this time, despite so few sightings.

The absence of blue whales from this area during the SW monsoon is not well established from sightings, since relatively little time has been spent at sea in this area at this season. But during one 16-day survey off NE Sri Lanka during October–November 1983 (by the RY *Tulip*), only one blue whale was recorded (Whitehead, 1983). Other data collected from the RY *Tulip* included sightings from a standard 20 n.miles (36km) transect running due E–W off Trincomalee; despite limited coverage during the SW monsoon, these data could suggest that blue whales are scarce in this area between late April and November (Table 3). Records of strandings in the Bay of Bengal are consistent with this pattern of seasonality, with 75% of strandings occurring during the period November to May. In addition, this pattern of blue whale seasonality is consistent with the seasonality of Chl-a (Fig. 3b), which peaks in November–January, suggesting peak zooplankton abundance during approximately December–March. The observed pattern of Chl-a seasonality may be heavily influenced by seasonally variable run-off from the Mahaweli Ganga (Sri Lanka's largest river), which enters the sea at Trincomalee (Alling *et al.*, 1991). In addition, physical processes may concentrate blue whale prey in the vicinity of the submarine Trincomalee Canyon, where blue whales congregate (Alling *et al.*, 1991).

While most blue whale strandings in the Bay of Bengal occur during the NE monsoon season, a few do occur during the SW monsoon. Whether these represent a few stragglers, or a regular year-round occurrence, remains unclear. Also, the distribution of strandings around the Bay of Bengal occurs over a much wider area than the distribution of known sightings, which are largely confined to the east coast of Sri Lanka. The disparity between the distributions of sightings and strandings no doubt in part reflects the distribution of observer effort. But it might also be partly explained by the fact that the East India Coastal Current flows northwards for most of the year, and therefore may disperse carcasses originating from near Sri Lanka more widely around the coasts of the Bay of Bengal. Soviet scientists certainly believed that the lack of blue whales in much of the Bay of Bengal was genuine, and that this was the result of relatively low plankton productivity (Zemsky and Sazhinov, 1994). Recent studies in Bangladeshi waters have not yet reported any blue whales (Smith *et al.*, 2008). Nevertheless, further surveys within the Bay of Bengal would be valuable.

Southern Sri Lanka

If blue whales are indeed largely absent from the NE coast of Sri Lanka after about April, the question arises, where do they go? The migration hypothesis presented here suggests that blue whales from Trincomalee are migrating to the Arabian Sea. They are unlikely to do so around the north of Sri Lanka, since the Palk Straight is so shallow, being just 10m deep in the dredged shipping channel (Hydrographic Office, 2007). Therefore it is predicted that blue whales must pass around the south of Sri Lanka in about April–May.

To test this prediction, the southernmost tip of Sri Lanka, Dondra Head, was visited in April 2007. Several blue whales were seen on every one of four days of observation. All of these sightings were in the vicinity of what appears, from the rather inadequate charts of this area, to be a canyon off Dondra Head. As a result of this finding, commercial whale watching has developed rapidly in the south of Sri Lanka, centred on the fishing port of Mirissa (just a few km west of Dondra). Most blue whales sighted by that operation appear to be associated with the continental slope.

Gunaratna *et al.* (1985) previously reported a sighting of two blue whales off Dondra Head on 7 May 1984. They further noted that since blue whales were seen off Trincomalee from November to mid-May, but apparently not at other times, these whales might migrate south to the south coast of Sri Lanka in the northern spring. Alling *et al.* (1991) did not speculate on migratory destinations of the blue whales they observed off Trincomalee, but they did present a diagram summarising blue whale swimming directions during February to April 1984 (Alling *et al.*, 1991; Fig. 5) which suggests a net southward trend.

Sightings data collected off the southern tip of Sri Lanka since 2007 (Fig. 5c) are bimodally distributed, with peaks in December–January and April. A very similar pattern is seen in the Maldives (Fig. 5d). Such patterns are consistent with an eastward movement of blue whales at the beginning of the NE monsoon (after zooplankton production associated with SW monsoon upwellings in the Arabian Sea has died down) and a westward return at the end of the NE monsoon. Off southern Sri Lanka blue whales have been seen travelling eastward during November–January (AA, pers. obs.). This is a rather extended period; perhaps if blue whales from both the western Arabian Sea and SE Arabian Sea (i.e. the SW coast of India and west coast of Sri Lanka) migrate to the Bay of Bengal after the end of the SW monsoon, they may pass eastwards at slightly different times, although this is no more than speculation at present. It was noted, however, that in both southern Sri Lanka and Maldives, although some blue whales seen at these times are travelling in the expected directions, others are not. Rather, they appear to be loitering, or even moving in the 'wrong' direction, and some are clearly feeding (diving repeatedly in the same area, and defecating). We also note frequent sightings of mother and calf pairs in March and April (RCA and AA, pers. obs.). This is consistent with an April peak in calving estimated for Arabian Sea blue whales by Mikhalev (2000). Sightings of blue whales breaching in March and April (RCA and AA, pers. obs.) might also suggest a peak in reproductive activity at this time. However, the reproductive cycle of NIO blue whales is probably more complex than this suggests, with another calving peak possibly in October, notably

among blue whales from Seychelles waters (Mikhalev, 2000).

Leatherwood and Reeves (1989) reported on several short surveys carried out, mostly by Sri Lankan scientists, off the south coast of Sri Lanka during the 1980s. Blue whales were not seen during surveys conducted in September, October, November and March. But blue whales were seen in December, both during a vessel survey, and from shore. More recently, Afsal *et al.* (2008) noted the presence of blue whales off the south coast of Sri Lanka in February and August.

In summary, we believe that many of the blue whales seen off the south coast of Sri Lanka are migrating between the Arabian Sea (including the west coast of Sri Lanka) and the Bay of Bengal (particularly the east coast of Sri Lanka). However, when food is present they may linger.

The Maldives

The seasonality of blue whale sightings in the Maldives is distinctly bimodal (Fig. 5d). This is similar to the pattern recorded from southern Sri Lanka (Fig. 5c), and can be explained in a similar way. During November to early January, blue whales pass eastward via the Maldives en route to the east coast of Sri Lanka. In April they return en route to the major upwelling areas of the western Arabian Sea. The relative scarcity of blue whales in February and March is genuine, not an artefact of survey effort, since a relatively large amount of time has been spent at sea in those months (RCA, unpublished data; Anderson, 2005). However, the lack of sightings in May likely reflects decreased survey effort in that month as the SW monsoon starts to take effect.

Blue whale strandings in the Maldives are highly seasonal, with all strandings recorded so far occurring during the short period December to February (Fig. 6d). This is consistent with the known pattern of sightings. During December–January, any blue whale that dies while passing through the Maldives or on towards Sri Lanka will be carried back by the westward-flowing North Equatorial Current, and may strand in the Maldives. In contrast, any blue whale that dies while travelling westward in April–May from Sri Lanka will be carried away from the Maldives and back towards Sri Lanka by the eastward-flowing Southwest Monsoon Current. This also suggests that most blue whales pass by the north of the Maldives (cf. Ballance and Pitman, 1998): if more passed through the Maldives Archipelago itself in April, then some strandings at that time might be expected.

All of the blue whale strandings observed in the Maldives in this study were of carcasses that appeared to have been dead and drifting for some days. During December–February, the prevailing North Equatorial Current flows to the west at about 1–2 knots (*ca.* 2–3 km/h) (Hydrographic Office, 2007). A blue whale that died off the coast of Sri Lanka would therefore drift westward, and might strand in the Maldives after about 10–12 days. There is evidence to support this scenario from a tragic source: after the tsunami of 26 December 2004, human corpses originating from Sri Lanka washed up in the Maldives from 12 days later.

While some blue whales must die of natural causes while passing between the Maldives and Sri Lanka, blue whales transiting southern Sri Lanka do pass through one of the busiest shipping lanes in the world. Ship strikes are an increasing cause of whale mortality worldwide (e.g. Berman-

Kowalewski *et al.*, 2010; Laist *et al.*, 2001; Van Waerebeek *et al.*, 2007), and it is likely that some blue whales are killed by ship strikes in this region.

Although most blue whales appear to pass by the Maldives biannually, some blue whales may loiter. In particular, during the NE monsoon there is a regular increase in plankton productivity on the downstream (western) side of the atolls (Figs 2a and 3; Anderson *et al.*, 2011). It is therefore predicted that some blue whales should be found west of the Maldives during the NE monsoon season. This does in fact appear to be the case, with blue whales being sighted west of Maldives on each of four crossings to Seychelles (Table 2). They may therefore be relatively common in this area, at least during January–April. We also have unconfirmed reports from Maldivian fishermen and foreign big-game fishermen of blue whales west of Maldives at this season.

NE Arabian Sea

In the NE Arabian Sea, Soviet catches included at least 31 blue whales taken in November 1966, from the coastal waters of India and Pakistan (the Indo-Pakistani aggregation of Mikhalev, 2000). This area is known to have a particularly high abundance of zooplankton (Paulinose and Aravindakshan, 1977; Qasim, 1982) including euphausiids (Brinton and Gopalakrishnan, 1973). In this general area high catches of yellowfin tuna (*Thunnus albacores*), whale shark (*Rhincodon typus*) and humpback whale (*Megaptera novaeangliae*) have also been recorded (Mikhalev, 1997; Pravin, 2000; Vivekanandan and Zala, 1994).

More specifically, the Soviet blue whale catches were centred on the Indus Canyon (around 23°N 67°E). Elsewhere in the world, blue whales are known to associate with submarine canyons, for example the Monterey Canyon off California (Croll *et al.*, 2000) and the Perth Canyon off Western Australia (Rennie *et al.*, 2009). In those cases, physical oceanographic processes associated with the canyons promote the formation and maintenance of dense krill swarms on which the blue whales feed. Within this region, blue whales have been reported to be associated with the Trincomalee Canyon off NE Sri Lanka (Alling *et al.*, 1991), the Basses Canyon off SE Sri Lanka (De Vos *et al.*, 2012), and the Dondra Canyon off southern Sri Lanka (see above). On the other hand, there are as yet no reports from the Swatch-of-no-ground Canyon off Bangladesh (Smith *et al.*, 2008). Nevertheless, it seems possible that searches in the vicinity of other canyons within South Asian waters during appropriate seasons might reveal other concentrations of blue whales.

Regarding the seasonality of blue whales near the Indus Canyon, all Soviet catches were taken in November, at the beginning of the NE monsoon. Strandings from this general area all occurred during December–June, i.e. during or immediately after the NE monsoon (Fig. 6d, Table 4). There are no strandings reported from July–November. Since winds are onshore for most of that time, it seems likely that blue whales are absent from the area for much of the SW monsoon season. The pattern of Chl-a seasonality in the vicinity of the Indus Canyon is complex (Fig. 3), but Chl-a is elevated between August and March. Zooplankton abundance may be highest from about October. This supports the suggestion that blue whales are commonest in this area during the NE monsoon.

All of the strandings from Pakistan and NW India in our compilation occurred before the period of Soviet whaling in the 1960s (Table 5). Prior to that period, blue whale strandings appear to have been relatively frequent. Kinnear (1915), for example, noted 'quite a number' of strandings of what were presumably this species in the vicinity of Bombay (Mumbai). Since 1967 there have been no confirmed, published reports of blue whale strandings within this area (Branch *et al.*, 2007b: Appendix 3), although there was one unconfirmed report by Ali *et al.* (2002). This lack of recent strandings, and of recent sightings (Gore *et al.*, 2012), suggests that Soviet whaling may have seriously depleted, perhaps even extirpated, this small component of the NIO blue whale population. A survey of the Indus Canyon area would be desirable.

Seychelles

In November 1964, Soviet whalers took exactly 500 blue whales in the vicinity of the Seychelles (Mikhalev, 1996; 2000), within the area bounded by 0°–3°S and 50°–54°E. These catches may have substantially impacted blue whales in this area; when one Soviet whaling fleet returned from the Antarctic in April 1965, no blue whales were seen here (Mikhalev, 2000), although that might also reflect seasonality of occurrence. Subsequently there have been very few post-whaling reports of blue whale sightings from the vicinity of Seychelles (Eyre, 1995; Kasuya and Wada, 1991; Robineau, 1991); those few reported with dates occurred in March and June. There are no strandings from this area, and the Chl-a data also provide few clues, since there are peaks in both the SW and NE monsoons (Fig. 3). The seasonality of blue whales in this area therefore remains unclear.

Chagos

The Chagos Archipelago (officially known as the British Indian Ocean Territory) lies south of the Maldives, in 6–7°S.

It is home to a US military base, on the island of Diego Garcia. No blue whale catches, sightings or strandings have been recorded. However, the International Monitoring System has maintained two underwater listening stations nearby for many years, in support of the Comprehensive Test-Ban Treaty, and these have detected blue whales in the vicinity. Using these acoustic monitoring data, Stafford *et al.* (2011) demonstrated that blue whales with a Sri Lanka call type (i.e. NIO blue whales) were present year-round in Chagos waters, but with a major peak in calls detected during April–May and a lesser peak in December–January (Fig. 7). The extent to which blue whales might be present but not calling at non-peak times is unknown. Nevertheless, this bimodal distribution corresponds rather closely with the bimodal distributions of blue whale sightings recorded here for both southern Sri Lanka and Maldives. Thus at least some NIO blue whales may be migrating through these waters biannually, travelling from the Arabian Sea during December–January. Where they are travelling to is unknown, but Stafford *et al.* (2011) raised the possibility that they are migrating to the southern Indian Ocean, since Sri Lanka calls have also been recently recorded near Crozet (in 46°S) in relatively low numbers but with a peak in December–February (Samaran *et al.*, 2010).

Chl-a is relatively low year-round in Chagos, with just a minor peak in June–August (Fig. 3), implying a peak in zooplankton abundance from about July or August onwards. Sri Lanka call detections are at a minimum during July–September (Fig. 7; Stafford *et al.*, 2011). If NIO blue whales are absent when food is possibly at its most plentiful, it seems unlikely that Chagos is a significant feeding area for these animals.

SE Arabian Sea

In the southern Arabian Sea, to the NW of Maldives, Soviet whalers caught over 300 blue whales (Fig. 1). All were taken

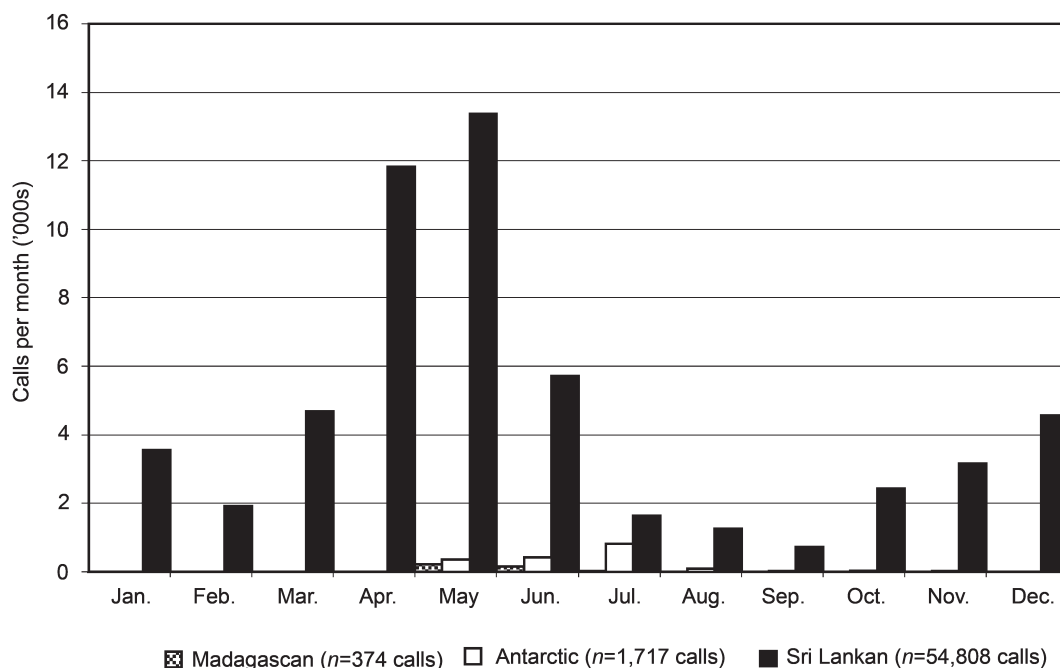


Fig. 7. Acoustic detections of three blue whale call types (Sri Lankan, Antarctic and Madagascan) near Diego Garcia (Chagos Archipelago) by month. Redrawn from Stafford *et al.* (2011) combining data from two listening stations supplied by K. Stafford. Diego Garcia is south of the Equator, so seasons differ from areas further north: SE monsoon May to October, NW monsoon December to March.

in November and December, mostly in 1964. Some were undoubtedly feeding, since they were caught with full stomachs (Mikhalev, 1996; 2000). However, relatively more blue whales from this area were taken with empty or near-empty stomachs (47%) compared with animals taken from the two other main areas exploited by the Soviets, namely the Gulf of Aden (32%) and north of Seychelles (23%) (Mikhalev, 1996; 2000). Ocean colour data (analysed by us but not presented here) show that mean Chl-a is relatively low (of the same order as that off the west of Maldives and Chagos). We think it possible that at least some of the blue whales caught to the northwest of Maldives may have been transiting the area; the timing of captures (in November and December) is certainly compatible with an eastward movement from the western Arabian Sea to the Maldives and Sri Lanka as predicted here. But this is another area where further studies would be welcome.

On *Balaenoptera indica* Blyth, 1859

Perrin *et al.* (2010) have recently inspected Blyth's holotype in Kolkata/Calcutta, India, confirmed that it is a blue whale, reviewed available information, and suggested that the name *B. musculus indica* (Blyth, 1859) should apply to the blue whales in the northern Indian Ocean. While that conclusion appears reasonable, it is not clear if this name should apply to these blue whales alone, since it has precedence over *B. m. brevicauda* (Ichihara, 1966). Furthermore, the degree of differentiation between northern and south Indian Ocean pygmy blue whale populations (or Sri Lanka, Madagascar and Australia call types) is still not well understood. There remains debate about the level of evidence needed to elevate blue whale populations to the status of subspecies (Branch *et al.*, 2007a; 2008; 2009). A standard definition of a subspecies includes two components: geographic isolation and distinguishing biological features (Branch *et al.*, 2007a). Regarding geographic isolation, this did seem fairly well established for NIO blue whales, but the recent recording of Sri Lanka type blue whale calls in the southern Indian Ocean suggest that things are not so clear cut (Samaran *et al.*, 2010). Regarding distinguishing biological features, although Perrin *et al.* (2010) cited the difference in length of female maturity between NIO blue whales and southern Indian Ocean pygmy blue whales as evidence of distinctiveness, this difference is small (just 0.5–0.6m) and there is overlap between putative populations (Branch and Mikhalev, 2008). The usefulness of this trait as a subspecific characteristic is therefore debatable. Another potentially distinctive trait of NIO blue whales is breeding seasonality consistent with that of a northern hemisphere population (Mikhalev, 1996; Mikhalev, 2000), although that understanding is based on sampling in predominantly just one month (November), and there was some suggestion of two breeding seasons (Mikhalev, 1996; 2000). In addition, the one genetic study conducted so far failed to separate northern from southern Indian Ocean 'pygmy' blue whales, although it included just two samples from the NIO (LeDuc *et al.*, 2007). In contrast, Chilean blue whales differ in length by 2m from both Antarctic and southern Indian Ocean blue whales (Branch *et al.*, 2007a), and are also genetically distinct (LeDuc *et al.*, 2007); but these whales are not currently considered to be a separate subspecies. Further studies, including additional acoustic and genetic analyses, are needed to clarify population

separation within the Indian Ocean. In addition, satellite tracking could not only test the migration hypothesis presented here, but also help delineate stock boundaries. It is already known that at least some NIO blue whales wander beyond the boundaries considered in this study. It is likely that their stock status, as well as their seasonal distributions and migrations, will prove to be more complex than the relatively simple scenario presented here.

Another source of uncertainty, raised by Rice (1998), was that Blyth's 'type specimen ... was 84ft (25.6m) long, and another individual 90ft (27.4m) long was reported, whereas the largest *brevicauda* ever taken was only 79ft (24.1m) long'. The longest Arabian Sea blue whale caught and measured by Soviet whalers was recorded as 24.0m (see also Gordon *et al.*, 1986; Mikhalev, 1996). But Blyth (1859) himself noted that the 90ft length he reported was 'as alleged' and the other stranding was 'stated to have been 84ft. in length', suggesting that any measurements may not have been especially accurate. Furthermore, it was common practice in the 19th and early 20th centuries to measure whales to the tip (rather than the central notch) of the flukes; no NIO stranding since 1927 has exceeded 24.1m reported length (Branch *et al.*, 2007b). Chari (1951) presented both measurements from one specimen of '*Balaenoptera indica*', the difference between them being about 8%. Applying this figure to the 84ft type specimen gives an estimated length of 23.6m. Blyth (1859) noted that the mandibles of this specimen were 'within less than 2 [inches] of 21 ft' i.e. 6.35m. From four strandings in the Maldives (lengths 16.8–22.9m, mandible lengths 4.82–5.50m, RCA unpublished data) mean mandible length was 26.6% (range 24.1–28.8%) of total length. Applying this figure to the 6.35m mandibles of the type specimen gives an estimated total length of 23.9m. The close agreement between these two total length estimates gives some confidence that the 'true' (i.e. central notch) length of this specimen may have been < 24m. We recognise that the conversion factors and estimates used here may not be highly accurate. But they nevertheless demonstrate that the reservation of Rice (1998) is, by itself, insufficient to dismiss Blyth's taxon.

The possibility that individuals of other subspecies of blue whale, for example Antarctic blue whale *B. m. intermedia*, occur in the NIO at least occasionally should be mentioned. Some strandings of very large blue whales have been recorded from the Indian region, including for example a 94ft (28.7m) individual stranded near Cochin in November 1927 (Moses, 1947). It is likely that most such cases are the result of incorrect measuring or reporting. However, the possibility of Antarctic blue whales straying north of the Equator, particularly in earlier days before commercial whaling reduced that subspecies to less than 1% of its original abundance (Branch, 2007; Branch *et al.*, 2004), cannot be entirely dismissed. Certainly, there is acoustic evidence of Antarctic-type blue whale calls in the vicinity of the Chagos Archipelago, where both Sri Lanka and Madagascar type calls have also been recorded (Stafford *et al.*, 2004; 2011). And LeDuc *et al.* (2007) presented genetic evidence (albeit from other regions) of blue whale vagrancy.

CONCLUSIONS

The available data suggest that there is a distinct population of blue whale, which should probably be known as *B.*

musculus indica, in the NIO. This population shows parallels with the Arabian Sea population of humpback whale, *Megaptera novaeangliae*, which also appears to be resident year-round in these tropical waters, to have a Northern Hemisphere breeding cycle, to be reliant on the SW monsoon upwellings and to have been heavily impacted by Soviet whaling in the 1960s (Mikhalev, 1997; 2000; Minton *et al.*, 2008; Reeves *et al.*, 1991).

It is proposed here that most of the NIO blue whales feed in the Arabian Sea off the coasts of Somalia and southern Arabia during the period of intense upwelling associated with the SW monsoon. At the same time some of these blue whales feed in the area of enhanced productivity off the southwest coast of India and west coast of Sri Lanka. When the SW monsoon dies down in October these upwellings cease. The blue whales subsequently disperse more widely, searching out other areas of enhanced productivity to last them through the leaner months of the NE monsoon.

One such NE monsoon feeding area is off the east coast of Sri Lanka. It is suggested that at least some of the blue whales feeding there originate in the western Arabian Sea. They must pass by the north of Maldives and south of Sri Lanka in November–January, while heading eastwards, returning westwards in April–May. Other blue whale feeding areas during the NE monsoon include the waters west of the Maldives and in the vicinity of the Indus Canyon. However, there have been no recent records from the NE Arabian Sea, which suggests the possibility that the Indus Canyon component of the NIO blue whale population may have been extirpated by Soviet whaling in the 1960s. Soviet whalers also caught large numbers of blue whales north of Seychelles; again, there have been few observations from that area since.

As more data become available, the use of abundance indices, such as sightings per day (rather than just sightings with no measure of effort, as used here) should provide more refined insights into blue whale seasonality in the region. However, even our crude data reveal patterns of seasonality that are consistent with our predictions, and with recent acoustic analyses, and do not simply reflect sightings conditions. Thus, blue whales have been sighted off the west coast of Sri Lanka (Fig. 5a) during the rough SW monsoon season (as predicted) despite the poor sea conditions and limited effort at that season. However, they have not been recorded there during the calmer NE monsoon (again as predicted) despite good sea conditions and greater effort during that season. Furthermore, the bimodal distribution of sightings off both southern Sri Lanka and the Maldives (Figs 5c and 5d) is consistent with our prediction of a biannual passage of blue whales through those waters. This cannot be explained by variations in sighting effort alone: there is for example a peak in sightings in Maldives in January, even though there has been much less sighting effort in that month than in either February or March (RCA, pers. obs.); it seems unlikely that the two peaks occur in the same months in both Maldives and southern Sri Lanka purely by chance; and this pattern of bimodal seasonality is supported by acoustic data from Chagos (Stafford *et al.*, 2011). With regard to strandings, we recognise the shortcoming of such data. Nevertheless, the broad pattern of seasonality of strandings in each area is consistent with our migration hypothesis, and

cannot be explained by seasonal changes in sea conditions alone. We note in particular the Maldivian strandings (Fig. 6c), which have been recorded only during the remarkably short time period of December to February. This is the only period during which we predict that blue whales should be transiting waters upstream of the archipelago, and therefore prone to stranding. In short, the available data do support most of our predictions.

But there are exceptions: expected sightings from the western Arabian Sea during June–August and perhaps from off NE Sri Lanka during December–January are lacking, possibly due to rough weather in these locations at these times. Satellite tracking, acoustic monitoring and photo-identification (e.g. Calambokidis *et al.*, 2009), should provide means of addressing such shortfalls and further testing the migration hypothesis presented here. Furthermore, although the use of satellite derived Chl-a data as a proxy for food availability has given some useful insights into blue whale seasonality, it is a crude measure. More detailed studies of both physical and biological oceanographic processes will be needed to provide improved understanding of blue whale feeding ecology, and its impact on their seasonal distributions in the northern Indian Ocean.

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Cetaceans in the Maldives: a review

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ABSTRACT

The cetaceans of the Maldives were poorly known until relatively recently, but have received increased attention over the past decade. Twenty-three species of cetacean have now been recorded. A number of sightings surveys, and one acoustic survey, have been completed. The species most frequently seen is the spinner dolphin (*Stenella longirostris*). A national system for reporting cetacean strandings has been in place since 2000, although some earlier strandings were also reported; approximately 160 strandings of 16 species have been recorded to date. The species most commonly reported stranding is the sperm whale (*Physeter macrocephalus*). Ambergris has been exported from the Maldives since ancient times; recent export statistics are reviewed. All cetaceans are protected by law within Maldivian waters. More significantly, most forms of net-fishing, including gill-netting and purse-seining are banned in the Maldives to protect the traditional pole and line tuna fishery. Cetacean-watching is becoming increasingly popular, with spinner dolphins being the main attraction, although other species are also sought after on specialist trips.

KEYWORDS: INDIAN OCEAN; SANCTUARIES; WHALING – HISTORICAL; INCIDENTAL SIGHTINGS; SURVEY – VESSEL; STRANDINGS; WHALEWATCHING

INTRODUCTION

The Republic of Maldives is a small island nation in the central Indian Ocean, to the southwest of India and Sri Lanka. It lies at the heart of the International Whaling Commission's (IWC) Indian Ocean Sanctuary and has an abundant and diverse cetacean fauna. Until recently, however, it had received relatively little attention from cetologists.

The Maldives consists of a chain of atolls running north-south from about 7°N to 0.5°S. The atoll chain is single in the north and south but double in the central part of the archipelago. Maximum depths within the atolls are typically 50–60m but vary from about 10–100m. Outside the atolls the reef slopes drop steeply away to the ocean floor, at about 2,000–3,000m. An exception is found in the area between the double chain of atolls in the central Maldives, where bottom depths are of the order of 200–500m.

The waters of the northern Indian Ocean surrounding the Maldives are strongly influenced by the monsoons. The southwest monsoon (SW or boreal summer monsoon) extends from about May to October, while the northeast monsoon (NE or boreal winter monsoon) lasts from about December to March. Under the influence of the SW monsoon, ocean currents flow predominantly to the east, while during the NE monsoon they flow predominantly to the west (Hydrographic Office, 2007; Molinari *et al.*, 1990; Shankar *et al.*, 2002; Wyrski, 1973). The southern Maldives (south of about 2–3°N) is less affected by the monsoons, and more influenced by equatorial currents.

There has been one previous review of information on cetaceans in the Maldives (De Boer *et al.*, 2002), but that was brief and much new information has been become available since then. The aim of this paper is to provide an updated overview of information on cetaceans in the Maldives.

HISTORICAL WHALING

There were two periods of commercial whaling in the region of the Maldives. During the mid-19th century, sperm whales (*Physeter macrocephalus*) were hunted throughout much of the tropical Indian Ocean, mostly by 'Yankee' whalers from New England (Bannister *et al.*, 2007; Clark, 1887; Townsend, 1935; Wray and Martin, 1983). Blyth (1859) reported the following from one Rev. H. Baker who wrote to him from Kerala, India: 'Whales are very common on the coast. American ships, and occasionally a Swedish one, call at Cochin for stores during their cruises for them ... The Maldives and Seychelles are said to be the headquarters of the whalers who seek for these Whales.' Clark (1887, map of whaling grounds) charted a sperm whaling ground in the north of Maldives. Wray and Martin (1983) considered the area between Sri Lanka and Maldives to be an important sperm whaling ground in the 1840s and 1850s, and noted one particular case of sperm whales being taken east of the Maldives (in February 1847).

During the 1960s there was a brief but intense period of commercial whaling in the Arabian Sea by Soviet whaling fleets (Berzin, 2008; Clapham and Ivashchenko, 2009; Yablokov, 1994). Large numbers of blue, Bryde's, humpback and sperm whales were taken in the region, including waters that are now within the Maldivian EEZ (Mikhalev, 1996; 1997; 2000). Some older inhabitants of islands in the north and centre of Maldives report that whale blows were a common sight on fishing trips in the 1950s and early 1960s, but were rare thereafter (Anderson, 2005; unpublished data). In Sri Lanka there were similar reports from fishermen of many whales, possibly humpback whales, off the NE coast in the 1950s and 1960s, but apparently not in the 1970s (Reeves *et al.*, 1991: Table 1).

Maldivians themselves have never undertaken commercial whaling (Anderson *et al.*, 1999). There is no evidence that large whales were ever hunted in Maldives as suggested by

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² Marine Research Centre, H. Whitewaves, Malé, Republic of Maldives.

Table 1
Cetaceans recorded from the Maldives.

Species	English name	Strandings	Encounters	Numbers
Mysticeta				
1 <i>Balaenoptera musculus</i>	Blue whale	8	0.7%	0.0%
2 <i>Balaenoptera edeni</i>	Bryde's whale	1	2.8%	0.1%
3 <i>Megaptera novaeangliae</i>	Humpback whale	0	0.1%	0.0%
Odontoceta				
4 <i>Physeter macrocephalus</i>	Sperm whale	57	0.5%	0.1%
5 <i>Kogia sima</i>	Dwarf sperm whale	0	4.2%	0.2%
6 <i>Steno bredanensis</i>	Rough-toothed dolphin	0	0.3%	0.2%
7 <i>Grampus griseus</i>	Risso's dolphin	2	11.4%	7.0%
8 <i>Tursiops truncatus</i>	Bottlenose dolphin	0	6.6%	2.4%
9 <i>Tursiops aduncus</i>	Indo-pacific bottlenose dolphin	0	6.6%	2.4%
10 <i>Stenella attenuata</i>	Pantropical spotted dolphin	1	3.5%	14.5%
11 <i>Stenella longirostris</i>	Spinner dolphin	2	34.8%	53.2%
12 <i>Stenella coeruleoalba</i>	Striped dolphin	0	2.4%	2.9%
13 <i>Lagenodelphis hosei</i>	Fraser's dolphin	1	0.9%	5.0%
14 <i>Peponocephala electra</i>	Melon-headed whale	12+	0.6%	4.7%
15 <i>Feresa attenuata</i>	Pygmy killer whale	2	0.2%	0.1%
16 <i>Pseudorca crassidens</i>	False killer whale	0	0.5%	0.6%
17 <i>Orcinus orca</i>	Killer whale	1	0.5%	0.1%
18 <i>Globicephala macrorhynchus</i>	Short-finned pilot whale	1	4.2%	1.9%
19 <i>Indopacetus pacificus</i>	Longman's beaked whale	1	0.2%	0.0%
20 <i>Mesoplodon densirostris</i>	Blainville's beaked whale	1	0.5%	0.0%
21 <i>Mesoplodon ginkgodens</i>	Ginkgo-toothed beaked whale	1	—	—
22 <i>Mesoplodon hotaula</i>	Atoll beaked whale	1	—	—
23 <i>Ziphius cavirostris</i>	Cuvier's beaked whale	2	1.2%	0.1%

Notes

Strandings: number of strandings from Anderson *et al.* (1999) plus additional unpublished records held at MRC; excludes specimens deliberately captured.

Encounters: is the percentage of *records* of each species among 1921 on-effort encounters reported by Anderson (2005: Table 4). Numbers: is the percentage of *individuals* of each species seen among 71,276 cetaceans by Anderson (2005: Table 7), and gives a very crude measure of relative abundance. Percentages do not add up to 100 since unidentified cetaceans are excluded here.

Tursiops species were not distinguished by Anderson (2005); together they accounted for 13.2% of encounters and 4.9% of numbers sighted in that study; we have split those figures equally between these two species for the purposes of this table.

Phillips (*in Hill*, 1958, p.9). A harpoon gun was apparently imported to Malé by the first President, Amin Didi, in about 1952 with the object of catching cetaceans for export, but it was never used (N.T. Hasen Didi, formerly of the President's Office, pers. comm., 1990 and 1998).

There was a traditional fishery for tiger sharks (*Galeocerdo cuvieri*) in the Maldives. Large tiger sharks have enormous livers, from which oil was obtained for treating wooden fishing boats. Dolphins were used as bait in this fishery, and they were caught by harpoon while bow-riding (Anderson and Ahmed, 1993; Didi, 1983; Ibrahim, 1991). The scale of the tiger shark fishery, known locally as *maa keyolhu kan*, is unknown. However, given that there are some 200 inhabited islands in the archipelago, it might perhaps have involved an annual take of many tens to a few hundred dolphins per year (species unknown, but likely including spinner dolphins). The tiger shark fishery and associated catching of dolphins died out in the early 1960s, when the more efficient method of longlining for sharks was introduced (Anderson and Ahmed, 1993) and other sources of oil became available. Although this fishery was undoubtedly an ancient one, before its demise fishermen were using toggle-head harpoons. This style of harpoon was invented in New England in 1848, and soon became widely used in the Yankee sperm whale fishery. It seems possible that New England whalers introduced it to the Maldives.

SIGHTINGS

Until relatively recently, reports of cetacean sightings from the Maldives were of limited scope. They included sightings by the Dutch sea captain Willem Mörzer Bruyns, who passed through or by the Maldives on several occasions in the 1950s and 1960s (Mörzer-Bruyns, 1971); Captain Jacques-Yves Cousteau, who visited the Maldives on board his famous ship *Calypso* in 1967 (Cousteau and Diolé, 1971; 1972); Stephen Leatherwood and fisheries worker Charles Peters who visited the Maldives separately during 1980–83 (Leatherwood *et al.* 1984) with additional information on some sightings in Gilpatrick *et al.* (1987), Leatherwood, (1986), Leatherwood *et al.* (1991) and Wilson *et al.* (1987); Japanese whaling researchers who passed through the Maldives on two scouting vessels in March 1982 (Kasuya and Wada, 1991); cetologists on the research yacht *Tulip* who visited Maldives in late 1983 and early 1984 (Alling *et al.*, 1984; Whitehead *et al.*, 1983) during the course of their research elsewhere in the Indian Ocean Sanctuary (Alling, 1986; Gordon, 1991; Whitehead, 1989); and some miscellaneous sightings by the senior author and colleagues (Anderson, 1990; 1996; Anderson *et al.*, 2006; Anderson and Shaan, 1998; 1999; Shaan, 2001). Sightings of whales from global surveys by British and Dutch merchant seamen, including some records from the vicinity of Maldives, were reported by Brown (1957) and Slijper *et al.* (1964) respectively. Popular accounts of the seasonality of

baleen whales around the Maldives were given by Buttress (2001) and Anderson (2002a).

There are several reports of dolphins from travellers, but without specific detail. For example, conchologist Alan Kohn visited the Maldives as part of the Yale Seychelles Expedition in 1957 (Kohn, 1964). He noted ‘In the lagoon of Mulaku Atoll, where we anchored [probably on 9 October 1957] in 14m in a *velu* [shallow lagoon], a large number of small porpoises, which made very short, high jumps, were observed.’ These were probably spinner dolphins, which still regularly occur in large numbers in this atoll. Travel writer Gavin Young sailed to Maldives (Young, 1981) and recorded bowriding dolphins accompanying his vessel in to Malé.

More systematic sightings surveys started with marine biologists Lisa Ballance and Robert Pitman who passed through Maldivian waters in April and June 1995 during the course of a cetacean survey of the western Indian Ocean (Ballance and Pitman, 1998; Ballance *et al.*, 1996). They recorded relatively large numbers of blue whales (*Balaenoptera musculus*) in the vicinity of Maldives. A 20-day cetacean survey in the north-eastern part of the Maldives was carried out during April 1998, with one aim being to obtain tissue samples from blue whales (Ballance *et al.*, 2001). That survey recorded 267 sightings of 16 cetacean species, with the spinner dolphin (*Stenella longirostris*) being the most commonly observed.

Subsequently, Anderson (2005) published a review of some 1,979 sightings of 20 cetacean species (plus 129 strandings), mostly recorded during 535 days at sea between August 1990 and June 2002. Again, spinner dolphins were the most abundant species recorded. They showed a clear diurnal pattern of behaviour, with many schools entering the atolls in the early morning, and leaving in the late afternoon. Spinner dolphins regularly occurred with pantropical spotted dolphins (*Stenella attenuata*) and both species associated with yellowfin tuna. Bryde’s whales (*Balaenoptera edeni*) also associated with yellowfin tuna and appeared to be most common in Maldivian waters during El Niño Southern Oscillation events. Blue whales were only recorded during November to April. Dwarf sperm whales (*Kogia sima*) were especially difficult to locate in rough weather but relatively common, making up one sixth of all sightings in flat-calm conditions. Melon-headed whales (*Peponocephala electra*) were particularly common in the south of the Maldives, but rare in the centre and north. It was noted that several species of cetacean were especially abundant along the steep atoll slopes. A summary of sightings is presented in Table 1.

Anderson (2005) recorded bottlenose dolphins as *Tursiops* sp. He noted that most appeared to be common bottlenose dolphins (*T. truncatus*), but that the possibility that some were Indo-Pacific bottlenose dolphins (*T. aduncus*) could not be discounted. In particular he noted differences between bottlenose dolphins seen inside atolls, and those seen out in the ocean. Subsequently, one of us (RCA) has confirmed from close observations and photographs, that both species occur in the Maldives. As suspected by Anderson (2005), *T. truncatus* is commoner outside of the atolls, tends to occur in larger groups, and often associates with other species. In contrast, *T. aduncus* occurs inside the atolls, or only just outside, tends to occur in small groups or singly, and rarely associates with other species.

Clark *et al.* (2012) report on two visits to the Maldives, in 2003 and 2004, by the research yacht *Odyssey* (Ocean Alliance, 2009). 157 cetacean sightings were recorded.

STRANDINGS

Some 16 species have been recorded from strandings so far, with the sperm whale being the most frequently recorded (Table 1) (Anderson *et al.*, 1999; Dalebout *et al.*, 2003; MRC, unpublished data). The relatively large number of sperm whale strandings, in comparison to the relatively few sightings recorded (Table 1) largely reflects the relatively little amount of survey effort conducted offshore. Many ‘stranded’ cetaceans are actually found floating dead at sea by fishermen (who may tow them to their islands in order to recover oil for treating wooden boats, and to search for valuable teeth and ambergris). Most of those carcasses that do wash up on islands or reefs appear to be dead at the time of stranding. Dead whales drift with the monsoon currents, so are found most frequently on the eastern sides of atolls and islands during the NE monsoon, and on the western sides of atolls and islands during the SW monsoon (Anderson *et al.*, 1999).

Two species, both beaked whales, have been so far been positively recorded in Maldives only from strandings: ginkgo-toothed beaked whale, *Mesoplodon ginkgodens* (cf Anderson *et al.*, 1999) and atoll beaked whale, *Mesoplodon hotaula* (Deraniyagala, 1963). The latter name is based on a single stranded female from Sri Lanka, and was relegated to the synonymy of *M. ginkgodens* by Moore and Gilmore (1965). However, genetic studies have shown that *M. hotaula* is a valid species, close to but distinct from *M. ginkgodens* (Dalebout *et al.*, 2007). More details of the single mature male stranded in the Maldives will be published separately (Dalebout *et al.*, in prep.). Another ziphiid, the previously little-known Longman’s beaked whale, *Indopacetus pacificus*, was redescribed in part on the basis of a Maldivian stranding (Dalebout *et al.*, 2003). Popular accounts of this ‘re-discovery’ were given by Anderson (2004), Dalebout (2002) and Pitman (2002), both of the latter two accounts being illustrated with photos of live animals from the Maldives (that in Pitman (2002) being mislabelled as from the Pacific).

Until early 2000 there was no standard scheme for reporting cetacean strandings in the Maldives. Reports of cetacean strandings were occasionally sent to the Government’s Marine Research Centre (MRC), in the capital Malé, and MRC staff collected information on other strandings during field trips. In late 2000, a more formal stranding reporting scheme was initiated. Each inhabited island has a government office and government-appointed island Chief (elected island Councillor since 2009). MRC sent recording forms to each island office, with instructions on how to report every marine mammal stranding. The main aim of the scheme is to obtain basic biological information about cetaceans in the Maldives. The recent spread of telecommunications to all islands is contributing to the more frequent reporting of strandings, while the increasingly widespread use of digital cameras is improving the frequency of reliable identifications.

There are few known instances of live strandings to date. This, combined with the geography of the country (numerous

small islands and reefs spread over a vast area of ocean, with consequent transport and communication difficulties), means that a network focusing on the welfare of live stranded cetaceans (as occurs elsewhere) is unlikely to develop in the foreseeable future.

Some other strandings were documented by Deraniyagala (1956), Leatherwood *et al.* (1984), Anderson (1990; 1996) and Branch *et al.* (2007). Gulland *et al.* (2001) provided a brief summary of the strandings reporting scheme. Anderson (2002b) provided a popular account of Maldivian whale strandings. Anderson *et al.* (1999) summarised all available strandings data up to 1998 ($n = 82$, of which 56 had not been previously reported). More than 80 additional strandings have been recorded since; these should be published in due course.

AMBERGRIS

Ambergris is occasionally recovered from some sperm whale strandings, and is also found floating at sea by Maldivian fishermen (Anderson, 1990; Godfrey, 1996; Klinowska, 1991; Whitehead, 1989).

Ambergris is known in Maldives as *maavaharu*. Maldivians recognise two types of ambergris: white (*hudhu maavaharu* or *hudanvaru*) and black (*kalhu maavaharu*). On Minicoy island, which was historically part of the Maldives but is now part of the Indian Lakshadweep islands, the same distinction has been reported.

Small quantities of ambergris are used in local medicines, but most is exported. This trade has been conducted since ancient times, as was noted by several early travellers, including: Arab traders from the 9th century onwards (Gray, 1890); the Chinese who accompanied the great admiral Cheng Ho (Zheng He) on his seven voyages into the Indian Ocean in the early 15th century (Ma Huan, 1970); and Portuguese adventurers from the early 16th century onwards (Gray, 1890). In 1753 Malé was attacked by an invading force from Malabar sent by the Ali Raja of Cannanore (present day Kannur in Kerala). Assistance was sought from the French in Pondicherry (now Puducherry, India), who sent a fleet of four ships, and saw off the Malabaris. The French remained until the following year, when they were apparently paid for their mercenary services with a piece of ambergris weighing 337½ lb (153kg) (Bell, 1940). Hockley (1935) noted that a small quantity of ambergris was included in the (by then largely ceremonial) annual tribute paid by the Maldives to the colonial Governor of Ceylon. He also noted three grades of ambergris; that trade in ambergris was a monopoly of the government; and that most was exported to Bombay (now Mumbai), since at that time foreign trade was dominated by Borah merchants from Bombay. Other relevant reports include Heyd (1879), Gode (1949) and Yamada (1955).

Fishermen who find ambergris normally sell it to middlemen in Malé (in practice there is one Maldivian company that dominates this minor trade). Most now goes to the Middle East where its reputed properties as an aphrodisiac are highly valued. Ambergris is unique among Maldivian marine products in that it is the only one subject to an export tax (amounting to 50% of the export price). Perhaps for this reason there may be some temptation to avoid declaring exports. Certainly the quantity and frequency

of ambergris exports has declined as unit price has increased (Tables 2 and 3).

Most pieces of ambergris found are of relatively modest size. But occasional large pieces are recovered, the largest in recent years being:

- (1) 214kg, 1983, location unknown;
- (2) 231kg, January 1989, K. Gaafaru;
- (3) 187kg, March 1995, H.A. Kelaa.

Table 2

Declared exports of ambergris from the Maldives (MRf=Maldivian rufiyaa).

	Quantity (kg)	Value (MRf)	Unit value (MRf/kg)	Value (US\$)
1974	190	21,000	100	—
1975	40	9,000	200	—
1976	150	66,000	400	—
1977	40	110,000	2,800	—
1978	130	534,000	4,100	—
1979	137.330	462,335	3,400	—
1980	121	1,610,043	13,300	—
1981	13	154,270	11,900	\$44,077
1982	90.602	627,278	6,900	\$104,546
1983	226.030	2,643,129	11,700	\$377,590
1984	43.742	483,956	11,100	\$68,646
1985	23.690	322,900	14,200	\$45,479
1986	26.058	535,370	20,500	\$74,877
1987	2.24	22,330	10,000	\$2,422
1988	0	0	—	—
1989	231	5,111,064	22,100	\$565,383
1990	0	0	—	—
1991	0.145	2,465	17,000	\$240
1992	0	0	—	—
1993	16.48	223,980	13,600	\$20,436
1994	21	222,000	10,600	\$19,154
1995	180	2,688,726	14,900	\$228,439
1996	10.50	189,000	18,900	\$16,058
1997	0	0	—	—
1998	0	0	—	—
1999	3.23	57,130	17,700	\$4,446
2000	0	0	—	—
2001	0	0	—	—
2002	3.10	93,000	30,000	\$7,237
2003	0	0	—	—
2004	1.21	36,300	30,000	\$2,825
2005	0	0	—	—
2006	0	0	—	—
2007	0	0	—	—
2008	0	0	—	—

Sources

Maldives Customs data 1974–78 from Anon (1979); 1979–2008 compiled annually by Ministry of Fisheries and Agriculture. Exchange rates from Anon (1992; 1997).

Notes

Data for 1974–78 were reported to the nearest 10kg and MRf 1,000. Unit prices given to nearest MRf 100. MOFA recorded 1991 quantity as 0.145MT, apparently in error. UNDP (1966) recorded exports of 24cwt (1,222kg) worth MRf 12,000 in 1963, and 17cwt (865kg) worth MRf17,000 in 1964; it seems likely that the quantities are incorrect.

Table 3

Average price and frequency of export of ambergris, by decade.

Period	Av. annual export	Av. unit value	% years with exports
1974–79	114.6 kg/y	1,750 MRf/kg	100%
1980–89	77.6 kg/y	14,800 MRf/kg	90%
1990–99	23.1 kg/y	14,700 MRf/kg	60%
2000–08	0.5 kg/yr	30,000 MRf/kg	22%

CETACEAN SPECIMENS

Relatively few cetacean specimens have been collected from the Maldives.

The 19th century French merchant-shipowner and naturalist Jean-Jacques Dussumier collected several cetacean specimens from the Indian Ocean (Arvy, 1972). These appear, from watercolour illustrations by Dussumier reproduced in Arvy (1972), to have included a pregnant female striped dolphin taken '1°N, 100 leagues to the east of the Maldiv Islands', and a female spinner dolphin 'caught a few leagues to the east of the Maldiv Islands, 73°E, on 31st July 1829.' Wilson *et al.* (1987) list both these records as *Stenella coeruleoalba*. (French leagues have been of different lengths at different times, but 19th century nautical leagues were usually of 4.448 km).

During his stay in Addu Atoll in 1958–59, W.W.A. Phillips collected one melon-headed whale and five spinner dolphin specimens, which he donated to the Natural History Museum in London (Anderson *et al.*, 1999). These specimens were noted in the data catalogues of Leatherwood (1986) and Gilpatrick *et al.* (1987), and referred to in the reviews of Dawbin *et al.* (1970), Perrin *et al.* (1989) and Perrin (1990).

In recent years it has become something of a trend among resort owners to have whale skulls and skeletons on display. A partial list of specimens on resort islands was given by Anderson *et al.* (1999). The National Museum in Malé holds a single ginkgo-toothed beaked whale tooth (Anderson *et al.*, 1999). The Marine Research Centre in Malé also has a small collection of cetacean specimens, including a complete skeleton of Longman's beaked whale.

Biopsy samples were collected by Robert L. Pitman during the survey carried out in April 1998 (Ballance *et al.*, 2001) and again during one leg of the Voyage of the *Odyssey* in 2004 (Clark *et al.*, 2012). Other Maldivian biopsy samples were taken by the crew of the *Odyssey* in both 2003 and 2004, mainly for a global assessment of pollutants in sperm whales (Ocean Alliance, 2009). Wise *et al.* (2009) reported on chromium levels in these sperm whales. In addition, some tissue samples have been collected from strandings by the senior author. Galver (2002) included six Maldivian biopsy samples in her unpublished study of the molecular ecology of spinner dolphins. Dalebout *et al.* (2003) incorporated genetic analysis of tissue samples from one Maldivian stranding in their reappraisal of Longman's beaked whale. LeDuc *et al.* (2007) included two Maldivian biopsy samples in their investigation of (mostly) Southern Hemisphere blue whale population structure. Chivers *et al.* (2007) included one biopsy sample from the Maldives (Susan Chivers, pers. comm., 28 August 2007) in their study of genetic population structure of false killer whales (*Pseudorca crassidens*), mainly in the north Pacific. Six pilot whale biopsy samples were confirmed as shortfinned pilots (*Globicephala macrorhynchus*) (Susan Chivers, US NMFS, pers Comm, October 2002).

ACOUSTICS

Little acoustic surveying has been carried out in the Maldives. Attempts were made to record blue whale vocalisations in 1998 (Ballance *et al.*, 2001), but without success. During the Voyage of the *Odyssey* in 2003–04 (Clark *et al.*, 2012) a total of 2,341 acoustic stations were

conducted, during 72 days at sea, with cetaceans recorded during 1612 (69%). This acoustic detection rate in Maldivian waters was 2.5 times higher than in areas of the eastern Indian and tropical Pacific also surveyed by the *Odyssey*. Cetacean detections consisted of delphinid species ($n = 1,260$), sperm whale ($n = 196$), killer whale ($n = 7$) and humpback whale (*Megaptera novaeangliae*) ($n = 1$).

WHALE AND DOLPHIN WATCHING

Spinner dolphins are particularly common in the Maldives (Anderson, 2005; Ballance *et al.*, 2001) and have become the focus of small-scale dolphin-watching ventures from tourist resorts. There are currently 95 resort islands in the Maldives. At least 20 offer excursions to see spinner dolphins. These excursions take advantage of the fact that many spinner dolphin schools (which feed out in the ocean at night) rest inside the atolls by day. They therefore enter through reef channels in the morning, and exit in the afternoon, on a fairly predictable schedule, which greatly increases the chances of successful encounters. Some excursions are run in the mornings, but most are offered in the afternoon, sometimes being marketed as a sunset cruise with the chance to see dolphins. One operator also offers multiday whale-watching cruises. These typically see several thousand individuals of anything up to 12 or more cetacean species during 7–10 days at sea (RCA, pers. obs.).

A recent global review of whale-watching (IFAW, 2009) estimated that over 14,000 tourists took part in dolphin and whale watching excursions in Maldives during 2008, spending over US\$580,000. This was up from an estimated revenue of US\$149,000 in 1998 (Hoyt, 2001).

FISHERIES INTERACTIONS AND PROTECTIVE MEASURES

There is no fishery for cetaceans in the Maldives today. Indeed, the capture of all cetaceans is specifically banned under Maldivian law (Fisheries Law, no. 5/87, iulaan no. FA-A1/29/93/14, 15 May 1993) as is the export of cetacean products (under the Import-Export Law, no. 31/79). The main fishing methods now used in the Maldives (pole and line for tuna and handline for reef fish and tuna) do not catch cetaceans. The lack of cetacean bycatch in the Maldivian tuna fishery was briefly noted by Lal Mohan (1994). There is also some pelagic longlining, although this is currently at a very low ebb following not only a recent ban on shark fishing and shark product exports, but also the current phasing out of licenses for foreign longliners. It is possible that there may have some cetacean entanglement by the longline fisheries, but there was no monitoring by observers and no data are available.

Pelagic gillnets, purse seines and trawls have never been used commercially in the Maldives, and have been banned for many years (Fisheries Law no. 5/87), mainly to protect the livelihoods of traditional pole and line tuna fishermen. Occasionally cetaceans entangled in bits of netting are stranded, but these are believed to have drifted into Maldivian waters from outside (Anderson *et al.*, 1999). There has also been some illegal pelagic gillnet fishing within the Maldivian EEZ by Sri Lankan vessels, but the extent of any cetacean bycatch is unknown.

A handline fishery for large yellowfin tuna (*Thunnus albacares*), aimed at the export market, started in Maldives in the mid-1990s. Fishermen use the presence of dolphins to locate the schools of yellowfin (Adam and Jauharee, 2009; Anderson, 2005; Anderson and Shaan, 1998; 1999). The species most commonly associated with yellowfin tuna is the spotted dolphin, although spinner dolphins do also associate. Yellowfin tuna and dolphins also regularly associate in Sri Lankan (De Silva and Boniface, 1991) and Omani waters (Ballance and Pitman, 1998).

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Cetacean sightings and acoustic detections in the offshore waters of the Maldives during the northeast monsoon seasons of 2003 and 2004

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ABSTRACT

Despite its central position in the Indian Ocean Sanctuary, little is known about the offshore cetacean fauna of the Maldives. Here we report survey results gathered by the R/V *Odyssey* in the Maldives during the 2003 and 2004 northeast monsoon seasons, and provide data on cetaceans from visual and acoustic observations. The survey was conducted over a period of 72 days and covered 10,915 track line kilometres. The main aim of the survey was to collect biopsy samples from sperm whales (*Physeter macrocephalus*) as part of a global survey of ocean pollutants. Totals of 157 sightings and 1,461 acoustic detections of 16 identified cetacean species were recorded. Risso's dolphin (*Grampus griseus*), pantropical spotted dolphin (*Stenella attenuata*), spinner dolphin (*Stenella longirostris*) and sperm whale were the most commonly sighted species. Sperm whales and pantropical spotted dolphins were particularly abundant in the southern Maldives. The cetacean acoustic detection rate was 2.5 times higher than in the eastern Indian Ocean and Western tropical Pacific, while the non-physeterid sighting rate was 1.7 times higher than the Eastern tropical Pacific and 6.7 times higher than the eastern Indian Ocean based on other research conducted by the R/V *Odyssey* using the same methodology. It is concluded that the Maldives has a diverse and seemingly abundant cetacean community.

KEYWORDS: INDIAN OCEAN; SANCTUARIES; SURVEY-ACOUSTIC; SIGHTING; SPERM WHALE; MALDIVES

INTRODUCTION

The Indian Ocean Sanctuary (IOS) was declared by the International Whaling Commission (IWC) in 1979, and prohibits commercial whaling in the region. It has also had the effect of allowing recovery of exploited populations of great whales within the Indian Ocean and facilitating benign research on populations of cetaceans not subjected to commercial whaling. Relatively few studies have been undertaken to shed light on cetacean communities within the IOS (Ballance and Pitman, 1998; De Boer *et al.*, 2003). Consequently there remains a need for expanding the knowledge of species composition, distribution, abundance and population sizes of cetaceans in the Indian Ocean, to establish baselines for management, conservation measures and mitigation of potential threats.

The Republic of the Maldives lies within the IOS, at the centre of the northern Indian Ocean, but relatively few cetacean studies have been undertaken (reviewed by Anderson *et al.* 2012). Among recent studies, Anderson *et al.* (1999) reviewed information on cetacean strandings. Ballance *et al.* (2001) reported on a cetacean survey around the northeast of the archipelago. Anderson (2005) summarised approximately 2,000 cetacean sightings from the period 1990–2002. These studies demonstrated that Maldivian waters have a rich cetacean fauna, comprising at least 23 different species of the families Balaenopteridae, Delphinidae, Physeteridae and Ziphiidae (Anderson *et al.*,

2012b). Other areas within the Indian Ocean hold equal or greater cetacean diversity, but Maldivian waters are particularly interesting from a cetacean monitoring and conservation perspective because there is no local whaling and the fishing methods employed (mostly pole and line for tunas and handline for reef fishes) result in apparently zero bycatch of cetaceans and negligible catch of their prey (Anderson *et al.*, 2012b; 1999; 1998). Thus, the Maldivian cetacean fauna may, in contrast to many other areas in the Indian Ocean, have suffered little from either deliberate or accidental takes. Nevertheless, in the offshore waters of the Maldives in particular very little is known about the cetacean fauna. Here we report data from the 2003 and 2004 surveys by the R/V *Odyssey*, which spent 72 days in the Exclusive Economic Zone (EEZ) of the Maldives seaward of the atoll slope in search of sperm whales.

The R/V *Odyssey*, research vessel of the Ocean Alliance, launched the Voyage of the *Odyssey* in the spring of 2000. The *Voyage* was a five-year global effort designed to gather the first ever baseline data on levels of contaminants throughout the world's oceans by collecting biopsies from sperm whales (*Physeter macrocephalus*) (Ocean Alliance, 2009). An important area in that study was the tropical Indian Ocean, including Maldivian waters. Since *Odyssey's* primary research objective involved the collection of biopsies from sperm whales, track lines were biased towards passing underwater features (such as seamounts) that

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increased the chance of finding this species. Thus, the sighting and acoustic data collected do not allow for estimation of absolute densities nor population sizes for species encountered. Nevertheless, the visual and acoustic observations collected in Maldivian waters offer relevant and much needed information on the cetacean community structure and zoogeography in the northern tropical Indian Ocean. Furthermore, the results of this survey provide a contrast to previous surveys in Maldives, which have concentrated on nearshore waters. Here we present sighting and acoustic data from at least 17 different cetacean species and discuss implications for the understanding of cetacean community structure and conservation within the Maldivian region of the IOS.

MATERIALS AND METHODS

Research area and platform

The Republic of the Maldives lies within the IOS, at the centre of the northern Indian Ocean. Comprising more than 1,200 low coral islands, the archipelago stretches north-south from about 7°N to 1°S, and is surrounded by deep oceanic water. The weather is dominated by the monsoons. The northeast monsoon lasts from about December to March (when ocean currents flow mainly to the west) while the stronger southwest monsoon blows from about May to October (when currents flow eastward) (Anderson *et al.*, 2011; Anderson *et al.*, 1999; Longhurst, 1998; Tomczak and Godfrey, 1994). November and April are inter-monsoon months.

Research was conducted aboard the R/V *Odyssey*, a 28m steel ketch, fitted for extended periods of off-shore research on marine mammals. The research in Maldivian waters was conducted in two study periods: the first from 12 January to 17 March 2003, the second from 9 February to 26 March 2004. Research was thus conducted during the annual northeast monsoon season, when winds are generally light and from the NE, and currents generally run from east to west. During each research season, three cruise legs were completed (Table 1). These cruises between them covered the area between about 7°N to 1°S and 71°E to 75°E (Fig. 1). A total of 10,915 track line km were covered (Fig. 1), 1,470 h were spent on acoustic and visual searches, and 70 sperm whale biopsies obtained. Mean sea state was 2.5 ± 0.9 (mean $\pm$ SD) (range 0–6) yielding excellent (Beaufort 0–2) sighting and listening conditions 52% of the time, and fair (Beaufort 3–4) observation conditions 47% of the time.

There were some differences in areas surveyed between years. During all three legs in 2003, the R/V *Odyssey* operated offshore, beyond the 2000m isobath, searching for sperm whales. In contrast, in 2004, much time was spent more inshore, searching for beaked whales along the outer atoll slopes. In addition, the only cruise leg to visit the north of Maldives was conducted in 2003. For the purposes of this report, northern Maldives is defined as the area north of 5°N; southern Maldives the area south of 3°N, and central Maldives as the area in between.

Visual survey methodology

A watch was maintained during daylight hours (~0600 to 1900h) from an observation platform located 4.6m above water level, with a maximum sighting distance to the horizon of 7.5km. One or two observers surveyed the area 180° forward of the vessel to the horizon by naked eye and 7x40 binoculars. All marine mammal sightings were recorded in the computerised database *Logger 2000* v. 2.05 (developed by the International Fund for Animal Welfare, IFAW). Sighting data included species identification, position (from GPS), number of animals, behaviour, water depth, bearing and distance to the vessel. In addition, the following data were automatically recorded in the database for each entry: time, vessel course and speed, sea surface temperature (SST) and sea state (SS). Sea surface temperature and weather conditions relating to sighting ability (sea state, swell and meteorological conditions) and navigation data were also entered in the *Logger* database every half hour. Visual effort was suspended during times of heavy rain. Sightings within 2km of the vessel's track were approached to obtain species identification, photographs and to estimate school size.

For all species, animals that were observed to be less than half the length of an accompanying animal were classified as calves. Animals more than half the length of an accompanying adult, but less than full size were classified as immature animals. For sperm whales, mature males were determined by their large size (estimated at greater than 12m). Sexually mature female sperm whales were classified by the presence of callosities on their dorsal fin (Kasuya and Ohsumi, 1966; Whitehead and Gordon, 1986), although this method is not fool-proof.

Acoustic survey methodology

Acoustic detections of marine mammals were made using a 100m long hydrophone array, consisting of two *Benthos* AQ4

Table 1
Summary of survey effort, by cruise leg.
Note: Regions N,C,S = north, centre, south (see text for definitions).

Leg	Dates	Survey effort		Acoustic stations	Region	Inshore/ Offshore	No. sperm whale biopsies
		km	h				
1	12–24/01/2003	1,938	241	325	C, S	Off	7
2	06–28/02/2003	3,567	448	562	N,C,S	Off	16
3	04–13/03/2003	1,636	199	309	C,S	Off	18
4	09–18/02/2004	1,517	200	261	C,S	In and Off	17
5	02–06/03/2004	443	95	217	C	In	0
6	13–26/03/2004	1,814	287	480	C,S	In and Off	12
	Total	10,915	1,470	2,154			70

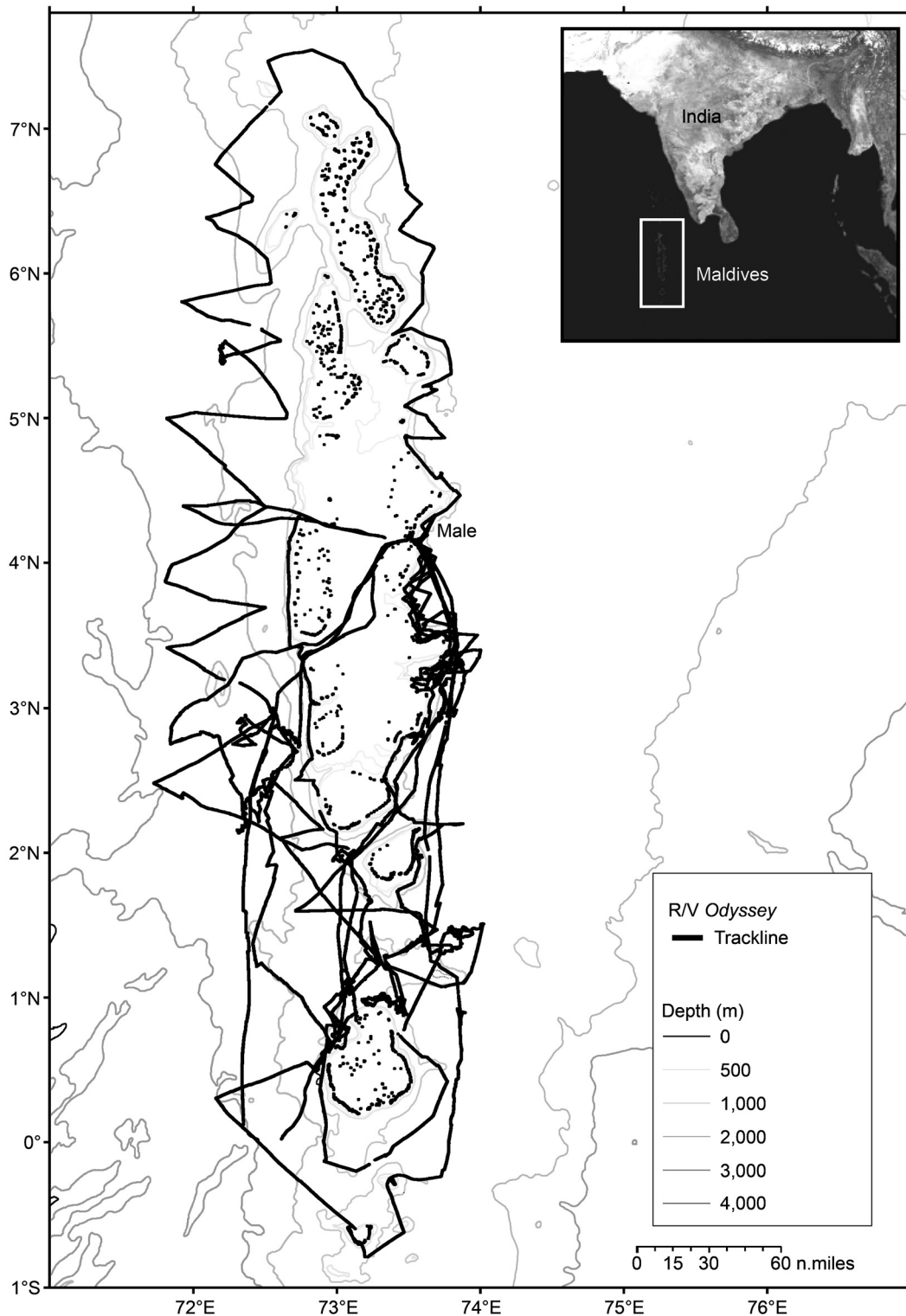


Fig 1. Trackline of R/V *Odyssey*.

hydrophone units with *Benthos* AQ201 pre-amplifiers separated by 2m. Effective listening range was 1–25km depending on weather conditions, vocalising species, and whether the vessel was motoring or sailing. The output signal was connected to headphones, as well as to a pair of stereo speakers located in the pilothouse. Sounds from the array were monitored continuously by the helmsman listening to the speaker set while the vessel was underway. When not actively working with sperm whales, listening stations with headphones were occupied every half hour. An acoustic stop

was made on even hours with the engine turned off and the vessel brought to a speed of less than one knot for a minimum of five minutes. During the half hour and odd hour stations, the engine was reduced to idle speed, the autopilot put on standby for a minimum listening period of five minutes. Acoustic contacts with marine mammals were entered in *Logger 2000*. Acoustic detection rates are reported as detections per listening station.

Incoming data from the acoustic array were automatically scanned for sperm whale clicks with different algorithms

depending on background noise levels. Once sperm whales were detected the vessel was manoeuvred to derive the bearing of clicking animals relative to the vessel. Incoming acoustic data from the array were automatically processed in real time by the software *Rainbow Click* v. 1.03 (IFAW). *Rainbow Click* analysed the stereo signal using time of arrival differences between the same clicks on the two channels to estimate a bearing to each click source.

RESULTS

Sightings

A total of 157 cetacean group sightings were made, of at least 17 different species (Table 2). 107 sightings (68%) were identified to species. Locations of all cetacean sightings are shown in Figs 2–3. Numbers of individuals observed, and mean group sizes are listed in Table 3.

For some species there were large differences in the numbers of sightings and of group sizes between years (Tables 2 and 3). For example, for sperm whales there were more sightings in 2003 ($n = 14$) than in 2004 ($n = 5$). Nine of the sighting in 2003 consisted of single animals, while no single animals were sighted in 2004. The mean size of the other sperm whale groups was 10.9 animals.

There was a marked increase in the number of spinner and pantropical dolphins sighted between 2003 and 2004. For pantropical spotted dolphins, there were more sightings ($n = 13$) in 2003 ($n = 13$) than 2004 ($n = 5$), but the mean group size was significantly larger ($t = 4.7$, $p \leq 0.0006$) in 2004 (191 ± 131) than in 2003 (24 ± 14). For spinner dolphins, the recorded number of groups was similar in both years (8 in 2003 and 7 in 2004) but the mean group size was significantly larger ($t = 2.3$, $p \leq 0.04$) in 2004 (108 ± 105) than 2003 (15 ± 9).

Table 2

Numbers of cetacean sightings by species during the 2003 and 2004 northeast monsoons.

		Number of sightings		
		2003	2004	Total
Bryde's whale	<i>Balaenoptera edeni</i>	4	2	6
Sperm whale	<i>Physeter macrocephalus</i>	14	5	19
Dwarf sperm whale	<i>Kogia sima</i>	–	1	1
Killer whale	<i>Orcinus orca</i>	–	1	1
False killer whale	<i>Pseudorca crassidens</i>	2	1	3
Pygmy killer whale	<i>Feresa attenuata</i>	–	1	1
Melon-headed whale	<i>Peponocephala electra</i>	1	1	2
Short-finned pilot whale	<i>Globicephala macrorhynchus</i>	–	1	1
Spinner dolphin	<i>Stenella longirostris</i>	8	7	15
Pantropical spotted dolphin	<i>Stenella attenuata</i>	13	5	18
Striped dolphin	<i>Stenella coeruleoalba</i>	5	3	8
Common bottlenose dolphin	<i>Tursiops truncatus</i>	1	4	5
Fraser's dolphin	<i>Lagenodelphis hosei</i>	1	1	2
Risso's dolphin	<i>Grampus griseus</i>	3	20	23
Cuvier's beaked whale	<i>Ziphius cavirostris</i>	–	1	1
Longman's beaked whale	<i>Indopacetus pacificus</i>	1	–	1
Beaked whale	<i>Mesoplodon</i> sp.	2	1	3
Unidentified whale		1	6	7
Unidentified dolphin		21	19	40
Total		77	80	157

Acoustics

A total of 2154 acoustic stations were conducted, with cetacean detections recorded during 1461 (68%). Cetacean detections included delphinid species ($n = 1175$), sperm whale ($n = 231$), pilot whales ($n = 19$), killer whale ($n = 1$) and unassigned (114). Thus, 55% of all listening stations detected the sounds of delphinids. The similarity in tonal and click sounds from a wide range of smaller delphinids did not allow for acoustic species identification, with the exception of dolphin detections which were augmented by visual identification (including Risso's dolphins, $n = 18$). However, short-finned pilot whales and killer whales could be identified by their distinctive whistles.

All sperm whale groups were first detected acoustically, followed by visual location. No sperm whale groups were detected by only one method. The mean time spent with a group was 14h (± 5 h) and acoustic and/or visual contact was maintained until effort was terminated upon data set completion; no groups were lost prior to termination of effort.

DISCUSSION

This study recorded 17 species from the Maldives. At the time of these surveys only four other cetacean species had been reported in Maldivian waters (Anderson, 2005; Anderson *et al.*, 1999; Ballance *et al.*, 2001).

Six species were sighted only once each (Table 1): dwarf sperm whale, Cuvier's beaked whale, Longman's beaked whale, killer whale, pygmy killer whale and short-finned pilot whale. The sighting of Longman's beaked whales was previously reported by Anderson *et al.* (2006). The one group of killer whales was seen attacking common bottlenose dolphins off the west side of the Maldives (at 3°03'N 72°49'E) on 24 March 2004. Killer whales and pygmy killer whales are both considered to be uncommon in the Maldives (Anderson, 2005; Ballance *et al.*, 2001). The other four species are not especially rare in the Maldives, indeed short-finned pilot whales and dwarf sperm whales are relatively abundant (Anderson, 2005; Ballance *et al.*, 2001), but they are encountered most commonly over the outer atoll slopes. This survey spent more time in offshore waters than slope waters compared to previous surveys.

More time was spent in near-atoll slope waters in 2004 than in 2003. This may explain inter-annual differences in sightings for some species. Thus, slope-associated species, notably Risso's dolphin, dwarf sperm whale and short-finned pilot whale, but also Cuvier's beaked whale (Anderson, 2005), were sighted only in 2004, but given the low sightability of this species no inferences can be drawn on year to year changes. In contrast, 'offshore' species such as sperm whale, striped dolphin and spotted dolphin, were sighted more frequently in 2003 than 2004 (Tables 2 and 4). However, there were more individuals of both striped and spotted dolphins recorded in 2004 than 2003, and we note that this division between inshore and offshore does not explain all interannual differences.

The pantropical spotted dolphin was the most common species recorded by number (Table 3). It was also the third most frequently sighted species over both seasons (Table 2). Pantropical spotted dolphins were most frequently

Table 3
Numbers of individuals seen and mean group sizes by species and survey season.

	Number of animals			Mean group size		
	2003	2004	Total	2003	2004	Total
Bryde's whale	4	4	8	1.0	2.0	1.3
Sperm whale	64	54	118	4.6	10.8	6.2
Dwarf sperm whale	0	2	2	—	2	2
Killer whale	0	8	8	—	8	8
False killer whale	40	70	110	20	70	37
Pygmy killer whale	0	10	10		10	10
Melon-headed whale	1	33	34	1	33	17
Short-finned pilot whale	0	15	15		15	15
Spinner dolphin	122	756	878	15	108	59
Pantropical spotted dolphin	288	955	1,243	22	191	69
Striped dolphin	71	127	198	14	42	25
Common bottlenose dolphin	10	107	117	10	27	23
Fraser's dolphin	100	175	275	100	175	138
Risso's dolphin	60	237	297	20	12	13
Cuvier's beaked whale	0	4	4	—	4	4
Longman's beaked	5	0	5	5	—	5
Beaked whale	3	4	7	1.5	4	2.3
Unidentified whale	2	13	15	2	2.2	2.1
Unidentified dolphin	283	226	509	13	12	13
Total	1,053	2,800	3,853			

encountered in the southern Maldives (Figs 2 and 3), and were not recorded at all from the north of Maldives. Ballance *et al.* (2001) considered pantropical spotted dolphins to be uncommon during their survey of northern waters. However, Anderson (2005) reported this species to be common throughout the Maldives, albeit especially so around the southern atolls.

Spinner dolphins have previously been recorded as the most frequently sighted species in the Maldives (Anderson, 2005; Ballance *et al.*, 2001), as well as the most abundant species in the western Indian Ocean (Ballance and Pitman, 1998). During this study, however, spinner dolphins were only the second most numerous and fourth most frequently sighted species (Tables 2 and 3). This might again be explained in part at least by the fact this survey spent much time offshore, since spinner dolphins are frequently atoll-associated (Anderson, 2005).

Sperm whales were the most commonly recorded species in 2003, and the second most commonly recorded species overall. This is consistent with the findings of both Ballance and Pitman (1998), who found sperm whales to be the most frequently sighted cetacean in the western Indian Ocean, and of Anderson *et al.* (1999), who reported the sperm whale to be the most commonly stranded cetacean in the Maldives. Furthermore, our survey was designed to maximise the likelihood of finding sperm whales, spending much time offshore and using previous experience of those bathymetric features which provide appropriate habitat for this species. In contrast, surveys of Maldivian inshore waters have recorded relatively low numbers of sperm whales (Anderson, 2005; Ballance *et al.*, 2001).

Nearly all of our sperm whale sightings and acoustic detections occurred in the southern Maldives, between about 0° and 3°N (Figs 2 and 3). This suggests that the mesopelagic prey of sperm whales may be most abundant in this area, at least during the northeast monsoon. The south of the Maldives is under the influence of the equatorial current

systems, rather than the seasonal monsoon currents that affect the northern and central atolls. As a result the south of Maldives is known to have a rather different pelagic fauna from the north and centre (Anderson, 2005; Anderson and Saleem, 1994; Anderson *et al.*, 1998).

A similar number of sperm whales were sighted during both years although there were differences in the number of groups sighted. Fourteen groups consisting of 64 sperm whales were sighted in 2003 while five groups consisting of 54 animals were sighted in 2004. However, nine of the 14 groups sighted in 2003 consisted of single animals, while no single animal sightings were recorded in 2004. Although groups of adult males and females, as well as the immature of both sexes were sighted during both years, calves were only sighted in one group in 2004. This group, which was the largest encountered during the study, included two calves and two adult females with callosities on their dorsal fin. Acoustic 'clangs/slow clicks', which are presumed to be made only by mature males (Whitehead, 2003), were recorded while with this group, suggesting that an adult male was within acoustic range of the array even though none was sighted. The two calves recorded represented less than 2% of the sperm whales sighted during this study. The ratio of calves to animals with callosities, which are presumed to be adult females (Kasuya and Ohsumi, 1966; Whitehead and Gordon, 1986), was 1 to 5.5; this is much lower than the 1:2 ratio reported for Sri Lanka (Gordon, 1987). On this basis, only 10% ($n = 11$) of sperm whales sighted were presumed adult females, which was lower than the average of 33% previously reported for tropical waters (Best, 1979). However, it is likely that there were some adult females without callosities. It is also possible that our working definition of 'calves' as being less than half the length of accompanying animals may have caused us to underestimate their true number. Nevertheless, the data we recorded suggest relatively low numbers of adult females and calves in the Maldives, and may indicate that this area is not a major

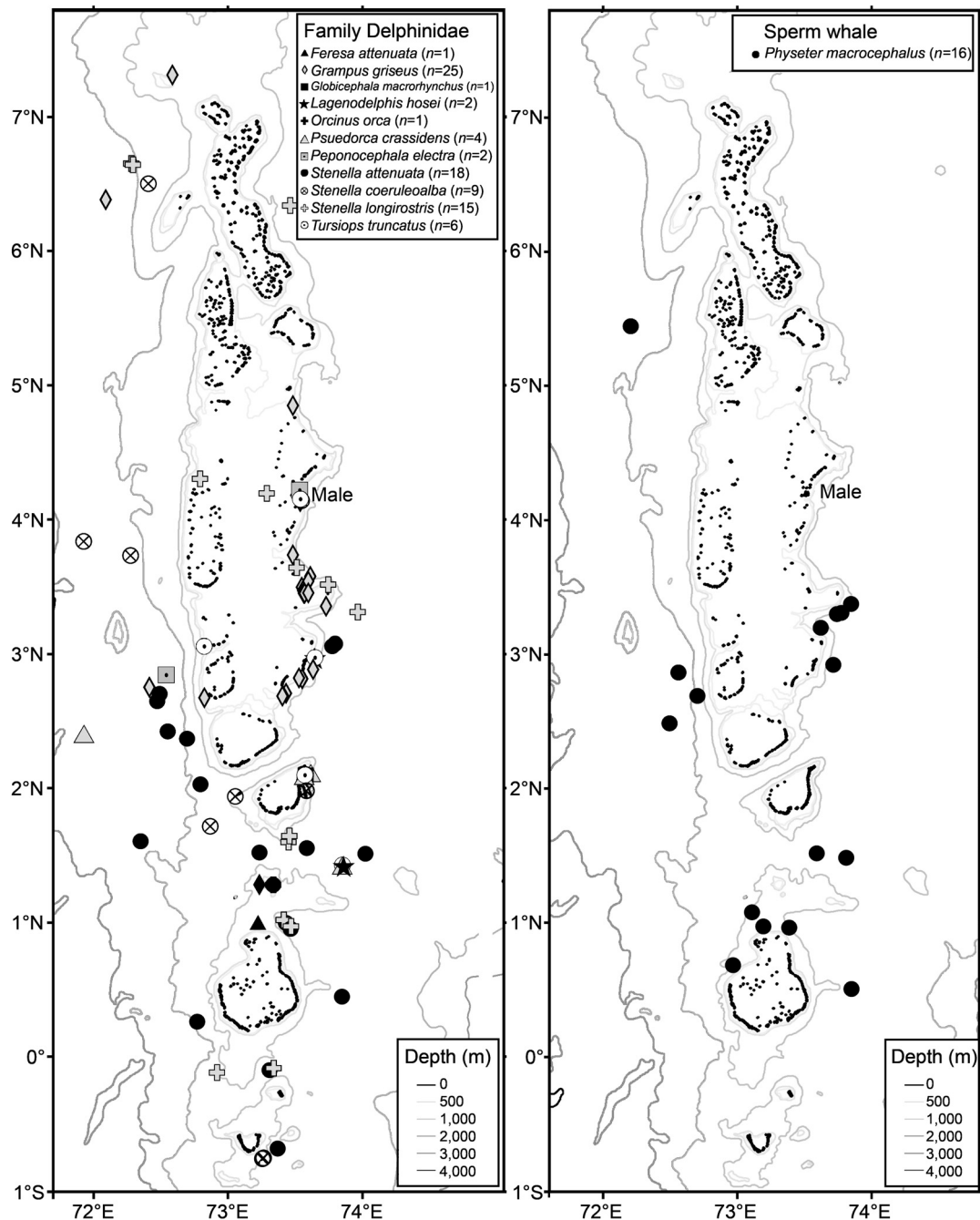


Fig 2. Delphinid and sperm whale sightings.

nursery ground for sperm whales. However, further studies, including surveys at different seasons, and of movements of sperm whale groups within the Indian Ocean, will be needed to understand the social structure of groups and how they change on temporal and geographical scales.

Subadult and adult male sperm whales ($n = 21$) accounted for nearly 19% of all sperm whales recorded. This is much higher than the 3% reported during peak breeding season in Galapagos (Whitehead, 1993) or the 4.2% reported in the West Indies (Whitehead, 1987). Furthermore Gordon (1987) rarely sighted adult males in Sri Lankan waters during the northeast monsoon; the sperm whale population there consisted almost entirely of adult females and immature animals of both sexes, with no animals exceeding 12 m in length (Gordon, 1991). In contrast, Maldivian stranding data show that about 22% of stranded sperm whales were greater

than 12m (Anderson *et al.*, 1999) suggesting that they were adult males.

We did not record any blue whales (*Balaenoptera musculus*) although this species had been previously recorded from Maldivian waters during several studies (Anderson, 2005; Anderson *et al.*, 1999; Ballance *et al.*, 2001; Ballance and Pitman, 1998). One reason may be that our hydrophone array was unable to detect blue whale calls due to flow noise, Lloyd mirror effects and a 400Hz high pass filter. In addition, most of our survey effort was in February and March, when blue whales appear to be relatively scarce in the Maldives (Anderson *et al.*, 2012a).

Both acoustic detection rates (defined as detections per listening station) and sightings rates for non-physeterid cetaceans were higher in Maldivian waters than in any other Voyage of the *Odyssey* study area (Ocean Alliance,

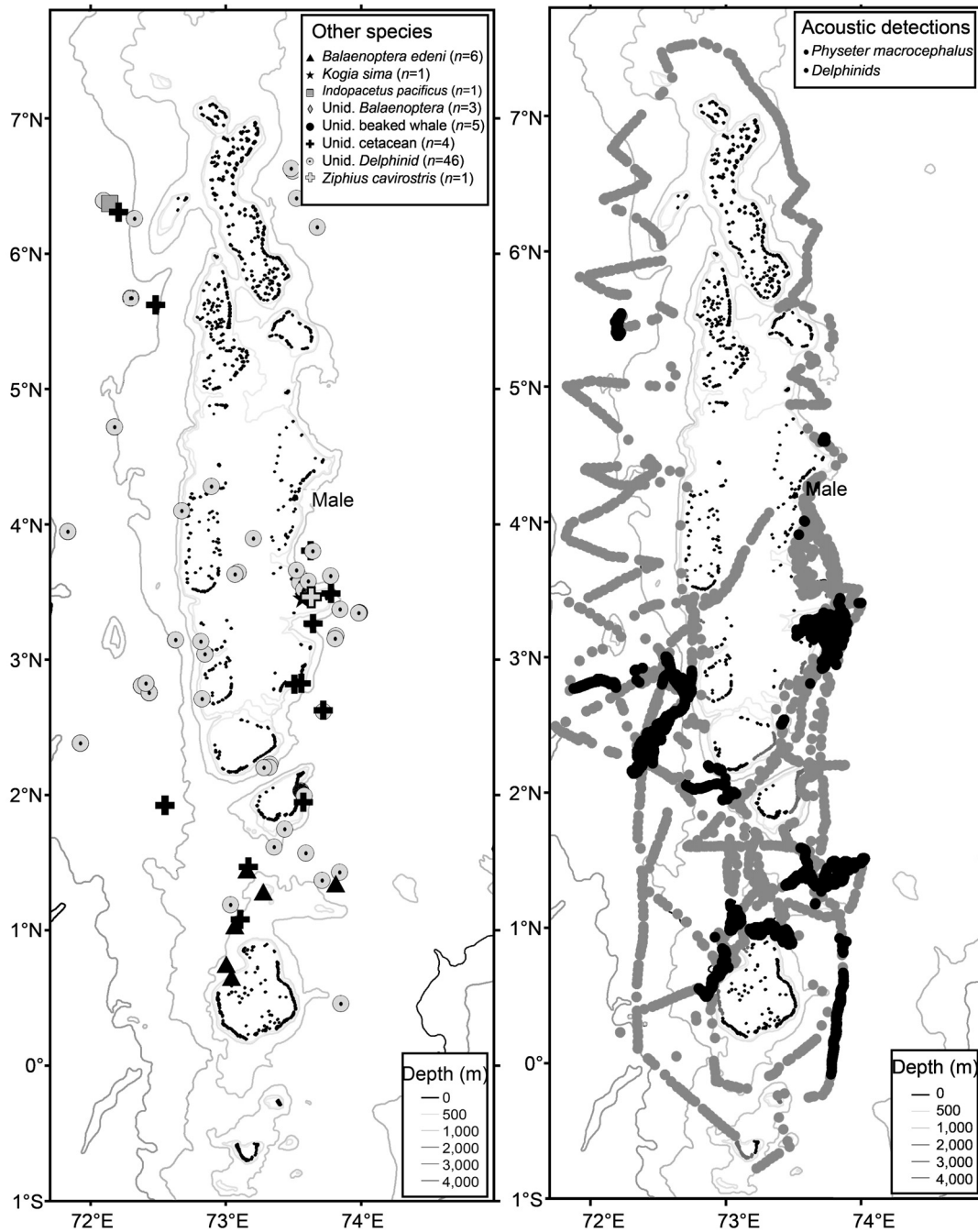


Fig 3. Sightings of other species and acoustic detections of delphinids and sperm whales.

unpublished data). Maldivian cetacean acoustic detection rates were double those for the rest of the western tropical Indian Ocean and over 2.5 times higher than both the eastern Indian Ocean and the Pacific Ocean. Maldivian sighting rates for non-physeterid cetaceans were 1.2 times higher than in the rest of the western Indian Ocean, 6.7 times higher than in the eastern Indian Ocean and 1.7 times higher than in the Western Tropical Pacific.

Differences in sea states and perhaps also seasonal effects in different survey areas will have influenced these regional differences. Nevertheless, the high acoustic and visual detection rates in the Maldives strongly suggest that these waters have a seemingly abundant cetacean fauna in comparison not only to the rest of the Indian Ocean but also to at least some parts of the Western tropical Pacific. One factor contributing to this apparently high cetacean

abundance may be the unique geographical setting of the Maldives island chain, which lies north-south across the east-west flow of the monsoon currents. Through upwelling and other processes, this juxtaposition enhances primary productivity, providing increased feeding opportunities for marine predators (Anderson *et al.*, 2011; Longhurst, 1998). In addition, fishing practice and policies within the Maldives result in apparently zero by-catch of cetaceans and very little waste of unwanted fish catch. Tuna fishing is of particular significance, and Maldivians continue to practice a traditional pole and line technique. All forms of pelagic netting (including gill-netting, purse seining and trawling) are banned. Thus, the Maldives represents a rare oceanic area in which fisheries policies are implemented with apparent benefits for cetaceans and the broader oceanic ecosystem.

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Occurrence of whales and dolphins in Pakistan with reference to fishers' knowledge and impacts

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ABSTRACT

This paper reports the findings of a project (Cetacean Conservation Pakistan) launched in 2004 with a view to: (a) undertaking quantitative surveys to determine the variety and abundance of species present; (b) working with local fisher communities to collate local knowledge and promote public awareness; and (c) promoting a marine cetacean conservation strategy and measures. Boat-based surveys for live animals and shore surveys for beachcast specimens have confirmed the presence of twelve species of whale and dolphin. Among these bottlenose dolphins (*Tursiops* sp.) occur both inshore along the coasts of Sindh and Balochistan, and offshore in parts of Balochistan; these two populations possibly representing different sub-species. Indo-Pacific humpback dolphins (*Sousa chinensis*) are common inshore around the mouth of the Indus Delta and in large sheltered bays in Balochistan, where finless porpoise (*Neophocaena phocaenoides*) also occur. Spinner dolphins (*Stenella longirostris*) were observed in very large schools (up to 2,000) around the shelf edge in eastern Balochistan, as were Risso's dolphins (*Grampus griseus*) in smaller numbers. Common dolphins (*Delphinus capensis*) were recorded even further offshore. There were two sightings of humpback whales (*Megaptera novaeangliae*), and one of a killer whale (*Orcinus orca*). Bryde's whales (*Balaenoptera edeni*), sperm whales (*Physeter macrocephalus*) and Cuvier's beaked whales (*Ziphius cavirostris*) were recorded only during beach surveys, while skeletal remains in institutions also supported the occurrence of blue whales (*Balaenoptera musculus*). Work with local fisher communities supported this picture of species distribution and provided information on threats to local cetaceans. These are principally occasional entanglement in fishing gear and opportunistic exploitation for use as food, as bait, as medicine or for other purposes. The project incorporated policy development and the preparation of a marine cetacean biodiversity action plan that included the listing of species in provincial conservation legislation, the designation of a marine protected area in Balochistan, the establishment of a national whale and dolphin conservation society, and trials of whale and dolphin watching as a means of raising public awareness and providing alternative economic value.

KEYWORDS: ABUNDANCE ESTIMATE; ARABIAN SEA; KILLER WHALE; BRYDE'S WHALE; SPERM WHALE; CUVIER'S BEAKED WHALE; BLUE WHALE; BOTTLENOSE DOLPHIN; CETACEANS; CONSERVATION; FINLESS PORPOISE; FISHERIES INTERACTION; HABITAT; RISSO'S DOLPHIN; COMMON DOLPHIN; INDO-PACIFIC HUMPBAC DOLPHIN; HUMPBAC WHALE; INCIDENTAL CATCHES; INDIAN OCEAN; SPINNER DOLPHIN; SURVEY-SHORE-BASED; SURVEY-VESSEL

INTRODUCTION

Scientific background

Until now there has been little information available on the identification, distribution and relative abundance of cetaceans occurring in the Pakistani portion of the Arabian Sea (NW Indian Ocean). Some reviews have indicated the species most likely to be present (e.g. De Boer *et al.*, 2002; de Silva, 1987; Roberts, 1997), while reports arising from illegal Soviet whaling off Pakistan during the 1960s (when 164 humpback whales were killed off Pakistan between late-October and mid-December over a three year period) indicate that significant, previously unstudied populations of humpback whales (*Megaptera novaeangliae*), blue whales (*Balaenoptera musculus*) and sperm whale (*Physeter catodon*) might be present (Mikhalev, 1997; 2000).

In addition, there have been various reports of incidental sightings or strandings. Ahmed and Rizvi (1985) reported a humpback whale caught off Port Qasim on the Sindh coast, as well as records of humpback dolphins (*Sousa plumbea*), long-beaked common dolphins (*Delphinus capensis*) and melon-headed whales (*Peponocephala electra*) off Sonmiani, Balochistan. Ahmad and Ghalib (1975) collated reports of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*), Indo-Pacific humpback dolphins, finless porpoises

(*Neophocaena phocaenoides*), blue whales, fin whales (*B. physalus*) and sperm whales from along both the Sindh and Balochistan coasts. Roberts (1997) reported a Bryde's whale (*B. edeni*) sighted off Las Belas, Balochistan, and a dwarf sperm whale (*Kogia sima*) sighted off the Indus Delta, Sindh province. A pygmy sperm whale (*K. breviceps*) was reported off Sonmiani (M. Khan and S.H.N. Rizvi, pers. comm). In addition Pilleri and Gühr (1972a; 1972b), on visiting coastal areas to search for cetacean remains, found four finless porpoises, seven humpback dolphins, five common dolphins and a bottlenose dolphin; they also found a vertebra that they suggested belonged to a Cuvier's beaked whale *Ziphius cavirostris* (see Gore *et al.*, 2007b for discussion). Similarly, until recently no systematic surveys of cetaceans had been conducted off the coasts of Pakistan's neighbours – India (Afsal *et al.*, 2008) and Iran (Braulik *et al.*, 2010a).

As noted by Kumarran (2002; 2009) a lack of data regarding threatened species invariably weakens national biodiversity policies. Thus in Pakistan, Rizvi *et al.* (1995) concluded there was inadequate information available on small cetaceans in Pakistan's Indus Delta region and called for detailed assessments to facilitate the preparation of species action plans. More recently such information has again been required in support of Pakistan's National Conservation

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Strategy and Biodiversity Action Plan. Accordingly the research reported here was undertaken between 2004 and 2009 in order to determine the identity, relative abundance, habitats, seasonality and association patterns of cetaceans occurring in the coastal waters of Pakistan.

Fishers and cetaceans

The territorial waters of Pakistan are included in the Indian Ocean Sanctuary, which was established in 1979 to protect whales from hunting. It should however be noted that this protection does not extend to dolphin species and that all cetaceans in the region remain susceptible to mortality or injury from non-targeted fishing activities. In this context, an early concern for this project was that Pakistan had greatly increased its export of fish in recent years (Marine Fisheries Department, 2006), an indicator of considerable intensification of fishing activities. As well as potentially diminishing the availability of food for cetaceans, increased fishing readily leads to increased cetacean bycatch, and perhaps also increased numbers of boat strikes (Niazi, 1990). On a global level Northridge (2002) concluded that porpoises (*Phocaenidae*) often entangle in gillnets, while dolphins are widely caught in pelagic trawls and purse seine nets, as well as on hooks. Reeves *et al.* (2003) suggested that local declines in small cetaceans are most usually due to increased vessel activity and intensification of fisheries. In Pakistan a variety of fishing vessels from 6–8m long *tony*, *katti* or *hori* to 15–25m trawlers are used nearer the coast, while offshore larger gill-netters and trawlers operate (Marine Fisheries Department, 2006). These different vessels deploy a very wide range of gear, including drift nets (2 types), bottom set gillnets (3 types), surround gillnets (4 types), encircling nets (like seine nets, 4 types) and trawl nets (3 types), as well as trap nets (5 types), pots (2 types), hand lines, long lines (3 types), and jig lines (2 types) (Hussain and Amir, 2006). Hence there is considerable scope for unintentional injury or bycatch of cetaceans, as well as a potential for deliberate targeting, which has already been reported as occurring to some degree in Pakistan (Niazi, 1990).

Thus in 2004 a project (Cetacean Conservation Pakistan) was launched with a view to: (a) undertaking quantitative surveys to determine the variety and abundance of cetaceans present in Pakistani waters; (b) working with local fisher communities to collate local knowledge of both cetacean occurrence and fishers' interactions with them; and (c) promoting public awareness of cetacean issues and developing a strategy and measures for securing cetacean conservation. As with other taxa, the extent to which effective conservation can be achieved depends on the attitude of key stakeholders, including most critically in this case local fishers; thus this work was also undertaken with a view to encouraging fishers' and wider community support for conservation measures. This paper reports the results of that project.

METHODS AND STUDY AREA

Study area

Pakistan has two coastal provinces with contrasting coastlines (Majid, 1988). The Balochistan or Makran coast bordering Iran in the west extends for about 800km, and is dominated by large rocky cliffs interspersed with long sandy shores. The continental shelf varies in width from about 3km (by Gwadar in the west) to 73km (by Hub River in the east), beyond which the shelf edge drops rapidly to 1,000m and then deeper to the Oman Abyssal Plain. By contrast the Sindh coast, which extends for 250km bordering India in the east, is dominated by sandy-muddy shores with innumerable creeks and deltaic tributaries often colonised by mangrove forest (Meynell, 1999; Quraishie, 1988). It has a broader continental shelf, ranging from about 77km wide by Karachi to 160km wide near Kori Creek mouth, except where a narrow trench 'The Swatch' that reaches 200m deep, extends shorewards in the southern part (see Fig. 1). The salinity along the Karachi coast ranges from 35.5 to 36.9ppt, but can reach 41–42ppt in tidal creeks (Ahmed and Rizvi, 1980). Oxygen levels are normally 4.0–4.5ml⁻¹ in the well mixed zones, but levels as low as 1.5ml⁻¹ can occur in shallow areas during the SW monsoon (Haq *et al.*, 1978). Tides are semi-diurnal with a range of about 3.5m.

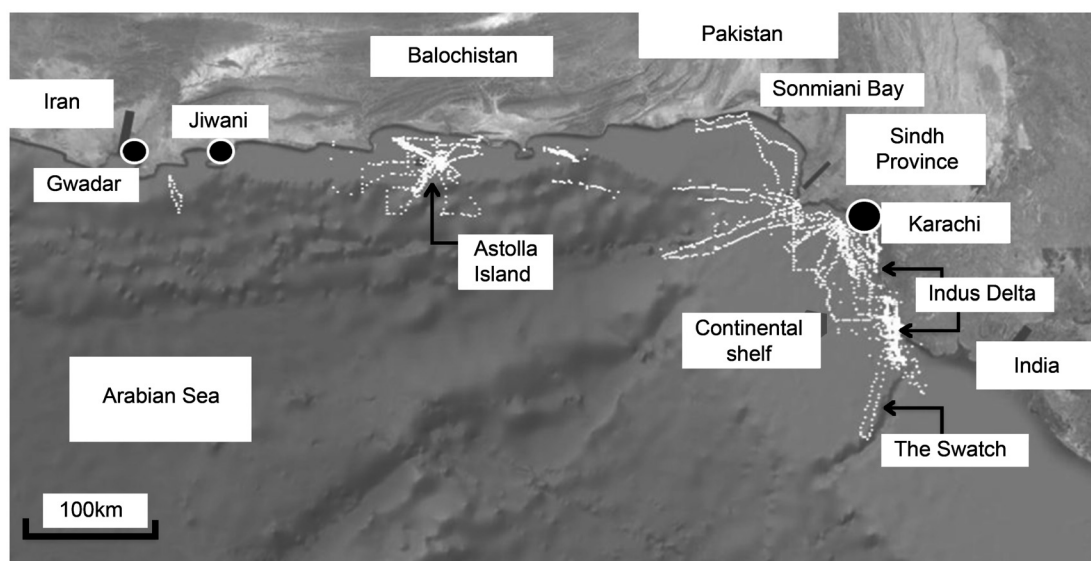


Fig. 1. Morphological and bathymetric map of the Pakistani coast and adjacent marine areas showing the regions and locations mentioned in the text together with, as a series of white dots, the majority of tracks generated during boat survey work (each dot representing a GPS location recorded during a survey).

Coastal weather contrasts sharply between NE and SW monsoon periods, which occur during November to February and June to September respectively, being separated by shorter Spring and Autumn Inter-monsoonal Periods (Kidwai and Amjad, 2000). The SW monsoon is characterised by greater wind speeds (*ca.* 25kt as opposed to <10kt) that extend water mixing below the thermocline (Wyrki, 1973) and produce extensive upwelling over a variable portion of the central Pakistan coast (Quraishie, 1988). This results in increased nutrient availability and high plankton biomass values (Qasim, 1977; Smith, 1988), although pelagic fish including mackerel, sardine and anchovy also occur along the coast during the NE monsoon (Majid, 1988).

Methods

Surveys to assess the abundance of cetaceans were conducted: (a) by boat; (b) by foot along the coastline; and (c) by interviewing fishers. Species identification guides used included Jefferson *et al.* (1993), (Perrin *et al.*, 2008) and Reeves *et al.* (2002), with a simpler identification leaflet being produced for distribution to fishers and the interested public.

Boat-based cetacean surveys

A total of 63 days of transect surveys for cetaceans were conducted by boat between 16 November 2005 and 11 December 2009. Surveys were conducted both inshore and offshore along different sections of coast, and in every month except July and October (Table 1); they were however more frequently undertaken during the NE monsoon than the SW monsoon or the inter-monsoon periods, since sea conditions are much more favourable at that time. Due to varying location and vessel availability several different platforms were employed, including a 12m fishing launch (used for longer surveys or further offshore), 5m wooden 'horas' (used largely in the Indus Delta area), and a 5m rigid inflatable boat (used both in the Indus Delta and along the coastline under more predictable conditions). Only single observation areas were available on each boat giving observer eye heights above the water of 2.5, 1.7 and 1.7m respectively.

During surveys data were collected on effort, species occurrence, relative abundance, behaviour and groupings (Ballance *et al.*, 2001; Weir *et al.*, 2001) in relation to four marine habitat zones: near shore (0–50m depth); continental shelf (50–200m depth); shelf edge (>200–1,000m depth) and pelagic (>1,000m depth). For a combination of logistical and security reasons it was not feasible to survey the whole study area either homogeneously or through a random sampling design (for discussion of this issue see Cañadas *et al.*, 2002). Instead courses were pre-selected: (a) to cover as much as

possible of the full length of the coast largely within sight of the shore; and (b) in selected sections to cover different marine zones by surveying along transects perpendicular to the depth contours (see Dawson *et al.*, 2008) (see Fig. 1). Normally surveys were initiated only when sea-state was equivalent to Beaufort wind scale force 3 or less with accompanying swells of 0.5m or less, and in weather conditions where there was little or no rain, and good or excellent visibility. Boat surveys were normally carried out over full days, with the earliest time that a survey commenced being 06:57 and the latest that one ended 19:24. Survey effort was measured as the distance (km) travelled per day with the length and route of the survey track being logged using a handheld Garmin GPS unit.

During surveys a 3-person observer team was stationed forwards on the vessel. Two scanned the water to the horizon with both the unaided eye and 7 × 50 binoculars, one observer sweeping an arc from the bow to beam on the port side, and the other likewise to starboard. The third member of the team acted both as recorder and between-times as a back-up observer. To avoid tiredness or eyestrain observers rotated their role every half hour, with each being replaced by another crew member and taking a full rest after every 1.5hrs on watch. 'Closing-mode' was adopted (Dawson *et al.*, 2008) with the search along the transect route being maintained until one or more cetaceans were sighted, at which point the vessel's course was changed to approach the animals for closer observation. At the end of the sighting, the survey track was regained at the point of departure. Data collected during sightings included: location; distance and bearing from boat at first sighting; time of day; species; group size (minimum/maximum/best estimate); group composition (adults/female and young/mixed age group); direction of travel; and observed behaviour (surface active/feeding/travelling/social interaction/interaction with vessels).

Otherwise, the following data were logged by the team recorder at ten minutes intervals throughout the duration of the survey: sea-state; apparent modal swell height in meters; speed and heading of boat; and latitude and longitude as determined by GPS. Weather conditions including wind strength (Beaufort scale) and direction, cloud cover and visibility were recorded hourly. Boat survey speed was 8–15kt [15–25km h⁻¹] dependent upon sea conditions and boat type. In addition to sightings of cetaceans, all piscivorous seabirds to a distance of 250m were recorded, as were all passing vessels to a distance of *ca.* 10km, for their potential influence on cetacean occurrence. Mean sea state was 1.8 in Sindh and 1.9 in Balochistan, with mean swell heights being 0.33 and 0.40m respectively. Mean air temperature was

Table 1

Days of boat-based survey undertaken by month, season and province (NE = northeast monsoon; IMS = spring inter-monsoonal period; SW = southwest monsoon; IMA = autumn inter-monsoonal period).

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
Season	NE	NE	IMS	IMS	IMS	SW	SW	SW	SW	IMA	NE	NE	Total
Sindh	1	0	3	4	4	1	2	2	2	0	7	12	38
Balochistan	3	18	1	0	0	0	0	0	0	0	2	1	25
Total	4	18	4	4	4	1	2	2	2	0	9	13	63

slightly higher in Balochistan than in Sindh (25.6°C vs. 23.2°C), but mean sea surface temperatures were similar (24.1°C vs. 24.0°C). During boat-based surveys numerous small fishing vessels were recorded in both provinces, but large cargo vessels and tankers were observed only in the Near Shore zone of Sindh. No military or seismic survey vessels were observed at any time.

In addition to sightings of cetaceans made while on-effort, other sightings made during transit at higher speed, during breaks, or in closing mode during surveys, were also recorded. The data on distance and bearing of first sightings have not yet been analysed to give estimates of absolute population density, but the numbers of individuals sighted per km of trackline has been used to provide a measure of relative abundance and distribution across the study area (Weir *et al.*, 2001). The data were analysed in relation to species type, abundance and grouping patterns, province, season, marine habitat type and human activity present. A general linear model was used to assess the statistical significance of trends, with the Unequal *N* Honest Significant Difference test being used as a *post hoc* test.

In addition to data from the above boat-based survey work, unpublished data from boat-based observations undertaken during an offshore seismic survey for gas and oil were provided to the authors and have been incorporated in the present study with the permission of those concerned (Pickering, 2004). This survey work took place in 320–1,300m of water approximately 190km offshore of Sindh between 11 October 2003 and 13 December 2003, in an area of 5,147 km² bounded by the points 23.70°N 66.62°E to the NW, 23.68°N 66.10°E to the NE, 23.42°N 65.62°E to the SW and 23.40°N 66.10°E to the SE. There was a single observer present throughout the daylight period who had a 180° view at 15.3m height on the bridge of a 86.9m vessel. A continuous scan was made by both unaided eye and binoculars and distance to the cetaceans was estimated. The total watching time was 746h, of which 452h 39min was during gun firing.

Shore-based surveys for beachcast specimens

A band transect method was used to survey beaches for beachcast cetaceans or their remains. Teams of surveyors walked in line abreast the full length of each beach with individual surveyors being placed approximately 4m apart, so that each observer carefully scanned 2m to either side, looking for signs of skeletal or other remains. On wider beaches the team covered the remaining width of the beach on the return journey. Observers noted their location (latitude and longitude) every ten minutes. When remains were found the date and time, the species of cetacean and condition (state of decomposition if recently dead) were also recorded and skeletal specimens and where possible tissue samples taken. Those sections of coast not surveyed were generally those that were either difficult to access, or where government permission to work the area was withheld for security reasons.

To complement field surveys and involve local communities, a community reporting scheme was established, with fishers, senior villagers and other personnel located on the coast being requested to alert the research team in the event of any stranded or beachcast cetaceans

being found. When dead specimens were encountered, body measurements and photographs were taken, and samples of tissues and teeth recovered and preserved. The authors also visited several institutions (including non-scientific ones) where cetacean skeletons were housed or on display to take measurements and check species identification.

Fisher community-based surveys

Fishing communities along the full length of the Pakistan coast were visited both to sample local knowledge through interviews with fishers, and to explain the work of the team to local people. The methods used were guided by the experience of community-surveys undertaken elsewhere (developing countries: Aragonés *et al.*, 1997; the Caribbean: Grant and Berkes, 2007; the UK: Howard and Parsons, 2006; Kenya: McClanahan *et al.*, 2005; Indonesia: Teh *et al.*, 2005). A simple questionnaire was designed and used to interview a sample of fishers in each community, along with a pictorial guide to the cetacean species likely to be present, copies of which were distributed in each community. In Sindh, 197 interviews were carried out (by BH) in 46 communities between 5 December 2005 and 12 July 2008, and in Balochistan, 105 fishers were interviewed (by UW) in 28 communities between 6 March 2007 and 30 April 2008. In addition approximately 50 fisher community leaders were invited to a workshop in each province; at each further information and feedback on project findings were provided and wider issues relating to cetacean conservation discussed.

RESULTS

Boat-based cetacean surveys

Species overview

The species recorded during boat surveys were humpback whale, Risso's dolphin (*Grampus griseus*), killer whale (*Orcinus orca*), humpback dolphin, spinner dolphin (*Stenella longirostris*), bottlenose dolphin (*Tursiops* sp.), and finless porpoise (Table 2). The most numerous species observed was spinner dolphin, which was more abundant in Balochistan than in Sindh (GLM Genus by Province: $F_{(6,518)} = 3.76$, $p = 0.001$), and also more numerous than any other species (as shown by post-hoc tests). Excluding spinner dolphins, statistical analysis showed no significant difference in relative abundance between species or between provinces (GLM Genus by Province: $F_{(5,449)} = 1.62$, $p = 0.15$).

Finless porpoise

Finless porpoises were observed only during the NE monsoon and Near Shore, but in both provinces (Table 2). They were recorded mainly between mid-morning and early evening (mean time = 15.14 hrs $\pm$ 0.3hrs), and in good sea conditions (mean sea state = 0.8 $\pm$ 0.1). In an analysis of factors including both time of day and sea state, as well as swell, depth and province, only time of day (GLM $F_{(1,20)} = 5.40$, $p = 0.031$) and sea state ($F_{(1,20)} = 11.53$, $p = 0.0028$) were significant predictors of the number of finless porpoises recorded per distance surveyed ($R^2_{\text{adj}} = 0.29$, $\text{df}_{\text{model}} = 5$, $F = 3.02$, $p = 0.034$), whereas swell ($F_{(1,20)} = 0.55$, $p = 0.5$), depth ($F_{(1,20)} = 0.24$, $p = 0.6$) and province ($F_{(1,20)} = 1.10$, $p = 0.3$) were not. Finless porpoises were observed in groups of 1–18, but were mostly encountered in small groups (mean size 2.86 $\pm$ 0.5) (Table 3); Groups could be composed of adults

Table 2

Numbers of sightings and individuals of different cetacean species recorded during different zones and seasons (abbreviations as for Table 1).

Province	Genus	Season	Habitat	Total no. sightings	Mean no. sightings per km	SE of mean	Mean no. individuals per km
Sindh	Finless porpoise	NE	Near shore	23	0.054	0.008	1.251
Sindh	Bottlenose dolphin	NE	Near shore	5	0.311	0.135	1.554
Sindh	Humpback dolphin	NE	Near shore	64	0.080	0.014	5.126
Sindh	Humpback dolphin	IMS	Near shore	17	0.051	0.006	0.868
Sindh	Humpback dolphin	SW	Near shore	5	0.089	0.028	0.444
Sindh	Unidentified dolphin	NE	Near shore	10	0.024	0.004	0.240
Balochistan	Finless porpoise	NE	Near shore	12	0.064	0.028	0.767
Balochistan	Bottlenose dolphin	NE	Near shore	3	0.410	0.053	1.231
Balochistan	Bottlenose dolphin	NE	Continental shelf	2	0.121	–	0.242
Balochistan	Bottlenose dolphin	NE	Pelagic	1	–	–	0.081
Balochistan	Spinner dolphin	NE	Near shore	1	–	–	0.121
Balochistan	Spinner dolphin	NE	Shelf edge	8	5.101	2.949	40.804
Balochistan	Spinner dolphin	NE	Pelagic	3	3.404	1.668	10.211
Balochistan	Humpback dolphin	NE	Near shore	1	–	–	0.040
Balochistan	Risso's dolphin	NE	Continental shelf	1	–	–	0.141
Balochistan	Risso's dolphin	NE	Pelagic	1	–	–	2.018
Balochistan	Killer whale	NE	Near shore	1	–	–	0.202
Balochistan	Humpback whale	NE	Near shore	2	0.020	–	0.040
Balochistan	Unid. dolphin sp.	NE	Near shore	4	0.056	0.035	0.222
Balochistan	Unid. dolphin sp.	NE	Shelf edge	1	–	–	0.020
Balochistan	Unid. dolphin sp.	NE	Continental shelf	1	–	–	0.040

or a mixture of ages (Table 4), but some compositions were more frequent than others (GLM $F_{(3,31)} = 3.92$, $p = 0.017$), with groups of adults being more likely to be observed than singletons (post-hoc test $p = 0.023$). The species was found both in locations where fishing nets or traps, and fishing boats or larger ships (cargo/tankers) were present, as well as where no human activity was absent, although most often fishing boats were in fact present ($F_{(3,31)} = 3.02$, $p = 0.044$) when the species were observed.

Bottlenose dolphin

Bottlenose dolphins were observed only during the NE monsoon, when they were recorded near shore in both provinces, and in the Continental Shelf and Pelagic zones in Balochistan (Table 2). Using Model A, sea state ($F_{(1,4)} = 33.35$, $p = 0.0044$) and swell ($F_{(1,4)} = 30.34$, $p = 0.0053$) were found to be significant predictors of the numbers of bottlenose dolphin observed per distance surveyed ($R^2_{adj} = 0.79$, $df_{model} = 5$, $F = 7.98$, $p = 0.033$), but time of day ($F_{(1,4)} = 5.24$, $p = 0.08$), depth ($F_{(1,4)} = 0.20$, $p = 0.7$) and province ($F_{(1,4)} = 0.75$, $p = 0.4$) were not. Bottlenose dolphins were observed in a wide range of depths and there was no significant effect of habitat type on abundance (GLM Habitat

type: $F_{(2,8)} = 1.27$, $p = 0.3$). The species was observed in small to medium-sized groups, (range 4–41, mean size 14.0 ± 3.4), with groups sometimes consisting of a mixture of age groups (Sindh only) and sometimes of adults only. Bottlenose dolphins occurred where fishing nets/traps, fishing boats and/or cargo vessels/tankers were present, but there was no significant effect of human activity on their occurrence (GLM human activity: $F_{(2,8)} = 3.33$, $p = 0.09$).

Spinner dolphin

Spinner dolphins were observed only in Balochistan during the NE monsoon (Table 2); they were encountered in Near Shore, Shelf Edge and Pelagic zones but always in relatively deep water ($>300\text{m}$). None of the factors included in Model A was a significant predictor of their relative abundance (GLM time observed: $F_{(1,6)} = 0.63$, $p = 0.5$; sea state: $F_{(1,6)} = 0.17$, $p = 0.7$; swell: $F_{(1,6)} = 1.86$, $p = 0.2$; depth: $F_{(1,6)} = 0.002$, $p = 0.9$). Spinner dolphins mostly occurred in very large groups of up to 1000 or more individuals (Table 3), that could be either be composed only of adults or include a mixture of age classes (Table 4), although no factors were a significant predictor of group composition (GLM $F_{(2,10)} = 0.83$, $p = 0.5$). They were sighted both in the absence of human activity and where fishing boats were present, but more were recorded when fishing boats were present than in their absence ($F_{(1,11)} = 4.33$, $p = 0.06$).

Humpback dolphins

Humpback dolphins were recorded during both NE and SW monsoons and during the spring inter-monsoon period. All sightings were in the Near Shore Zone, and all save one in Sindh (Table 2). They were observed throughout the day in waters up to 30m (mean $9.1\text{m} \pm 0.7$) deep with a notably wide range of sea surface temperatures ($12\text{--}31^\circ\text{C}$; mean $23.1^\circ\text{C} \pm 1.2$). However, none of the factors – time observed, sea state, swell, depth or weather – predicted the relative abundance of humpback dolphins (GLM time

Table 3

Total numbers of sightings and individuals, and group sizes, of each species recorded during boat surveys.

Species	Total no. sightings	Total no. individuals	Mean group size ($\pm$ S.E.)	Range of group size
Finless porpoise	35	100	2.86 ± 0.5	1–18
Bottlenose dolphin	11	154	14.0 ± 3.4	4–41
Spinner dolphin	13	2,535	195.0 ± 92.6	1–1,000+
Humpback dolphin	87	321	3.7 ± 0.5	1–35
Risso's dolphin	2	107	53.5 ± 46.5	7–100
Killer whale	1	10		10
Humpback whale	2	2	1	1
Unidentified dolphin	15	25	1.7 ± 0.5	1–8

Table 4
Frequencies of different group compositions for each species in each province (as number of sightings per 100km).

Province	Species	Single animal	Adults only	Mixed ages	Juveniles only	Mothers and young	Unknown
Sindh	Finless porpoise	0.33	0.84	0.48	0	0	0.59
Sindh	Bottlenose dolphin	0	0.84	1.50	0	0	0.48
Sindh	Humpback dolphin	1.17	3.56	3.85	1.47	0.95	0.70
Sindh	Risso's dolphin	0	0	0	0	0	0
Sindh	Killer whale	0	0	0	0	0	0
Sindh	Humpback whale	0	0	0	0	0	0
Balochistan	Finless porpoise	0.18	1.21	0	0	0	0
Balochistan	Bottlenose dolphin	2.82	0	0	0	0	0
Balochistan	Spinner dolphin	0	1.87	9.10	0	0	0
Balochistan	Humpback dolphin	0	0	0.07	0	0	0
Balochistan	Risso's dolphin	0	3.92	0	0	0	0
Balochistan	Killer whale	0	3.92	0	0	0	0
Balochistan	Humpback whale	0	0.37	0	0	0	0

observed: $F_{(1,70)} = 0.34$, $p = 0.6$; sea state: $F_{(1,70)} = 1.64$, $p = 0.2$; swell: $F_{(1,70)} = 0.02$, $p = 0.7$; depth: $F_{(1,70)} = 0.87$, $p = 0.4$; weather: $F_{(1,70)} = 0.04$, $p = 0.8$). Humpback dolphins were observed either as singletons or in groups of up to 35 individuals (mean 3.7 ± 0.5) (Table 3) composed either of adults or a mixture of different aged individuals or mothers and calves (Table 4). Mixed age groups were encountered significantly more often than singletons (GLM: $F_{(5,81)} = 5.23$, $p = 0.0003$; *post hoc* test: $p = 0.004$). The species was recorded both when nets/traps and fishing boats were present, and when these were absent, with human activity not being a significant predictor of their presence (GLM: $F_{(3,161)} = 0.36$, $p = 0.8$).

Risso's dolphin, killer whale and humpback whale

Risso's dolphins, killer whales and humpback whales were all observed only in Balochistan and only during the NE monsoon. Killer whales and humpback whales were recorded only in the Near Shore zone (in 19m and 9–11m of water respectively), while Risso's dolphins were recorded in deeper water (360–750m) in the Continental Shelf and Pelagic zones (Table 2). The humpback whale sightings were of single animals, the Risso's dolphins of medium to large size groups (mean 53.5 ± 46.5) of adults, and the killer whales were a group of about 10 adults (Table 3). The killer whales when encountered were pursuing a large group of rays under the vessel and onward, and the groups of Risso's dolphins also appeared to be hunting on both occasions. All sightings of these species were between late morning and late afternoon, but there were too few sightings of these species to draw conclusions on the influence of other environmental factors.

Seismic surveys

During cetacean observations undertaken during the offshore seismic survey both bottlenose and spinner dolphins were recorded both in shelf edge and pelagic zones, while there were single observations of Risso's dolphins on the shelf edge and of common dolphin in the pelagic zone (Table 5). Mean group size varied considerably between species, from one for Risso's dolphin (observed associated with a pod of bottlenose dolphin) to 92.3 for spinner dolphin (Table 5). Bottlenose and spinner dolphins were observed both when the seismic airgun was firing (on 7 and 6 occasions respectively) and when it was not (on 7 and 4 occasions respectively), while common dolphins were seen when the airgun was not firing (2 occasions) and the Risso's dolphin when it was (1 occasion). All cetaceans observed were adults except for one group of juvenile bottlenose dolphins and one group of juvenile spinner dolphins, both seen on the shelf edge.

Human activity

Table 6 shows the frequency with which all cetacean species combined were recorded in the presence and absence of different forms of human activity in each habitat zone. While a variety of fishing and shipping activities were common in the Near Shore Zone, in the other zones fishing vessels were the only human activity recorded. In general cetaceans were observed whether human activity was present or not, but it is noticeable that mean relative abundance tended to be slightly higher in the absence of human activity.

Shore-based surveys and strandings reports

No live strandings were found during the shore-based surveys, but the remains were encountered of 12 dolphins

Table 5

Numbers of sightings and of individuals and range and mean of group sizes of cetacean species recorded during the 2003 offshore seismic survey (abbreviations as per Table 1).

Season:	NE monsoon				Autumn IM		Range of group sizes	Mean group size
Zone:	Shelf edge		Pelagic		Shelf edge			
Species	Sightings	Individuals	Sightings	Individuals	Sightings	Individuals		
Bottlenose dolphin	3	32	6	130	5	107	4–50	24.5 ± 5.6
Spinner dolphin	9	898	1	25			1–600	92.3 ± 49.0
Common dolphin			2	13			10–15	
Risso's dolphin	1	1					1	

Table 6

Comparison of cetacean abundances per km in different marine zones (habitats) in the presence and absence of different human activities.

Marine zone (habitat)	Type of human activity	Total no. cetacean sightings	Mean abundance of all cetaceans	Mean abundance per single species
Near shore	None	90	0.069	0.001
Near shore	Nets/traps	16	0.029	0.002
Near shore	Fishing boat(s)	39	0.044	0.001
Near shore	Cargo/tanker	2	0.001	0.001
Continental shelf	None	4	0.047	0.012
Shelf edge	None	9	8.344	0.927
Shelf edge	Fishing boat(s)	1	8.125	–
Pelagic	None	3	2.123	0.708
Pelagic	Fishing boat(s)	1	0.970	–

(six in Sindh and six in Balochistan), and of a sperm whale in Balochistan (see Gore *et al.*, 2007a). None of the dolphin specimens was in a condition to be identified *in situ*, but samples of tissue and teeth are currently being analysed to determine species and gender.

Between 2005 and 2008 a total of 57 stranded animals were reported through the strandings network (Table 7). These included in both Sindh and Balochistan, finless porpoises, humpback dolphins, bottlenose dolphins, spinner dolphins, sperm whales, and Bryde's and other unidentified baleen whales, and in Sindh only, a Cuvier's beaked whale (see Gore *et al.*, 2007a; 2007b). There were more strandings reported during the NE monsoon than in other seasons. It was observed that many of the finless porpoise had their flukes cut off. The pre-existing skeletal material located in institutions in Sindh and Balochistan mostly constituted large baleen whales, including notably two blue whales.

Fisher community-based surveys

Forty six fishing communities were identified in Sindh and 28 in Balochistan. 302 fishers were interviewed; all were male. In Sindh the men were largely of a single ethnic group, while in Balochistan there were at least 6 ethnic/language groups present. The men ranged in age from 12 to 80yrs but their distribution among age categories (<20, 20–29, 30–39, 40–49, 50–59 and 60+yrs) was similar for the two provinces (Wilcoxon Matched Pairs Test: $t = 10.0$, $z = 0.104$, $p = 0.9$, $n = 6$) and there were no significant differences between age categories in their responses (Kruskal-Wallis ANOVA by ranks: $H_{(5,N=352)} = 9.88$, $p = 0.08$). When asked about the

species they encountered, the local names used and the size of groups and body sizes, most fishers identified and reported bottlenose dolphins (local name *hum*) occurring in groups of five or more, humpback dolphins (*malhar*) seen in groups of 1–10 individuals, and finless porpoises (*tabi*) seen in groups of 5–10. Whales were more frequently encountered by fishers in Balochistan than Sindh, although the four local names (*whiser*, *leare*, *leed* and *abroo*) were known in both provinces. Spinner dolphins (*goco* or *tooshunk*) were not seen often, and although common dolphins occur in both Oman (Baldwin, 2003) and Iran (Braulik *et al.*, 2010b), were not reported by fishers in either province.

However when fishers were asked whether cetaceans impacted on their fishing there was a significant difference between the provinces (Mann Whitney U test: $Z_{adj} = -2.57$, $p = 0.01$, $N_{Sindh} = 177$, $N_{Balochi} = 175$), with more Balochis responding that cetaceans did cause problems. Their complaints included that cetaceans competed for and/or were depleting fish stocks, and that dolphins and porpoises becoming entangled in and damaged fishing nets. In addition it was claimed that large dolphins and whales could capsize small fishing boats.

Fishers did not describe finding live stranded cetaceans but Balochi fishers did describe finding bones of cetaceans on the shore throughout the year. They also described their interaction with cetaceans and commented on cetacean behaviour much more frequently than did Sindhi fishers. Ten fishers (six from Balochistan and four from Sindh) spread evenly across the age groups 20 to 59 yrs, reported that they or others had killed or used cetaceans. The purposes reported included: to free fishing nets; as bait for fish or sharks; for food (apparently by 'Somalis'); for medication (for example to ease pain in the legs); and for sexual gratification (finless porpoise). In relation to the damage caused to nets it was noted that while locally a fishing net cost 4,000 Pakistani Rupees (Rs.), the wholesale price for a dolphin was only Rs 4.

DISCUSSION

This study, covering most of the 1,050km coastline of the country over a four year period, represents the first systematic survey of marine cetaceans in Pakistan. In addition to boat-based surveys, shore-based surveys were undertaken for stranded or beachcast specimens and a strandings reporting scheme established, which revealed the occurrence of several further species.

Table 7

Numbers of beachcast cetaceans recorded between 2005 and 2008 by species, province and season (abbreviations as for Table 1).

Species	Sindh					Balochistan			
	Season:	NE	IMS	SW	IMA	NE	IMS	SW	IMA
Bryde's whale	—	1	—	—	2	—	—	—	—
Unid. baleen whale	1	2	—	—	2	1	—	—	—
Sperm whale	1	1	—	—	1	—	1	1	—
Cuvier's beaked whale	—	—	1	—	—	—	—	—	—
Killer whale	1	—	—	—	—	—	—	—	—
Humpback dolphin	3	—	6	—	4	2	—	—	—
Spinner dolphin	—	2	—	—	—	—	—	—	—
Bottlenose dolphin	2	1	—	—	2	—	—	—	—
Unid. dolphin	—	—	7	—	1	2	—	—	—
Finless porpoise	1	1	—	—	6	1	—	—	—

Species occurrence

Finless porpoise

During inshore boat surveys finless porpoises were recorded relatively frequently, more often in Sindh than in Balochistan, but finless porpoise remains were also found on beaches, mainly in Balochistan. During boat survey work they were almost invariably recorded under calm sea conditions during the NE monsoon (which may partly reflect the difficulty in detecting them when waves are present), and in shallow water near shore. Finless porpoises have previously been reported from both the Indus Delta and Balochistan. Pilleri and Gühr (1972a, 1973–1974) had records of live porpoises at Gadani, Dahm and Sonmiani, all in Balochistan, and they encountered small groups in the Indus Delta creeks, although by 1979 fewer were being recorded (Pilleri and Pilleri, 1979). Roberts (1997) also noted that finless porpoises were found in mangrove creeks along the Baluchistan coast between September and April, since when a number of other records have been collated by Collins *et al.* (2005). The species has also been reported in neighbouring Oman (Braulik *et al.*, 2010a; Collins *et al.*, 2005).

Bottlenose dolphin

In the present study bottlenose dolphins were observed in both Balochistan and Sindh, and beachcast specimens were also found in both provinces. The species is known from adjacent countries: Baldwin (2003) describes them as present in Yemen, Oman and the Arabian Gulf, while Braulik *et al.* (2010a) recorded a skull of the Indo-Pacific bottlenose dolphin in the Sistan/Baluchistan area of Iran, and Afsal *et al.* (2008), using a fisheries-oceanographic ship as a vessel of opportunity, recorded Indo-Pacific bottlenose dolphins in the Arabian Sea off the coast of India at depths of up to 50m.

Two forms of bottlenose dolphin are found in the Indian Ocean, the Indo-Pacific bottlenose dolphin (*T. cf. aduncus*), and the larger, globally more widespread, common bottlenose dolphin (*T. tursiops*). In general, *T. cf. aduncus* is thought to be a coastal form found in near-coastal tropical waters, while *T. truncatus* also occurs in temperate waters and offshore (Hale *et al.*, 2000). Hale *et al.* compared the morphology of the two forms; the separation into two distinct species was said to be unresolved, although genetic analysis may show a degree of divergence, which would be consistent with them being distinct species.

In the present study bottlenose dolphins were recorded in a wide range of habitats including near shore, continental shelf and shelf edge, from shallow water to ocean over 1,000m deep. It seems possible that the groups observed inshore in both Sindh and Balochistan were *T. cf. aduncus*, while those observed offshore in Balochistan may have been *T. tursiops*. Similarly, Baird *et al.* (2009) found that in the Hawai'ian Islands bottlenose dolphin close inshore remained resident and did not mix with the offshore inter-island population. However in the present study no clear difference in visual appearance of inshore and offshore animals was evident and consequently bottlenose dolphins recorded in the present study have been classed as *Tursiops* spp. There is a case for further study and a genetic analysis is underway.

Bottlenose dolphins were observed when fishing gear or boats were present as well as when there was no other human

activity evident. In fact on at least one occasion the pod sometimes present near Clifton Beach (near Karachi, Sindh) appeared to be driving fish towards drift nets deployed by fishers, a manoeuvre from which both dolphins and fishers could potentially benefit. Bottlenose dolphins were also recorded during the seismic survey in both shelf edge and pelagic zones, when the airgun was firing and when it was not, although the numbers recorded per sighting were slightly greater when there was no firing. From these data it would appear that the bottlenose dolphin is relatively insensitive to human disturbance, although this is not to imply that the animals are not impacted, since clear propeller damage was observed on members of the bottlenose dolphin pod sometimes encountered near Karachi Harbour.

Spinner dolphin

Our data on spinner dolphins complement records of the species from adjacent waters. Afsal *et al.* (2008) found spinner dolphins in water between 1,000 and 3,000m deep in the Arabian Sea area off India; Ponnampalam (2009) has studied a population resident off the coast of Muscat, Oman; and Braulik *et al.* (2010b) recorded the species in Iran, based on a stranding, in the Sistan/Baluchistan area. Spinner dolphins were observed in both Pakistani provinces, usually in very large assemblages of adults or mixed age individuals and invariably on the outer shelf or around the shelf edge. These observations match evidence that the species is specialised in feeding on meso-pelagic squid and fish around the shelf edge (Ponnampalam, 2009). Like bottlenose dolphins, spinner dolphins were often observed despite human activities, including seismic airgun firing, occurring locally. Fishing boats were also often present, perhaps because both dolphins and fishers were attracted independently to a common potential resource.

Indo-Pacific humpback dolphin

In the present study humpback dolphins were frequently recorded in both NE and SW monsoons and also in the Spring Inter-monsoon period, but only in specific coastal areas (around the Indus Delta and in bays along the coast of Balochistan) in waters less than 30m deep. These observations match those from adjacent regions. Sutaria and Jefferson (2004) found humpback dolphins along the west coast of India, as far north as the Gulf of Kutch, just south of the border with Pakistan, as did Afsal *et al.* (2008) who reported humpback dolphins along the Arabian Sea coast of India in depths of up to 50m. Humpback dolphins were also the most frequently recorded cetacean in Oman (Baldwin *et al.*, 2004), occurring principally in coastal waters with soft sediments and low-energy sandy shorelines. However the species was not recorded during a survey of the Sistan/Baluchistan area of Iran (Braulik *et al.*, 2010a).

Two species of Indo-Pacific humpback dolphin have been distinguished: *Sousa plumbea* and *S. chinensis*. The animals observed in Pakistan had phenotypic characteristics of both forms, with a very distinctive hump but often heavy spotting on the head and hump areas. Jefferson and van Waerebeek (2004) studied skull morphology of *Sousa* spp. and suggested that Indo-Pacific specimens should be referred to a single species, *S. chinensis*, until further molecular genetics and morphological studies are undertaken. The Pakistan

population may thus represent an intermediate form within a single species cline. As noted by Jefferson and van Waerebeek (2004), irrespective of their taxonomic status, each geographic form should be treated as an evolutionary significant unit for conservation and management purposes.

The restricted use of selected coastal areas by this species has been described from other regions. In Zanzibar, Stensland *et al.* (2006) found that humpback dolphin concentrate their activities within only 2–11.5% of their range. In Mozambique humpback dolphins were found to be resident within selected bays, for example Maputo Bay (Guissamulo and Cockcroft, 2002). In Algoa Bay, South Africa, Karczmarski *et al.* (2000) mainly found humpback dolphins in water less than 15m deep and within 400m of shore. Similarly in Richards Bay, South Africa, humpback dolphins were found to stay within 2km (rarely 3km) of the shore and in water less than 20m deep (Atkins *et al.*, 2004); important feeding areas were around breakwaters and an estuary mouth, with resting areas being located further off shore.

Mean group size in the present study was small (3.7 animals), but larger, often mixed aged groups of up to 35 animals were sometimes seen, with groups being commoner than singletons. These data are comparable with those from other studies. On the west coast of India, Sutaria and Jefferson (2004) found that in shallow water ($\leq 10\text{m}$) mean group size was 3.9 (median 2), but in deeper water ($\leq 30\text{m}$) mean group size was 9.5. Similarly Parsons (1998) recorded group size of humpback dolphins in Goa, western India, as ranging from single individuals to nine, with a mean group size of 2.6. However, Razafindrakoto *et al.* (2004) found that humpback dolphins in west Madagascar had a mean group size of 13, and Guissamulo and Cockcroft (2002) reported that those resident in Maputo Bay, Mozambique, had a mean group size of 14.9, irrespective of season, daylight or tidal state.

Despite the fact they are sometimes exploited in Pakistan, humpback dolphins did not seem to avoid fishers, given that there was no significant difference in rate of sightings with presence or absence of fishing gear or boats.

Risso's dolphin, common dolphin and killer whale

Risso's dolphins were observed offshore and strandings were recorded in both provinces. The species is also known from neighbouring countries. Afsal *et al.* (2008) recorded them in depths of *ca.* 2,000m in the Arabian Sea off India, and Baldwin (2003) describes them as widespread in the Arabian Sea, Gulf of Aden and Gulf of Oman, where exceptionally large groups of up to 800 individuals are occasionally seen. Braulik *et al.* (2010a) recorded the species stranded in the Sistan/Baluchistan area of the Gulf of Oman. Baumgartner (1997) describes Risso's dolphins as being associated with steep areas of the upper continental slope, possibly due to the concentration of their prey (squid) along fronts that form in such areas. In the present study however, matching Baldwin's (2003) observation that they are more common seawards of the continental shelf, we recorded more Risso's dolphins in the pelagic than the shelf edge zone, although in Pakistan both areas possess a relatively steeply sloping sea floor.

Long-beaked common dolphins, generally recognised as a distinct subspecies, *Delphinus capensis tropicalis*, are

regarded as abundant in the Arabian Seas and Gulf of Aden (Baldwin, 2003). They have also been reported in the Gulf of Oman (Braulik *et al.*, 2010b) and western India, although not from the area adjacent to Pakistan (Afsal *et al.*, 2008). The species was observed twice during the seismic survey reported in the present study but not during the dedicated boat-based surveys, although the species may be among the unidentified dolphin remains collected during beach surveys and currently undergoing genetic analysis.

A single pod of killer whale was observed off Astola Island, Balochistan (by MG), apparently pursuing rays beneath the survey boat. Their presence is in keeping with other records from the northwest Indian Ocean region, where it appears to be rare but widespread. They have been observed only infrequently in Oman (Baldwin *et al.*, 1999) and there is one report from the Gujarat coast of India (James and Lal Mohan, 1987). However they were not recorded during the boat-based survey of the Indian Arabian Sea by Afsal *et al.* (2008), nor in the review for the Gulf of Oman by Braulik *et al.* (2010a). These reports may represent sightings of only one or two pods that travel very widely through the region.

Whales

The Bryde's whale is regarded as common in Southern Arabian waters (Baldwin, 2003), but none were observed with certainty during our boat surveys. Likewise James and Mohan (1987) failed to record Bryde's whales from the coastal waters of western India, although they did report the skeleton of a sei whale (*B. borealis*), which could possibly be a misidentified Bryde's. However in the present study a stranding of a Bryde's whale was recorded, as did Braulik *et al.* (2010a) in the Sistan/Baluchistan area of Iran; thus it is likely that Bryde's whales do occur regularly off the Pakistan coast, but perhaps mainly during the southwest monsoon when their food would be more abundant, but when it is very difficult to undertake small boat work.

Although a live Bryde's whale was not recorded in this study, a humpback whale was encountered in relatively shallow waters off the coast of Balochistan. Similarly humpback whales in the Arabian Sea are usually seen in water of less than 50m deep (Baldwin, 2003), so they are perhaps more likely to be encountered during inshore small boat surveys.

A blue whale was sighted off the Sindh coast northwest of the Swatch in the late 1960s (M. Khan and S.H.N. Rizvi, pers. comm.) and they have also been reported by Ahmad and Ghalib (1975). None were seen during the present survey work, but a locally-collected skeleton present in the Zoology Department Museum of Karachi University was inspected.

A Cuvier's beaked whale was identified from a skull found during a beach survey of Khobar Creek, Sindh (Gore *et al.*, 2007b), but the species was not observed during boat work. To date there have been about a dozen records of the species from the northwest Indian Ocean, all from the Gulf of Oman and the south-eastern coast of Arabia (Baldwin, 2003), although James and Mohan (1987) also reported the species from the Lakshadweep Islands off Calicut, south-west India, and it is uncommon in the Maldives (Anderson, pers. comm.). Their restricted distribution may reflect long-term site fidelity to areas of preferred habitat, such as McSweeney *et*

al. (2007) recorded in Hawai'i, where known individuals were observed over at least 15 yrs. When seen, the species is almost always encountered over very deep water in which it is presumed to feed, and Baird *et al.* (2008) noted that in Hawai'i they spend less time near the surface during the day, probably to avoid predation.

A single sperm whale was recorded, a young individual cast on Manjar beach, Sindh (Gore *et al.*, 2007a). Sperm whales were exploited commercially in the Arabian Sea off the coast of Southern Arabia during the 19th century and again briefly in the 1960s (Baldwin, 2003). More recently the species has been reported by Baldwin *et al.* (1999) off Oman, by Afsal *et al.* (2008) in the south-eastern Arabian Sea off India, and by Braulik *et al.* (2010a) (from a stranding) in the Sistan/Baluchistan area of Iran. Thus the species is still present in the region, though to what extent it is recovering from past exploitation remains unknown.

Confirmed cetacean species for Pakistan

Given the above data and information, the occurrence in Pakistan of 12 species of marine cetaceans can be confirmed, including a single porpoise species, six dolphin species (including killer whale) from six different genera, and five whale species representing four further genera, including both odontocetes and mysticetes (Gore *et al.*, 2007a; 2007b). Of these species, two are listed as endangered (blue and humpback whales) and two as vulnerable (sperm whale and finless porpoise) in the International Union for the Conservation of Nature Red List¹; eight are included within the Appendix to the Convention on Migratory Species².

As also remarked by Mikhalev (2000), the occurrence of good numbers of some of these species in this range may reflect the relatively high productivity of Pakistani waters. While during the NE monsoon there is thermohaline stratification both near and offshore, during the SW monsoon the waters become well mixed, returning nutrients to surface waters. As a result there is high primary productivity, especially in October and November (Rivzi *et al.*, 1995; Saeed *et al.*, 1995), and high secondary productivity and biomass of zooplankton, higher than that further south on the South Asian coast or in the Bay of Bengal.

Anthropogenic impacts

Direct evidence of anthropogenic impact was found on shore-stranded cetacean specimens, particularly finless porpoises, from which the flukes had been removed, presumably to facilitate removal from fishing nets in which they had become entangled. Baldwin (2004) likewise described not infrequent entanglement, especially of whales and of humpback dolphins, in inshore fishing nets in Oman. Similar mortalities have also been described from elsewhere in the Western Indian Ocean, for example affecting humpback dolphins in Maputo Bay, Mozambique (Guissamulo and Cockcroft, 2002). Bottlenose dolphins, a species that feeds in shallow water, may be affected, because when they focus on sonar echoes from their prey they suppress echoes from other objects (such as the nets) and

so may not detect them (Goodson, 1994 *in* Atkins *et al.*, 2004).

Occasional reports were received of both dolphin bycatch and intentional kills for bait, especially in Balochistan, or medicine or other purposes, particularly in Sindh. Baldwin *et al.* (2004) have likewise noted that opportunistic hunting of dolphins may occur in southern Arabia. Reports of cetacean meat being used as bait for shark fishing are of particular concern, since shark fishing has been intensifying as a consequence of the demand for shark for the Asian restaurant trade. More regular targeting of humpback dolphins as a source of meat in west Madagascar has been reported by Razafindrakoto *et al.* (2004). It is not easy to assess whether in Pakistan such intentional and unintentional exploitation will cause population decline, but Stensland *et al.* (2006) studying bottlenose and humpback dolphins in Zanzibar estimated that across the two species bycatch generated an annual mortality of about 12%.

Occasional boat strikes were also described to us during the present study, though whether such strikes or the more general disruption caused by boat activity generate the greater impact remains unclear. Ng and Leung (2003) investigated the effect that vessel traffic might have on humpback dolphins. The dolphins increased their dive duration and performed avoidance behaviour when oncoming vessels were detected; slow-moving vessels appeared not to cause immediate stress, but fast-moving vessels did disrupt behaviour.

In Pakistan various forms of pollution also seem likely to have affected inshore dolphin populations. There are very high levels of chemical pollution in creeks and tributaries near Karachi (such as Korangi and Gizri Creeks and Port Qasim), and around the Hub River and the ship-breaking area of Gadani, Balochistan (Ali and Jilani, 1995; Khan and Saleem, 1988; Rivzi *et al.*, 1988). Around Karachi untreated industrial effluents input toxic metals, pesticides, PCBs (polychlorinated biphenyls) and lubricating oils, while untreated municipal sewage causes high biological oxygen demand (BOD), and inputs organic nitrogenous compounds, suspended solids, soaps and detergents, nutrients, phenols, sulphur compounds and pathogenic bacteria (Ali and Jilani, 1995; Saleem and Kazi, 1995). At Gadani, up to 100 ships per year are dismantled leading to the release of large amounts of heavy metals, asbestos, dioxins and other persistent organic pollutants. The effects of such pollution on local dolphins have yet to be studied, but Parsons (2004) studied contaminants of humpback dolphins in similarly polluted Hong Kong and found very high levels of organochlorines and mercury.

In addition to pollution from terrestrial sources, chronic low-level oil pollution is generated by busy nearby shipping lanes, and there have since the 1980s been two major oil spills affecting the Sindh coast: 700 tons of crude oil in 1984; and 30,000 tons in 2003. Another potential impact in open water may be harmful algal blooms (HAB) due to phytoplankton such as *Gonyaulax* and *Lingulodinium* spp.; extensive blooms are common in coastal waters, as well as in more enclosed areas such as Korangi Creek and Manora Channel (Baig, 2004; Chaghtai and Saidullah, 2001), but have been a feature of the coast since before it became industrialised (M. Khan, pers. comm.).

¹ IUCN Red List website <http://www.iucnredlist.org> [Accessed April 2010]

² CMS website HTTP://WWW.CMS.INT/ACCOBAMS/ACC_SPP.HTM [Accessed 2008]

Views of fishers

The responses of fishers to our questionnaires suggested that many of them were observant of cetaceans, noting species, group size, body size and behaviour, and sometimes taking pleasure in their presence. The Balochi fishers were noticeably more knowledgeable, which may reflect the finding that Balochis interviewed were more likely to be full-time (rather than part-time) fishers. It was also noted, as also described by Grant and Berkes (2007), that in general fishers were very keen to improve their knowledge of marine life especially when relevant to fishing activities. Howard and Parsons (2006) have explored this effect in Scotland where they found that while noise pollution was of interest to the wider community, water pollution was of special concern to fishers. Likewise we found fishers concerned about water quality, particularly in Sindh and near the Gadani ship breaking area. In addition to the individual interviews, the Fisher Workshops provided valuable comment on species occurrence and the range of current threats to cetacean populations, pointing out for example that discarded nets could be a significant problem.

Conservation and management

The results of this study have been used in support of both national and regional cetacean conservation and management initiatives. Hitherto marine cetaceans have not been gazetted as protected species in either Sindh or Balochistan, largely because neither the species concerned nor their status were known. Consequently the findings of this study have been provided to the Convention on Biodiversity Working Group within the Ministry of Environment for further action. In addition, following discussion with the then Minister of the Environment for Pakistan during his visit to Astola/Haft Talar Island, the area proposed for Pakistan's first marine protected area (MPA), a proposal was developed (in collaboration with WWF-Pakistan and the government's own Pakistan Wetlands Programme) for extending full protection to all cetaceans within the MPA.

To further promote effective protection measures, an Action Plan for the Conservation of Marine Cetaceans of Pakistan (Gore, 2008) was agreed and circulated to the relevant government departments and non-government organisations. Recommendations included the establishment of a national cetacean conservation group (as a result of which the Pakistan Whale and Dolphin Society was established on 11 February 2007), and the trialling of whale and dolphin watching trips (the first of which was organised by WWF-Pakistan in 2008). It is intended that both activities should increase public awareness of whales and dolphins in Pakistan and involve an expanding cross-section of the local community in their conservation.

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Recent records of marine mammals in Tanzanian waters

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ABSTRACT

Marine mammal species diversity off Zanzibar and Tanzania, East Africa, has been recorded by the Marine Mammal Education and Research Group at the Institute of Marine Sciences, Zanzibar, Tanzania since 1998. The data presented in this report reflect the efforts of 10 years collection of information from marine mammals stranded and incidentally caught in Tanzanian waters. Additional information from dedicated surveys of cetaceans (whales and dolphins) and incidental sightings reported by the general public are also provided. From 1992 through 2008 a total of 235 specimens of 13 cetacean species and the dugong were recorded. 214 (90.7%) records referred to specimens from bycatch in drift and bottom-set gillnets and 22 (9.3%) referred to specimens from strandings. Based on incidental catch and sightings records, Indo-Pacific bottlenose, spinner and Indo-Pacific humpback dolphins, observed year-round, and humpback whales, observed seasonally during July to November, were the most common species in Tanzanian coastal waters.

KEYWORDS: STRANDINGS; BYCATCH; INDO-PACIFIC BOTTLENOSE DOLPHIN; INDO-PACIFIC HUMPBACK DOLPHIN; SPINNER DOLPHIN; HUMPBACK WHALE; SPERM WHALE; DUGONG; ZANZIBAR; TANZANIA

INTRODUCTION

Cetaceans (whales and dolphins) and dugongs are an integral part of the marine and coastal fauna of tropical and subtropical waters of the East African region (Berggren, 2009). For many species, these waters serve as key habitat for a range of primary activities including feeding, mating and calving (Amir *et al.*, 2005b; Stensland *et al.*, 2006). However, there is a lack of information about the distribution, ecology and abundance for most species due to limited coverage by dedicated research programmes (Berggren *et al.*, 2007; Kiszka *et al.*, 2008). This lack of information is significant, as the East African region is located within the Indian Ocean Sanctuary established by the International Whaling Commission (IWC) to encourage conservation and research of cetaceans in the region (IWC, 1980).

In 1998 a project was launched in Zanzibar, Tanzania with the objective to assess the status of cetaceans and build capacity for their conservation and management. This was facilitated through collaboration between the marine mammal research group at Stockholm University, Sweden (between 1998 and 2010) and since 2010 by Newcastle University, UK, and the Institute of Marine Sciences, University of Dar es Salaam, based in Zanzibar, Tanzania. The activities have focussed on two research areas; vessel based surveys to collect data for cetacean distribution, abundance, genetic population structure, ecology and behaviour and documentation of strandings and incidental catches of marine mammals occurring in Tanzanian coastal waters. A number of scientific papers and reports have been published documenting the results of these activities (see e.g. Amir *et al.*, 2002; Amir *et al.*, 2005a; Amir *et al.*, 2005b; Berggren, 2009; Berggren *et al.*, 2007; Christiansen *et al.*, 2010; Mwevura *et al.*, 2010; Sarnblad *et al.*, 2011; Stensland and Berggren, 2007; Stensland *et al.*, 2006). However, to

date there have been no scientific papers published documenting the diversity of marine mammals present in Zanzibar and Tanzanian waters. Therefore, the aim of this paper is to summarise and present information on the diversity of marine mammal species known to occur in Zanzibar and Tanzania waters using stranding and bycatch data supplemented by available sighting records. This paper also updates information on bycatch of marine mammals documented by Amir *et al.* (2005a)

MATERIALS AND METHODS

Study area

Most of the information on marine mammals was collected in the coastal waters around Unguja Island located at 06°2'S, 39°2'E about 40km off the central coast of the Tanzania mainland (Fig. 1). Unguja Island is often referred to as Zanzibar although the latter also includes Pemba Island.

Samples and sampling procedures

Since 2000, strandings and bycatch of marine mammals have been documented and collected by the Marine Mammal Education and Research Group based at the Institute of Marine Sciences, Zanzibar (Amir *et al.*, 2005b). The group coordinates and records all reported animals around Zanzibar with the help of a network of observers (beach recorders from Department of Fisheries Development, Zanzibar and the general public). Where possible, the reported carcasses are then necropsied, sampled and preserved at the Institute of Marine Sciences for further biological and ecological studies.

Strandings

The group often receives reports from beach recorders, fishermen or the general public stating that an animal has been found stranded. In most cases, members of the group

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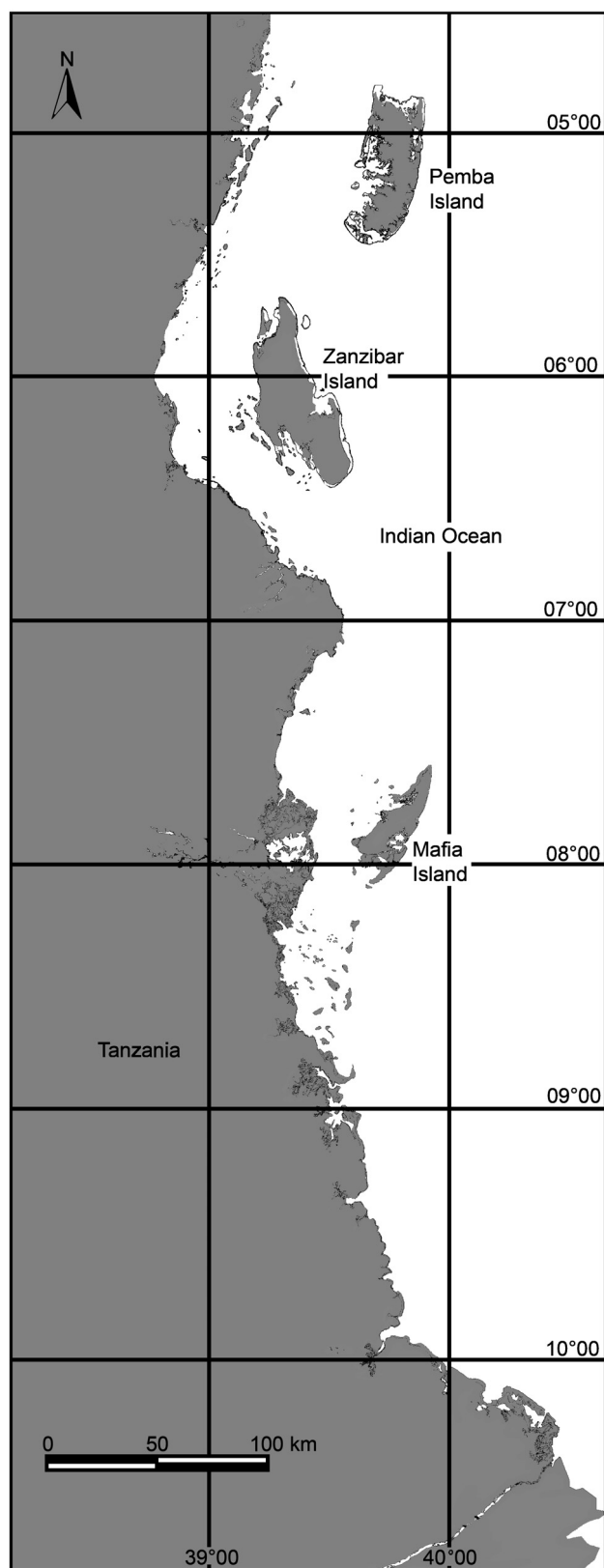


Fig. 1. Map of Zanzibar (Unguja and Pemba Island) showing the study area.

respond by going to the location of the event to examine the animal. A few records of stranded marine mammals exist from 1992 and 1993 collected during a sea turtle survey conducted in 1994. During this survey fishermen were also asked to answer questions regarding stranding of marine mammals (Fiona Clark and Asha Khatib, pers. obs.). These records were accepted into this study only if the information

provided allowed verification of species identification. All stranded animals were identified, measured and photographs taken. When possible, stranded dead animals were collected by the group members for further analyses.

Bycatches

Since fishermen's cooperation is on a voluntary basis, in order to encourage them to report and bring carcasses a nominal financial compensation has been paid (\$5 for small specimens and \$10 for larger animals) for the delivery of the carcass. This compensation was paid to cover fishermen's time and expenses to transport the fresh specimens to the location of the beach recorder or to Zanzibar central market (Amir *et al.*, 2005b). The respective authorities were advised of the importance of collecting and documenting all bycatches that occur in fisheries. Fishermen hand over any bycaught animal to the fisheries beach recorders of the landing site in the village or to a contact person in Zanzibar central market. These beach recorders or contact person then provide a report of the event to the member of the research group at the Institute of Marine Sciences. The incidentally caught animals were measured, weighed and photographed and later necropsied when possible.

RESULTS

Strandings

From 1992 to 2008, 22 marine mammals were reported stranded (Table 1). All of the strandings were found dead. Two species comprised the majority of stranding events; humpback whales (*Megaptera novaeangliae*) with 50% of the total strandings followed by sperm whale (*Physeter macrocephalus*) with 36.4%. The majority of the strandings (85.7%) occurred during the second half of the year between July and November (Fig. 2). Many of the stranded animals were found dead and exhibiting various stages of decomposition. For small cetaceans there were only single records of strandings for shortfinned pilot whale (*Globicephala macrorhynchus*), pygmy sperm whale (*Kogia breviceps*) and killer whale (*Orcinus orca*). However, two mass strandings have occurred on Zanzibar. In 1933, 44 false killer whales (*Pseudorca crassidens*) stranded along the Mtoni seashore on the west coast of Zanzibar (Zanzibar Natural History Museum collection) and on the night between 27-28 April 2006 a group of approximately 600 common bottlenose dolphins (*Tursiops truncatus*) stranded and died on the northwest coast of Zanzibar (Berggren, 2009).

Bycatches

From January 2000 to December 2008, 213 bycatches of cetaceans and one dugong were reported (Table 2). All the reported animals had been entangled in artisanal (drift- and bottom set) gillnets. Drift gillnet fishing is almost exclusively carried out during night-time, where nets are set in the evening and retrieved before moonrise. Bottom-set gillnets are usually set in the evening and hauled in the morning, soak time seldom exceeding 24 hours. Fishing takes place over about three weeks during the dark moon phase for both type of gillnets. A detailed description of these fishing methods can be found in Amir *et al.* (2002).

Table 1
Species and occurrence of marine mammals stranded off the Zanzibar coast between 1992 and 2008.

Scientific name	Body length range (cm)	1992	1993	1999	2000	2001	2002	2003	2004	2006 ¹	2007	2008	Total	%
<i>M. novaeangliae</i>	415–1,040	1	1	1	1	1	2	1	2	0	0	1	11	45.5
<i>P. macrocephalus</i>	900–1,520	1	0	1	1	1	1	0	0	0	3	0	8	36.4
<i>K. breviceps</i>	210	0	0	0	0	1	0	0	0	0	0	0	1	4.5
<i>G. macrorhynchus</i>	–	0	0	0	0	0	0	0	0	1	0	0	1	4.5
<i>O. orca</i>	–	0	1	0	0	0	0	0	0	0	0	0	1	4.5
Total		2	2	2	2	3	3	1	2	1 ¹	3	1	22	100

¹Approximately 600 common bottlenose dolphins stranded and died on the night between 27–28 April 2006 on the NW coast of Zanzibar (Unguja Island).

Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) was the most frequently reported species, with 45.8% of the total bycatch, followed by spinner dolphin (*Stenella longirostris*) with 32.7%, Indo-Pacific humpback dolphin (*Sousa chinensis*) with 7.5% and Risso's dolphin (*Grampus griseus*) with 7.0%. Other species that were only occasionally bycaught included: pantropical spotted dolphin (*Stenella attenuata*), humpback whale (*Megaptera novaeangliae*), common bottlenose dolphin (*Tursiops truncatus*), Fraser's dolphin (*Lagenorhynchus hosei*) and the dugong (*Dugong dugon*). The high percentages of bycatch for Indo-Pacific bottlenose and spinner dolphins do not reflect the abundance of the respective species (although only limited data is available for spinner dolphins). These species maybe more vulnerable to entanglement in gillnets or the species' distributions could have greater overlap with the distribution of gillnet fishing effort compared to other dolphin species in the area.

DISCUSSION

The result of these studies show that humpback and sperm whales are the most frequently stranded marine mammals (excluding the two incidences of mass strandings) on the coasts of Zanzibar and mainland Tanzania. This indicates that these two species are the most regularly occurring large whale species in Tanzanian waters. All of the stranding events ($n = 19$) reported for these species occurred between the months of July and November. These strandings thus

support the idea of seasonal occurrence of these species in the area. All of these documented strandings involved single dead animals (excluding the mass strandings) for which cause of death has not been determined. Some of the humpback whales may have died from net entanglement in drift and bottom-set gillnets. Fishermen usually try to disentangle the whales by cutting the ropes and nets but often fail to remove the whole net. It is difficult to establish either the cause of these strandings or cause of death as in most cases when we arrive at the site there are many people around that have already started to cut-up the stranded animal for consumption. This usually happens when the animals are fresh. However, even when the carcass is in an advanced stage of decomposition people use the meat and blubber for making oil which is used as medicine. There were few reported strandings for small cetaceans and it is not clear if these represent the total number of animals stranded or if strandings are not being reported because they are being used locally for bait and other products.

The seasonal occurrence (July–November) of strandings and bycatch of humpback whales is also supported by sightings records from vessel based surveys carried out off the south coast of Zanzibar (P. Berggren, pers. obs.). This may indicate that the humpback whales encountered off Zanzibar are part of the migrating stocks from the Antarctic Ocean that have their breeding grounds off South and East Africa (Ersts and Rosenbaum, 2003). However, the relationship between the humpback whales found off Zanzibar and Tanzania and those in neighbouring areas, and the discreet breeding stock in the northern Indian Ocean still needs to be investigated. Zanzibar fishermen complain that they lose their nets when humpback whales are entangled. There are a few incidences when bycaught humpback whales have been killed by fishermen. For example, in four cases involving bycaught humpback whales, only two were released from the nets alive in 2003 and 2004 due to the quick response of the Department of Fisheries Development. The other two animals were killed by villagers in 2002 and 2004 and the meat was distributed for consumption in the local villages.

The results of this study show that sperm whales are the second most frequently recorded stranded cetacean species. Despite the high frequency of strandings, sightings of this species in Tanzanian waters are rare and no survey efforts have been done for this species in the area. Carcasses of sperm whales have been found washed up on beaches between July and December, usually of animals which have already died at sea. Most of the sperm whale strandings

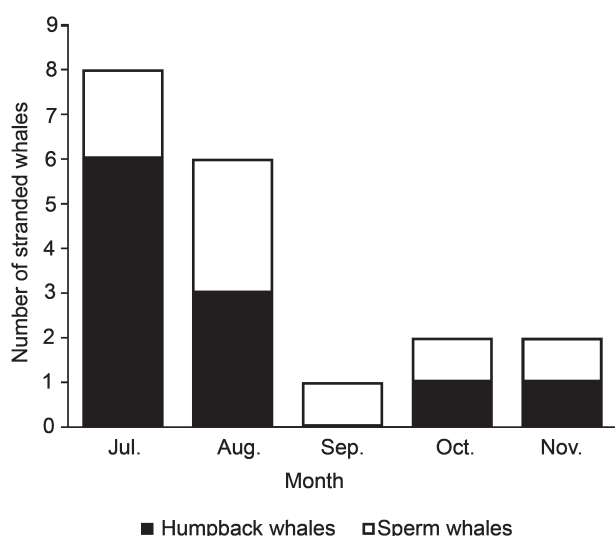


Fig. 2. Monthly distribution of humpback and sperm whales stranded off Zanzibar between 1992 and 2008.

Table 2
Species and occurrence of marine mammals bycaught in gillnet fisheries between 2000 and 2008.

Scientific name	Body length range (cm)	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total	%
<i>T. aduncus</i>	103.5–238	32	12	14	15	9	5	1	2	9	98	45.8
<i>S. longirostris</i>	101–213.5	20	18	0	10	1	2	10	8	1	70	32.7
<i>S. chinensis</i>	128–250	1	5	1	4	0	4	0	0	1	16	7.5
<i>G. griseus</i>	164–251	1	11	0	1	1	0	1	0	0	15	7.0
<i>S. attenuata</i>	173–228	0	4	0	2	1	0	0	0	0	7	3.3
<i>T. truncatus</i>	167–230	0	0	1	1	0	0	0	0	0	2	0.9
<i>L. hosei</i>	158	0	0	0	0	1	0	0	0	0	1	0.5
<i>M. novaeangliae</i>	415–1,040	0	0	1	1	2	0	0	0	0	4	1.9
<i>D. dugon</i>	235	0	0	0	0	0	1	0	0	0	1	0.5
Total		54	50	17	34	15	12	12	10	11	214	100

occurred on the east coast of Unguja Island which is very close to deep water (>1,000m within 10 n.miles).

The number of incidental catches of (mostly) small cetaceans varied from year to year but there has been a notable decrease in the number reported during the survey period. The decrease in incidental catch could be due to depletion of populations, the decrease in effort by beach recorders or increased awareness of fishermen to the conservation issues of marine mammals and fear that reports of incidental catch may lead to fisheries restrictions.

The results of this study show that Indo-Pacific bottlenose dolphins are the most widespread of all dolphins and occur all around the coast of Zanzibar. The species occurs in small resident populations, e.g. in the inshore waters of Menai Bay, south coast of Unguja with an estimated population size of between 136–179 bottlenose dolphins (Stensland *et al.*, 2006).

The bycatch data indicate that spinner dolphins are distributed in all coastal waters of Unguja Island except off the west coast where no specimens were retrieved from fisheries bycatch. This area is relatively shallow (maximum depth <50m) and may not meet the habitat requirements for the species. However, most of the spinner dolphin bycatch was reported from northwest of Unguja Island and in the area between Unguja Island and along the coast of Tanga, Tanzania mainland. Few bycatches of spinner dolphins have been reported from the south of Unguja Island. Sightings of spinner dolphins have been reported off Unguja Island along the coast of Nungwi and Matemwe (N. Ortland, pers. obs.) and on the west coast of Pemba Island (L. Karczmarski, pers. comm.).

Bycatch of Indo-Pacific humpback dolphins have been reported mainly from southwest and northwest of Unguja Island especially in the inshore areas and bays. This species is also known as resident in Menai Bay, off the south coast of Unguja with population estimates of about 58–65 animals (Stensland *et al.*, 2006).

Pantropical spotted, Risso's and Fraser's dolphins have only been reported as bycatch off the northeast coast of Unguja Island. This indicates that these species are rare in the coastal waters of Zanzibar. However, Pantropical spotted dolphins have been observed in mixed groups with spinner dolphins off the coasts of Nungwi and Matemwe on the north coast of Unguja Island (O. Amir and P. Berggren, pers. obs.). No Fraser's dolphin sightings have been recorded in the waters of Tanzania.

The two common bottlenose dolphins recorded were bycaught off the southwest and northwest coasts of Unguja Island. This gives an indication that this species is rare in the coastal waters of Tanzania, though it may be common offshore. The mass stranding of about 600 common bottlenose dolphins in April 2006 shows that the species can be present in the region in relatively large numbers. These animals were live stranded and died on the beaches. The cause of the mass stranding could not be established although all of the 66 specimens sampled on site had empty stomachs indicating that the animals may have stranded on an unfamiliar shore in search for prey.

The bycatch of a dugong, which occurred in 2005, is the first case to be recorded in Zanzibar. Dugongs have also been recorded as bycatch off the Tanzanian mainland. For example, 26 dugongs were bycaught in the Rufiji Delta and off Kilwa, along the coast of the Tanzanian mainland from 2000 to 2004 (WWF Eastern African Marine Ecoregion (EAME), 2004). A single dugong was also found stranded on Pemba Island in 2006. These records indicate that dugongs are still present in Tanzanian waters although their status remains unclear.

A pilot aerial survey conducted in Zanzibar and Tanzanian coastal waters in February 2000 revealed the occurrence of several other cetacean species including; rough-toothed dolphin (*Steno bredanensis*), Cuvier's beaked whale (*Ziphius cavirostris*) and Longman's beaked whale (*Indopacetus pacificus*) (Berggren *et al.*, 2001).

CONCLUSIONS

The results of this study demonstrate a relative high diversity of dolphin species present in the coastal waters of Tanzania. This information is important to the region since it demonstrates the potential for tourism based on whale and dolphin watching activities. The results are also cause for concern regarding the possible impact of the high mortality due to the gillnet fishery on local populations and this warrants further investigation. Hence, there is a need for more research in order to understand the ecology, abundance and conservation status of marine mammals in the region and to monitor their populations, especially for those species and geographical areas where no studies have been conducted. There is also a need for further cooperation and the building of trust between fishermen and Fisheries authorities in order to get precise information for the incidental catch to allow assessment of impact on populations.

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Occurrence and residency patterns of humpback whales off Réunion Island during 2004–10

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ABSTRACT

Dedicated humpback whale surveys were conducted around Réunion Island during 2004–10. Boat-based surveys were conducted from June to October, in the main objective of collecting photo-identification data. For 2004–10, a total of 501 survey trips, representing 1,530 hours of on-searching effort, and 724 humpback whale sightings were achieved. Although effort had a significant influence on the number of sightings, sighting rate was shown to increase significantly from 2007 onwards, with a peak in 2008. Seasonal variations were observed, with significantly higher numbers of sightings occurring in July–September. Larger number of whales, together with increased survey effort, led to larger datasets collected in 2008–10, allowing further investigation of residency pattern. Within-year recaptures from fluke photographs showed that a relatively large proportion (30%) of the identified whales was recaptured on more than one day around the island. Maximum recapture interval reached 64 days, with a mean ranging 22–29 days for 2008–10. Mean residency, estimated from expected lagged identification rate, was 25 days. Mothers with a calf were shown to reside around the island for longer period of time than other individuals. A seasonal pattern of residency was demonstrated, with single capture individuals occurring early in the season, mainly as singleton or pairs, while individuals showing higher recapture interval were present around the island from August to October. Between-year recaptures were reported for 2009–10, with five individuals re-sighted on consecutive years. The fluke catalogue for Réunion includes 312 distinct individuals identified during 2004–10 surveys, together with 21 additional whales captured opportunistically since 2001. The increasing trend in the number of whales, the high residency time observed for 2008–10 and the recent occurrence of inter-annual recaptures suggest that Réunion Island has become an important migratory site for humpback whales within the south-western Indian Ocean (Breeding Stock C). The species might expand its spatial range by occupying new breeding sites (or re-occupying old ones) within the south-western Indian ocean, as a result of population growth.

KEYWORDS: HUMPBACK WHALE; INDIAN OCEAN; BREEDING GROUND; RESIDENCY PATTERN; PHOTO-ID; SURVEY-VESSEL

INTRODUCTION

Réunion Island is a French overseas territory. It is a small (72km long), oceanic island in the south-western Indian Ocean, located 700km east of Madagascar and 250km west of Mauritius. The island shelf is very narrow (200m depth contour lies 3km from the coast on average) and sea depth increases very rapidly near the shore, down to 3,000m deep. Since 2004, ongoing cetacean surveys have been carried out in Réunion's coastal waters (<5 n.miles offshore), and 21 species have observed to date (Dulau-Drouot *et al.*, 2008; Globice, unpubl. data). The humpback whale (*Megaptera novaeangliae*) is one of the most frequent species seen in shallow waters during the southern winter.

The humpback whale is the only species showing a clear seasonal pattern in Réunion. Sightings occur from early June to late October (although few sightings are made in November and rare sightings occurred in December 2007 and 2008 and in February 2009), which is consistent with the general migration pattern of the species. Humpback whales undertake annual migration between high latitude summer feeding areas and low-latitude winter breeding areas (Dawbin, 1966). Although major migratory corridors have been described at the basin scale (Best *et al.*, 1998), knowledge of humpback whale migration pattern in the south-western Indian Ocean is still incomplete. Best *et al.* (1998) proposed three principal migratory streams: one on the east coast of southern Africa, one along the Madagascar Ridge, and one in the central Mozambique Channel. The

International Whaling Commission (IWC) designated seven breeding population (stocks A–G) in the Southern Hemisphere (IWC, 1998). The south-western Indian Ocean is considered as Breeding Stock C, sub-divided into 3 major subpopulations (IWC, 2000): C1, along the east coast of South Africa to Mozambique; C2, central Mozambique channel islands (Comoros, Aldabra, Eparses islands); and C3, coastal waters of Madagascar. The possibility of a further breeding sub-region, C4, in the Mascarene Islands (Réunion, Mauritius and Rodrigues) has been proposed (IWC, 2011b). However, because limited information was available, humpback whales from this region were not considered in the assessment of Breeding Stock C conducted recently by the Scientific Commission of the IWC (IWC, 2011a). Although the presence of the species has been reported in Réunion, Mauritius and Rodrigues little published data exist (Corbett, 1994; Dulau-Drouot *et al.*, 2008). There is evidence that whaling on humpback whales took place in Mauritius at the end of the 18th century (logbook from the ship *Asia*, 1791–94), but the Mascarene Islands did not appear to represent a whaling ground for humpback whales in the 19th century (Townsend, 1935). In the 20th century, although modern whaling expanded in South Africa, Mozambique and Madagascar (Tønnessen and Johnsen, 1982), no catch records are available from the Mascarene Islands. Therefore, there is no existing long term data for the species in this area. In this paper results are presented on sighting rate, residency patterns and movements of

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humpback whales in Réunion, from data collected during 2004–10 southern winters.

MATERIAL AND METHODS

Data collection

Dedicated boat surveys were conducted throughout the year off La Réunion (55°33'E, 21°07'S) from 2004 to 2010. Humpback whale data were collected, from June to October, in the coastal waters of the island. Surveys boats of similar sizes (5m long on average) were used and were launched at different locations along the coast: Saint Pierre; Etang sale; Saint-Leu; Saint Gilles; Le Port; and Sainte Marie. The spatial distribution of effort was constrained by general weather conditions, port locations and boat availability. The west coast is sheltered from dominant winds and was therefore mostly covered. Surveys off the northern coast were limited due both to difficult weather conditions during winter and lack of boat available in this area. No boat was available in Saint Rose, so the eastern coast of the island, exposed to dominant winds, was not covered during this study.

During surveys, watches were undertaken by 3–5 observers, searching the sea surface with the naked-eye. The same type of survey boats were used across years, thus the observers were surveying at a consistent height above the water surface. Searching effort was recorded by noting time, GPS position and sea state condition every 15 minutes. When humpback whales were sighted, the group size and composition were recorded, together with behavioural data. This sighting phase dedicated to data collection was considered off-effort. Groups of whales were classified into five categories based on group size and composition and according to behavioural characteristics previously described for this species (Tyack and Whitehead, 1983): singletons, pairs, mother-calf pair, mother-calf-escort and competitive groups. Groups that did not fall into one of these categories were classified as 'undetermined'. Whenever possible during humpback whale encounters, photographs were taken of the ventral side of the fluke and of both sides of the dorsal fin. Digital cameras (*Canon 10-50D*, *Sony A100*) equipped with 75–300mm lenses were used.

Data analysis

Humpback whale sighting rate was computed for each survey trip, by dividing the number of humpback whale sightings by the number of hours on-effort (include only searching phases and excluding time spent on sighting of any cetacean species) and expressed as the number of sightings per hour of searching effort. Mean sighting rates were calculated monthly and annually. A Generalised Linear Model (GLM) analysis was applied to determine whether variations in sightings numbers could be attributed to annual differences, and/or if other factors, such as month surveyed, area prospected and survey effort were expected to have a significant influence. The response variable being count data (number of sightings), a Poisson loglinear regression was applied, including three categorical variables as predictors: 'year'; 'month'; and 'area', with 'effort' as a covariate. The study area was divided into three zones: northern; western; and the southern part of the island (the eastern coast was not surveyed). All statistical tests were conducted using *SPSS*.

Within-year recaptures were assessed by comparing all fluke photographs taken within each year survey. For each individual, the best image of the fluke and, when available, of the right and left side of the dorsal fin were catalogued. The choice of the most representative image was based on both the quality of the photograph and the distinctiveness of pigmentation features of the ventral fluke (Friday *et al.*, 2000). In cases where multiple pictures were needed to allow a complete identification, several fluke photographs were chosen to represent an individual in the catalogue. All photographs of the catalogue were rated for quality on a five-level scale: excellent; good; fair; poor; and not useable. Photographs in the latter category were discarded from the comparison process. The portion of the fluke visible above the surface was also recorded. Flukes were classified into the nine pigmentation categories of the Antarctic Humpback Whale Catalogue (AHWC, <http://www.coa.edu/antarctic>). Photograph not selected for the catalogue were saved in archive files. Comparisons of the fluke catalogue of each year were undertaken to assess between-year recaptures. A 'capture' was defined as the first identification of an individual (based on a photograph of the pigmentation pattern in the ventral surface of the fluke), and a 'recapture' was defined as the subsequent photographic re-identification of the same individual.

Due to the small number of photographs available from 2004–07 and the small number of recaptures recorded these years, only 2008–2010 data were used to assess residency and movement pattern from within-year recaptures. Recaptures of animals identified more than once during the same day were not taken into account, so that within-year recaptures relate only to individuals identified in different days. For individuals re-sighted on multiple days, residence time was assessed by calculating the maximum recapture interval: time interval (in days) between the first capture and the last recapture of the whale. Residency was also investigated using the sighting histories of all individuals (including those seen only once), by computing the lagged identification rate (LIR). The LIR is an estimate of the probability that an individual identified in the study area at any time will be identified again in the study area some time lag later (Whitehead, 2001) and is calculated as follows:

$$R(\tau) = \frac{\sum_{j,k | (t_k - t_j) = \tau} m_{jk}}{\sum_{j,k | (t_k - t_j) = \tau} n_j \cdot n_k}$$

Where n_j is the number of individuals identified on occasion j ; m_{jk} is the number of individuals identified on both occasions j ; and t_j is the time of identifications at occasion j .

Lagged identification rates were first calculated for all adult whales identified in 2008–10. The LIR was then computed for mothers with a calf separately, to assess any difference in their residency pattern compared to other individuals. The observed lagged identification rates were fitted to exponential mathematical models of residency (Whitehead, 2001). Models were fitted with maximum likelihood methods. The Akaike Information Criterion (AIC) was used to determine the best fitting model and bootstrap

techniques were used to calculate 95% confidence interval and standard errors of LIR and model parameters (Whitehead, 2007). Lagged identification rates computation and residency model fitting were carried out using the computer software *SOCPROG* 2.4 (Whitehead, 2009).

RESULTS

Survey effort and data collected

Searching effort deployed from June to October increased with year, ranging from 120 hours on-effort (29 survey trips) in 2004 to 378 hours (141 survey trips) in 2008 (Table 1). In 2008–10, survey effort was intensified, as a response to the increase abundance of whales; an average of 21, 26 and 34 survey trips were conducted per month in 2008, 2009 and 2010 respectively (Table 1). The spatial coverage of effort tended to expand across years as well, with the northern part of the island being only covered in 2008–10 (Fig. 1). The western and southern parts of the island were covered every

year, while the eastern part had never been surveyed during the whale season (Fig. 1).

A total of 720 humpback whale sightings were undertaken from June to October during 2004–10 surveys. The number of humpback whale groups sighted increased with year, to reach a maximum of 272 sightings in 2010 (Table 1). More photo-identification data were collected during 2008–10, as a result of increased survey effort and increased number of whale sightings. Subsequently, the number of individuals identified from fluke photograph increased across years. In 2004–06, 7 individuals were identified per year and 17 in 2007. The number of identified whales increased notably in 2008, 2009 and 2010, with respectively 83, 80 and 116 adult individuals captured. In addition, 12 individuals were photographically identified in years prior to the present survey (9 in 2003, 2 in 2002 and 1 in 2003), although these were not associated with effort data. Furthermore, 9 individuals were identified from fluke photograph taken

Table 1

Details of survey effort carried out during the humpback whale season (June–October) at Reunion Island in 2004–10.

	Number of survey trips	On-effort survey (in hour)	Number of HW sightings	Mean sighting rate (sighting/hour)	Number of identified individuals
2004	29	120.5	12	0.1	7
June	5	22.3	1	0.04	1
July	7	28.5	6	0.21	5
August	7	27.5	2	0.06	0
September	4	18	2	0.11	0
October	6	24.3	1	0.04	1
2005	36	171.5	10	0.06	7
June	13	70	7	0.10	5
July	7	36.5	1	0.03	1
August	3	16.5	0	0.00	0
September	5	18.5	2	0.11	1
October	8	30	0	0.00	0
2006	42	192.3	13	0.08	7
June	18	90.8	3	0.03	0
July	3	10	2	0.20	2
August	4	15	2	0.13	2
September	7	30	1	0.03	2
October	10	46.5	5	0.11	1
2007	55	153.5	53	0.52	17
June	19	52.4	14	0.27	6
July	13	30.4	12	0.39	6
August	5	12.18	10	0.82	2
September	14	44.6	16	0.36	2
October	4	13.9	1	0.07	1
2008	91	207	168	1.06	83
June	7	16.6	3	0.18	1
July	19	39.6	24	0.60	7
August	21	53.2	60	1.13	44
September	25	50.3	53	1.05	26
October	19	47.2	28	0.59	4
2009	107	306.3	196	0.81	80
June	4	12.6	0	0.00	0
July	27	67.8	53	0.78	36
August	33	98.8	50	0.51	30
September	26	77.7	68	0.88	7
October	17	49.4	25	0.51	7
2010	141	378.5	272	0.92	116
June	5	16.7	0	0.00	1
July	26	76.7	26	0.34	19
August	43	102.7	118	1.15	59
September	36	94.7	105	1.11	31
October	31	87.7	23	0.26	6

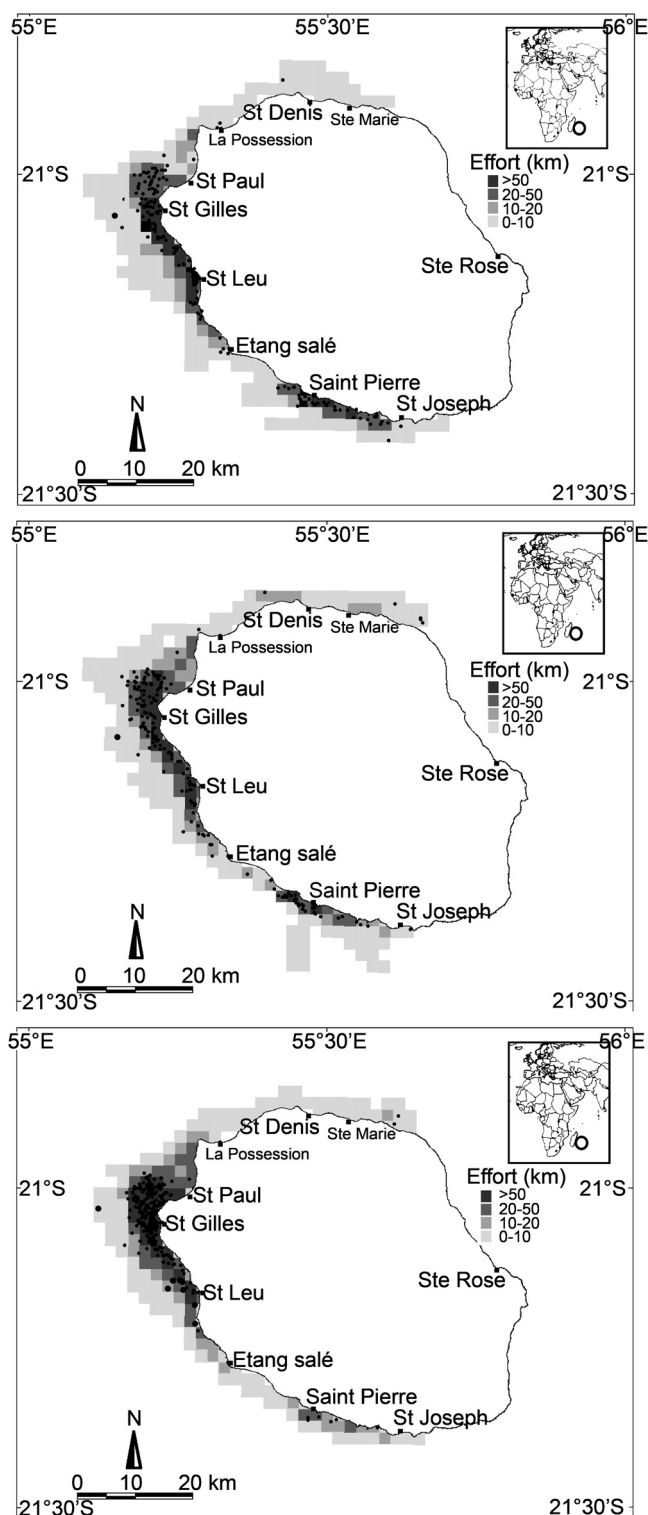


Fig. 1. Map of Réunion showing distribution of effort (2×2km grid) and humpback whales sightings from (A) 2008, (B) 2009 and (C) 2010 surveys.

opportunisticly in 2009 and 2010. These additional data were included in when undertaking between-year comparisons.

Sighting rate

The annual sighting rate increased from a mean of less than 0.1 sighting hr^{-1} during 2004–06 to a mean of 0.5 sighting hr^{-1} in 2007, and reached a peak of 1.1 sighting hr^{-1} in 2008 (Table 1). In 2009 and 2010, the mean sighting rates

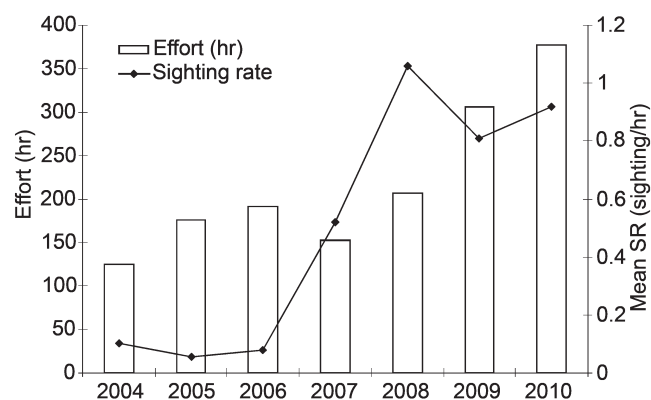


Fig. 2. Humpback whale mean encounter rate (sighting hr^{-1}) observed in 2004–08 in Réunion. Error bars indicate SE. Dotted line indicate a rate of increase of 10.3% from 2004 value.

remained relatively consistent (0.81 and 0.92 sighting/hour respectively), although higher effort was achieved (Fig. 2).

The output of Poisson regression indicates that years, months and effort were highly significant in determining the observed variation in the number of whale sightings, while the area did not appear to be a significant explanatory variable (Table 2). Therefore, for a given month and effort, there was no significant difference in the number of sightings made in different survey areas whereas there was a significant effect of year. The results of the Wald χ^2 tests indicate that the number of sightings was significantly higher in July, August and September, than in October and June (Table 3). Negative parameters for years 2004–07 indicate that the number of sightings was lower over this period than in 2010 (reference year), and the difference was statistically significant for years 2005 and 2006 ($\chi^2 = 1.505$, $p = 0.017$, $\chi^2 = 1.543$, $p = 0.01$, respectively). In 2007 and 2009, the number of sightings was not significantly different to 2010, while in 2008 significantly higher numbers of sightings were observed ($\chi^2 = 1.018$, $p = 0.001$). Therefore, the regression analysis confirms, for a fixed month and effort, an increased humpback whale occurrence in 2007–2010, with a peak observed in 2008. The odd ratios indicated there were 4 times less sightings in 2005 and 2006 than in 2010 and 2.7 times more sightings in 2008 compared to 2010.

Group size and structure

Groups ranged from 1 to 8 individuals, with a mean group size of 2.2 individuals. Of the 720 groups sighted, 26.7% were singletons, 20.7% pairs, 24.9% mother-calf pairs, 8.5% mother-calf-escort, 11.3% competitive groups and 8.3%

Table 2

Overall test of significance of the effect of zone, year, month and effort in the loglinear model.

Tests of model effects (Type III)			
	Wald χ^2	df	p
Intercept	0.215	1	0.643
Area	5.202	2	0.074
Year	53.591	6	<0.001
Month	33.993	4	<0.001
Effort	47.113	1	<0.001

Table 3

Analysis of coefficient estimates and the significance of each of the variables included in the loglinear regression.

Parameter	Estimate (β)	Std. error	95% Wald confidence interval		Hypothesis test			Odd ratio Exp(β)
			Lower	Upper	Wald χ^2	Df	<i>p</i>	
(Intercept)	0.279	0.3828	-0.472	1.029	0.530	1	0.467	1.322
Zone=North	-0.752	0.3653	-1.468	-0.036	4.235	1	0.049	0.471
Zone=West	0.123	0.2619	-0.390	0.636	0.221	1	0.638	1.131
Zone=South	0 ^a	—	—	—	—	—	—	1
Year=2004	-1.062	0.6084	-2.254	0.130	3.047	1	0.081	0.346
Year=2005	-1.505	0.6307	-2.741	-0.268	5.690	1	0.017	0.222
Year=2006	-1.543	0.5973	-2.714	-0.373	6.678	1	0.010	0.214
Year=2007	-0.043	0.3552	-0.739	0.653	0.014	1	0.904	0.958
Year=2008	1.018	0.2968	0.436	1.600	11.768	1	0.001	2.768
Year=2009	0.399	0.2108	-0.014	0.812	3.583	1	0.058	1.490
Year=2010	0 ^a	—	—	—	—	—	—	1
Month=6	-0.246	0.4147	-1.059	0.567	0.352	1	0.553	0.782
Month=7	0.558	0.2644	0.040	1.076	4.452	1	0.035	1.747
Month=8	0.656	0.2451	0.175	1.136	7.159	1	0.007	1.927
Month=9	1.140	0.2352	0.679	1.601	23.513	1	<0.001	3.127
Month=10	0 ^a	—	—	—	—	—	—	1
Effort (hours)	0.038	0.0056	0.027	0.049	47.113	1	<0.001	1.039
(Scale)	3.307 ^b	—	—	—	—	—	—	—

^aSet to zero because this parameter is redundant (reference variable). ^bComputed based on the Pearson chi-square.

were undetermined. This latter category included mainly groups of 3–4 individuals not showing any surface active behaviour. Therefore, calves were observed in 33% of the sightings. The proportion of each group type varied across months (Fig. 3). Early in the season, in June and July, more than 80% of the sightings consisted of singletons or pairs of individuals. During the season, the number of groups including a calf increased consistently. By October, 64.1% of the sightings consisted of mother-calf pairs or mother-calf-escort groups. Competitive groups were mainly observed in August and September (Fig. 3).

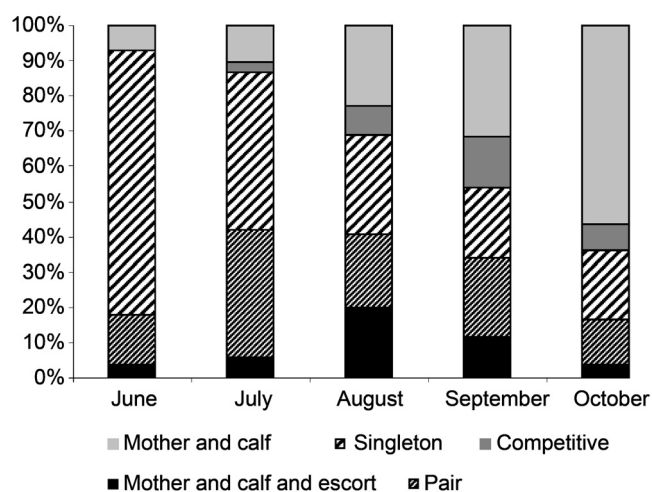


Fig. 3. Monthly distribution of sightings according to group types (2004–10).

Within-year recaptures and time residency

In 2008, 2009 and 2010 within-year recapture rates were relatively high, reaching 30%, 20% and 42% of the 83, 80 and 116 individual identified respectively. Therefore, on average over these three years, 69.4% of the identified individuals were captured only once, while 30.6% were recaptured on more than one day over the season. Overall,

there was a trend for individuals captured only once to occur early in the season: 79% of the whales photographically identified in July were single capture individuals while in September and October the majority of the whales identified consisted of recaptures (65 and 68% respectively).

The number of recaptures per individual ranged from 2–7 in 2008 and 2009 and up to 12 in 2010, with most recaptured whales been seen 2–7 times on different days (88%). Although most of the recaptured whales were not seen often, their maximum recapture interval was relatively high and consistent, with a mean of 22 ($\pm$ SE = 2.8) days in 2008, 29 ($\pm$ SE = 5.3) days in 2009 and 23 ($\pm$ SE = 2.3) days in 2010. The longest interval between first and last recaptures was 45, 64 and 60 days in 2008, 2009 and 2010 respectively. Thus, no whale has been observed in Réunion over a period of more than two months within the same year. Among all individuals recaptured on more than one day, 31% were re-sighted after an interval of less than 10 days (28 individuals), 32% were sighted around the island between 11 to 30 days (29 individuals) and the remaining 36% stays over more than 31 days (33 individuals) (Fig. 4). Of the 90 individuals recaptured within 2008, 2009 and 2010 seasons, 11 were females accompanied by a calf and 8 were ‘escort’. Mother-calf pairs showed a significantly longer residency than other individuals, with a capture interval of 36 days on average (Table 4), ranging from 19 to 60 days (T-test = 3.59, p = 0.003). Individuals escorting a female with a calf tended to have relatively long residency as well, with a mean capture interval of 28 days, ranging from 19 to 56 days, however, the difference was not significant statistically (T-test = 1.136, p = 0.286).

The residency model best fitting the overall lagged identification rate (Goodness of fit χ^2 = 39.9, df = 39, p = 0.4291) indicates that there were approximately 32 whales ($31.7 \pm$ SE = 3.7, 95% CI = 26.3–41.9) in the study area at any one time and the estimated mean residence time of individuals was 25 days ($25.1 \pm$ SE = 2.92, 95% CI = 20.5–31.5).

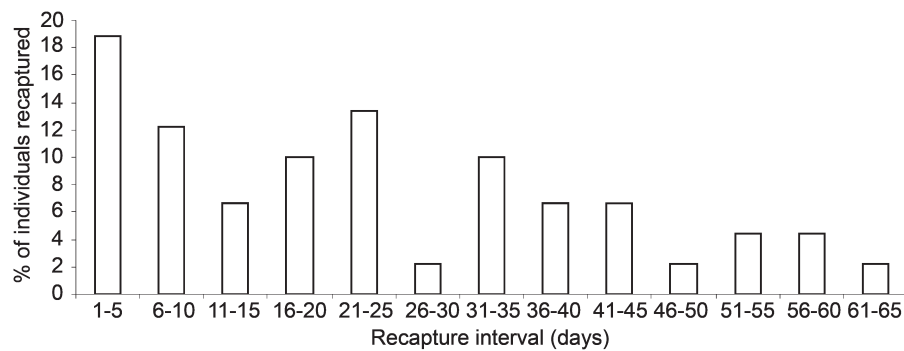


Fig. 4. Distribution of the individuals captured in 2008, 2009 and 2010 off Réunion (in percentage), according to the maximum recapture interval (in days).

When computed separately, the LIR of mother with calf appeared to be higher than those of other individuals, with the observed rates remaining relatively high for up to 45 days (Fig. 5). Therefore, the probability of recapturing a mother with a calf after its first capture was higher than for other whales, indicating that mothers with calves tended to reside longer in the study area compared to other individuals. The parameter estimates of the fitted model indicate that there were five ($4.7 \pm \text{SE} = 1.37$, 95% CI = 2.7–7.8) mothers with a calf at any one time in the study area and their mean residence time was 53 days on average. Other individuals (males or females without a calf) showed a lower probability of being recaptured with lag time (Fig. 5). They occurred in greater numbers, with approximately 30 individuals present at any given time in the study area ($29.9 \pm \text{SE} = 4.1$, 95% CI = 23.5–40.9) and were expected to reside for a shorter period of time (24 days $\pm \text{SE} = 3.0$, 95% CI = 19.3–30.9).

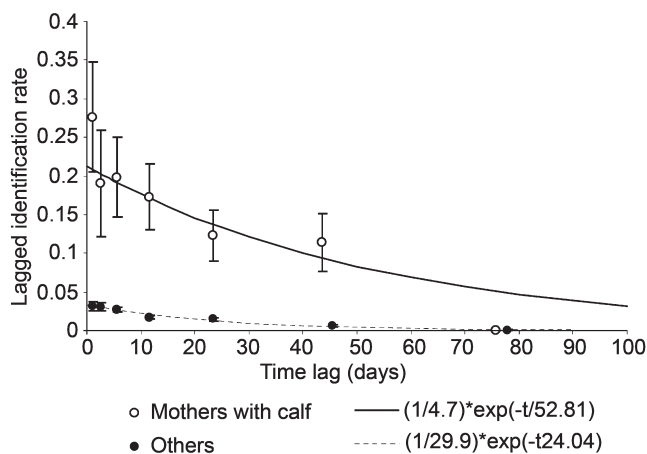


Fig. 5. Lagged identification rate of mother with calf and other individual humpback whales identified in 2008–10 in Réunion, together with the expected lagged identification rates from residency models. Vertical lines are standard error.

Spatial movement

The distance between recaptures of individuals ranged from 0.2 to 75 km. On average, the whales moved along the coast at a rate of 3.3 km per day, with displacement rate ranging from 0.02 km to 52 km day⁻¹ (Table 4). The maximum distance travelled in one day (52 km) correspond to a whale sighted off Saint-Gilles and resighted south of Saint-Pierre the day after. There was no difference in mean displacement

rate between mother-calf pairs, escorts and other individuals (Kruskal-Wallis Test = 0.672, $p = 0.715$). Displacement was not significantly correlated with time lag and there was no evidence of any coordinated movement pattern of whales: different whales could either move long distance in one day or remain in the same area for several days. Individuals recaptured on at least seven occasions during 2008–10 are presented in Fig. 6, where re-sightings of mother-calf pairs ($n = 6$), escort ($n = 3$) and other individuals ($n = 3$) were linked with direct separated lines to better visualise long-distance movements. Although most recaptures occurred off Saint Gilles, where most effort was conducted, whales appear to be travelling around the island, and thus using all of the coastline, during their stay in Réunion, independent of whether they are mothers with a calf, escorts or other individuals (Fig. 6).

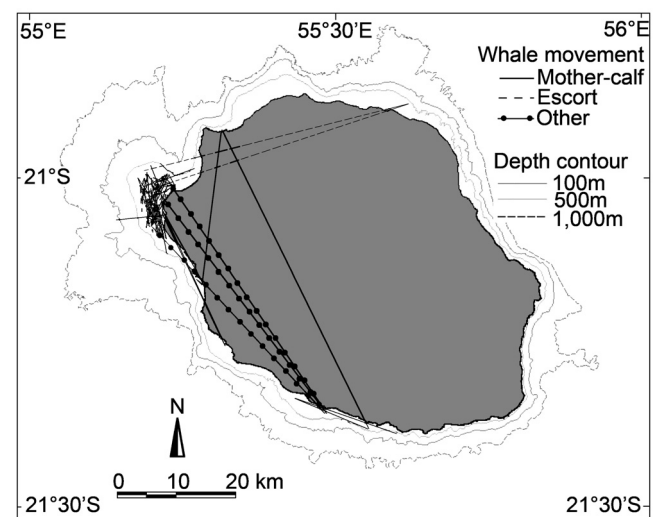


Fig. 6. Map showing re-sightings of whales recaptured seven times or more during 2008–10 season, linked by a direct line to illustrate movements of mother-calf, escort and other individuals separately.

Between-year recaptures

Five between-year recaptures were found during the study period (2004–10). All were first captured in 2009 and recaptured in 2010 at Réunion. Therefore of the 80 individuals identified in 2009, five came back to Réunion the following year. Among them, one individual appeared to be a female, observed with a calf in 2010. The gender of the four other recaptured individuals was not known, although they were all sighted at least once in competitive groups and

Table 4

Descriptive statistics of recapture intervals and displacement rates of individuals recaptured on different days during 2008–10 seasons.

	N	Recapture interval (days)				Displacement rate (km/day)			
		Mean	SD	Min	Max	Mean	SD	Min	Max
Overall	86	23.1	17.9	1	64	3.26	5.10	0.04	28.78
Cow-calf	12	36.6	14.1	19	60	2.17	2.46	0.45	8.55
Escort	8	27.9	17.7	3	56	3.59	3.83	0.68	10.68
Other individuals	68	20.4	17.4	1	64	3.38	5.52	0.04	28.78

were thus involved in reproductive activity. An additional between-year recapture was recorded from an individual first identified in 2003 (before the study period) and recaptured during the 2010 survey at Réunion, when it was sighted 8 times over a 56 day period. This individual was observed both in 2003 and 2010 as escorting a mother with a calf, and was thus suspected to be a male. There was no consistency in the timing of the first capture day between years, with sightings occurring from 2 to 33 Julian days from the date of their initial capture year.

Therefore, taking account of between-year matches, the final catalogue included 312 different individuals captured in Réunion Island during 2004–10 surveys, five of which were recaptured on consecutive years. Fluke photographs of 21 individual whales were also available from previous years (2001–03) and opportunistic photographs (2009–10), allowing a seven year interval recapture. Altogether, the catalogue from Réunion includes 322 individuals identified from fluke photographs up to 2010.

DISCUSSION

The results show a significant increase in humpback whale numbers visiting Réunion during 2007–10 compared to previous years (2004–06). Increases in humpback whale numbers have been inferred in others sites of the south-western Indian Ocean such as in Sainte Marie, on the East coast of Madagascar (F.X. Mayer, pers. comm.) and in Zanzibar (P. Berggren, pers. comm.), although no published data are available from these areas. The increase in sighting frequency observed in Réunion or other localised places might result from an increase in humpback whale population at a regional scale. Using mark-recapture data collected from Antongil Bay in 2000–07 (Cerchio *et al.*, 2008), an annual growth rate of 8% has been estimated for Madagascar (breeding sub-stock C3, Johnston and Butterworth, 2008). However, the increase in humpback whale sightings observed in 2008–10 in Réunion appears to be larger than the medium rate of population increase estimated for Madagascar and exceeds the maximum plausible rate of increase of 11.8% yr⁻¹ established from the examination of life-history parameters in humpback whales (Zerbini *et al.*, 2010). Therefore, although part of the rise observed in recent years in Réunion might result from a population growth at a regional level, other factors have to be considered. An increased immigration to Réunion Island might reflect a density-dependent response of whales within Breeding Stock C, whereby whales investigate new sites (or re-occupy historical ones) as other sites are becoming saturated because of recent population growth. First movements of individual

humpback whales from Madagascar to Réunion have been reported recently (Dulau-Drouot *et al.*, 2011). Although an analysis of exchange probability has not been conducted yet, these preliminary results tend to support the hypothesis that Réunion might represent an extension of the Madagascar wintering area as oppose to a separate entity (sub-stock C4) within the south-western Indian Ocean. Furthermore, the recent between-year recaptures reported in the present study suggest that some degree of site fidelity might have begun to occur at Réunion. However, most whales captured at Réunion have been sighted in only one year indicating a general trend for whales to use different breeding sites across the years. Studies on major breeding areas of the south-western Indian Ocean have shown low site fidelity between years (Cerchio *et al.*, 2008; Ersts *et al.*, 2006) and evidence of exchanges of individuals between eastern Madagascar and the northern Mozambique Channel (Ersts *et al.*, 2011). Therefore migration movement of humpback whales between breeding sites of the south-western Indian Ocean might be particularly complex. Other environmental factors such as changes in water temperature, might also affect migration routes and choice of breeding areas. However, to date, the forces driving migrations on a fine scale remain unclear (Rasmussen *et al.*, 2007).

Humpback whales were present in coastal waters of Réunion from early June to late October, with a peak in July–September. The consistent occurrence of newborn calves and competitive groups in the present study confirm that Réunion Island represents a breeding area for the species in the south-western Indian Ocean, as suggested in previous studies (Dulau-Drouot *et al.*, 2008).

Within-year recapture results from 2008–10 data showed that an average of 30% of the captured whales were observed on multiple days, with a mean recapture interval ranging from 22–29 days and a maximum residency of 64 days. These recapture rates and intervals are respectively higher and longer when compared to other studies. In Antongil Bay (Madagascar), within-year recapture rate ranged 6–18% of individuals captured on more than one day and mean recapture interval ranged from 3–8 days (Cerchio *et al.*, 2008). In the Pacific, Cerchio (1998) reported that the percentage of recaptured whales in Kauai Island (Hawai'i) ranged from 5–14%, with a mean re-sighting interval of 15 days. Thus, within-year recapture intervals demonstrate relatively high residency of humpback whale in Réunion. These variations might be explained by differences in the size and remoteness of the survey area and survey effort, together with differences in the size and composition of the population. In fact, the probability of recapturing a whale

decreases with increasing survey area and population size. Réunion Island is isolated and relatively small (207km of coastline) with steep underwater slope, restricting humpback whale habitat within 2km from the coast, excepted off Saint Gilles where 100m contour lies 7km from the coast (Dulau-Drouot *et al.*, 2008). Overall, the habitat used by humpback whales around Réunion corresponds to an area of 345km², while Antongil Bay (Madagascar) for example encompasses 1,800km² (Cerchio *et al.*, 2008) with adjacent potential habitat. Furthermore differences in survey effort are observed between studies. In Antongil Bay, Cerchio *et al.* (2008) reported a mean sampling effort of 31 days per season spanning from mid-July to mid-September, while in this study, an effort of 91 to 141 survey trips was achieved from early June to late October in 2008–10. Thus, larger sampling effort, spanning a larger period, might explain the larger recapture intervals obtained in Réunion compared to Madagascar. Réunion being located at a higher latitude compared to Antongil Bay, the breeding season might span a longer period (allowing extended survey effort), as whales might afford to stay longer in southern sites before heading back to Antarctic feeding grounds. Despite an increased effort deployed in 2009 and 2010, relatively consistent recapture intervals were found in 2008–10 in Réunion, suggesting that they are representative estimates of time residency in the survey area. This was confirmed by the lagged identification rate analysis, leading to similar expected residency (25 days).

The results demonstrate a significantly higher residency time for mothers accompanied by a calf compared to other individuals. Furthermore, a seasonal trend was observed in recapture rates, whereby individuals captured in July tended to be sighted only once while the proportion of recaptured individuals increases from August to October. These results suggest that the earlier part of the season encompass mostly individuals with transient residency, while the later part of the season hosts individuals using Réunion coastal waters for a longer period. Therefore, the island seems to represent an 'endpoint destination' for at least some of the whales migrating to Réunion, which remain in coastal waters for a relatively long period (maximum of two months). This seems to be particularly the case for mothers with calves, showing a recapture interval of 36 days on average and expected mean residency (from LIR) of 53 days. Other individuals, including escorts, have also been observed for extended lengths of time (maximum recapture interval of 28 days on average). A seasonal pattern in group structure was also demonstrated, with sightings made early in the season consisting mostly of singletons and pairs of individuals, competitive groups being most frequently observed in August, and mother-calf pairs mainly occurring later in the season, in September and October. This seasonal trend is consistent with the migratory timing described for the species. Both historical catch data and photo-identification studies have demonstrated that humpback whale migration to and from the winter grounds were segregated on the basis of age, sex and reproductive condition (Dawbin, 1997; Graig *et al.*, 2003). Females in late pregnancy or with newborn calves are among the last whales to arrive at the wintering grounds and the last to migrate back to the feeding ground. The year they give birth, females might tend to extend their

stay in the feeding ground to maximise their food intake prior to parturition and lactation and to delay their departure from the breeding ground until their calf is sufficiently robust to enhance their chance of survival during their first migration to higher latitude (Graig *et al.*, 2003).

Analysis of spatial movement showed that whales resighted on multiple days moved around the island at a rate of 3.3km per day on average. Although the eastern and northern coasts were not or poorly surveyed, opportunistic sightings from land were consistently reported from these areas (Globice, pers. comm.), supporting the view that whales are using the coastal waters of the entire island. In contrast, the majority of captured whales (69% on average for 2008–10) were observed only once. These individuals showing transient residency were mostly encountered early in the season, suggesting a trend for individuals arriving early in the season to stopover in Réunion, before moving to other breeding area such as Mauritius, the Seychelles archipelago or the Tromelin islands. Land based surveys conducted in Tromelin, indicate that this small island of 1km² located 535km North of Réunion also hosts humpback whales during the austral winter, with competitive groups and new born calves being observed there (Globice, unpublished data). Interestingly, no peak of newly identified individuals was observed at the end of the season (the discovery curve flattens out in September–October), suggesting that no (or very few) whales from lower latitude breeding grounds are transiting to Réunion on their southward migration. To date, no inter-regional recaptures of individuals from Réunion have been reported with other sites of the south-western Indian Ocean on the same year, so migration routes are still largely unknown. Further inter-regional comparisons will be encouraged to improve knowledge and understanding of humpback whales migratory movements.

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Organ weights of three dolphin species (*Sousa chinensis*, *Tursiops aduncus* and *Delphinus capensis*) from South Africa: implications for ecological adaptation?

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ABSTRACT

Data from bycaught, but otherwise presumed healthy individuals can contribute important biological data on species of cetaceans that are otherwise lacking. This study utilises data collected from systematic necropsies performed between October 1970 and May 2010 on 142 Indo-Pacific humpback dolphins (*Sousa chinensis*), 607 Indo-Pacific bottlenose dolphins (*Tursiops aduncus*), and 640 long-beaked common dolphins (*Delphinus capensis*) incidentally caught and drowned in the shark nets off KwaZulu-Natal, South Africa. The aim of this analysis was to: (1) determine average absolute and relative organ weights for the three taxa as baseline values for later pathological examinations; and (2) examine potential correlations with the physiology and ecology in the three genera. Body length-weight relationships were described for the three species, indicating that *S. chinensis* is more robust than *T. aduncus*, with *D. capensis* being the smallest species out of the three taxa. Organ weights, as a percentage of total body weight were examined for the three delphinids. Organs examined included heart, lungs and trachea, liver, kidneys, spleen, and testes. Relative heart, liver and kidney weights were significantly larger in the small-bodied, fast-swimming *D. capensis*, than in the slower, more coastal *S. chinensis* and *T. aduncus*, possibly reflecting differences in activity patterns between the three species. Relative lung and trachea weights were not significantly different in the three species. Combined testes weight, as a percentage of total body weight, in combination with information on group size and sexual dimorphism suggested a monogamous or extreme polygynous (harem) mating system in *S. chinensis*, frequent copulations in *T. aduncus*, and sperm competition in *D. capensis*. The results of the present study suggest that the relative sizes of the major organs in the three genera are a reflection of the differing life histories and ecologies of the species examined.

KEYWORDS: INCIDENTAL CATCHES; AFRICA; INDO-PACIFIC HUMPBACK DOLPHIN; INDO-PACIFIC BOTTLENOSE DOLPHIN; LONG-BEAKED COMMON DOLPHIN

INTRODUCTION

Allometric relationships between organ weights and body weights have been the topic of numerous studies of mammalian taxa (Calder, 1983; Davis, 1962; Jürgens *et al.*, 1981; Lindstedt and Calder, 1981; Piscitelli *et al.*, 2010; Stahl, 1965; 1967; Western, 1979). Data from the Order Cetacea, however, are generally lacking. Information on organ weights in wild cetaceans is valuable for a number of reasons: to further the understanding of the physiology and overall biology of these animals, to provide comparative data with other species (both marine and terrestrial), and to establish baseline data that may be used to evaluate pathological change. Allometry is an important tool in comparative anatomy and physiology; the weight of an organ must, however, be examined in relation to the absolute size of the body to determine whether its weight is above or below the average value normally observed (Prothero, 1982; Slijper, 1958).

A number of previous studies have examined organ weights in odontocetes (for example Cowan, 1966; Cowan and Tajima, 2006; Gahr and Pilleri, 1969; Innes *et al.*, 1986; Kastelein and van Battum, 1990; McLellan *et al.*, 2002; Miyazaki *et al.*, 1981; Perrin and Roberts, 1972; Pilleri and Gahr, 1969; Piscitelli *et al.*, 2010; Turner *et al.*, 2006) and pinnipeds (Bryden and Erickson, 1976; Oftedal *et al.*, 1989;

Stewardson *et al.*, 1999). However, studies that examine organ weights in relation to body weights in an ecological context are rare for cetaceans (McLellan *et al.*, 2002; Miyazaki *et al.*, 1981; Perrin and Roberts, 1972; Ridgway and Kohin, 1995). There is therefore a lack of consideration as to the physiological and ecological pressures that may have shaped the observed patterns. This may in part be due to the logistical constraints in obtaining total body weight measurements from cetaceans. Body length measurements are taken as part of standard necropsy protocols of cetaceans (Norris, 1961), but body length is not always sufficient to accurately calculate body weight in these animals (Kastelein and van Battum, 1990). Although Slijper (1958) remarked that organ weights for a number of large baleen whale species were available as a byproduct of the economic importance of these animals at that time, enormous logistical challenges and time constraints are involved in weighing baleen whale carcasses, either whole or piecemeal (Lockyer, 1976; Lockyer and Waters, 1986; Omura, 1950). Thus due to logistical reasons, body weight measurements often pose a problem, even in smaller odontocetes (Cowan, 1966).

Baseline data on the normal variability in organ size in relation to body weight as well as histology are necessary to better interpret pathological changes in these genera (Cowan and Tajima, 2006; Turner *et al.*, 2006). Such data from

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stranded animals are sometimes compromised because the animals can be desiccated or emaciated, and as a result may not yield a normal organ weight/body weight ratio (Cowan and Tajima, 2006). As the animals used in the present study were incidentally caught in shark nets off the South African coastline and subsequently died, it was assumed that they were in a normal condition and therefore may be considered representative of a wild population.

Indicators such as testes weight to body weight ratio, sexual dimorphism and group size have been used to provide information on the mating systems of terrestrial mammals (Harcourt *et al.*, 1981; Kenagy and Trombulak, 1986; Rose *et al.*, 1997). This approach has been applied in cetaceans as a basis to formulate hypotheses about the mating system of a species (e.g. Aguilar and Monzon, 1992; Brownell and Ralls, 1986; Cockcroft, 1993; Slooten, 1991; Van Waerebeek and Read, 1994). In odontocetes, small testes in relation to body weight, together with a large degree of sexual dimorphism and small group sizes, are thought to be indicative of a monogamous or extreme polygynous mating system, such as a harem or roving male strategy. Conversely, large relative testis weights, the absence of sexual dimorphism, and large group sizes are attributed to frequent copulations and sperm competition (Cockcroft, 1993; Connor *et al.*, 2000; Plön and Bernard, 2007; Van Waerebeek and Read, 1994).

Shark net installations along the KwaZulu-Natal coastline of South Africa have been in place since 1952 and today cover 23km in total along a 320km stretch of coast (Fig. 1) (Cliff and Dudley, 1992; Cliff, pers. comn). The nets are checked and maintained about 20 times per month by the KwaZulu-Natal Sharks Board (KZNSB). As part of a long-term agreement, data and samples from dolphins incidentally caught in these nets are being accessioned to the Graham Ross Marine Mammal collection at the Port Elizabeth Museum (PEM) in the Eastern Cape province of South Africa. These data and samples provide invaluable information on the natural history and ecology of the individual species caught, as well as information on diseases and any potential adverse effects of environmental conditions on the dolphins. The three main species incidentally caught in the nets are the long-beaked common dolphin *Delphinus capensis*, the Indo-Pacific bottlenose dolphin *Tursiops aduncus*, and, to a lesser extent, the Indo-Pacific humpback dolphin, *Sousa chinensis* (Best, 2007).

As the data from the present study are examined in view of the different mating styles shown by the three dolphin species considered, a brief overview is given here on different ecological aspects of the individual species, such as body size, group size and distribution.

S. chinensis is thought to exhibit sexual dimorphism – males are larger, with a maximum length of up to 279cm, compared to females, which have been recorded of reaching up to 249cm (Best, 2007; Ross and Best, 1989). The average group size is less than 10 animals for the species off South Africa (Karczmarski *et al.*, 1999; Ross, 1984; Ross *et al.*, 1994). These dolphins are coastal and are usually not observed in water depths over 25m or more than 400m offshore (Karczmarski *et al.*, 2000) and are found most often in the surf zone (less than 15m deep) (Friedmann and Daly, 2004; Ross *et al.*, 1994).

Despite bottlenose dolphins being cosmopolitan and widely studied, their taxonomy is unresolved (Fury and Harrison, 2008; Hale *et al.*, 2000; Rice, 1998). *T. aduncus* was first described from South Africa (Ross, 1977), and later confirmed genetically (Natoli *et al.*, 2004). It occupies inshore areas along the coastline compared to *T. truncatus*, which is found further offshore (Rice, 1998; Ross, 1977; 1984). Although it is not always possible retrospectively to discern which form/species some of the past records apply to, it has been assumed that all coastal records belong to the *aduncus* form (Best, 2007). Average adult lengths are 243cm in males and 238cm in females, and the form is smaller than *T. truncatus* (Best, 2007; Ross, 1984). Group sizes for this species range from 40 to 100 animals (Cockcroft *et al.*, 1992; Saayman *et al.*, 1973). *T. aduncus* mostly occupies the coastal regions in waters less than 50m deep, and is found all along the South African coastline between False Bay and Mozambique (Best, 2007) in a wide range of habitats, including lagoons and estuaries (Findlay *et al.*, 1992).

Although both *D. delphis* and *D. capensis* have been reported from the South African subregion (Best, 2007), prior genetic (Natoli *et al.*, 2006) and morphometric (Samaai *et al.*, 2005) analyses of specimens caught in the shark nets off KwaZulu-Natal have identified the specimens as *D. capensis* and thus all animals included in the present sample are assumed to belong to that species. *D. capensis* off South Africa show a maximum adult body length of 254cm in males and 222cm in females (Heyning and Perrin, 1994; Ross, 1984; Ross and Best, 1989). This species is found in groups of 100s to 1,000s of individuals, with an average group size of 302, but appear to have social units of around 30 animals (Cockcroft and Peddemors, 1990; Evans, 1994). Along the South African coastline *D. capensis* occupies waters of less than 500m in depth (Findlay *et al.*, 1992; Rice, 1998). Annual migrations in winter along the east coast are common, following the annual ‘Sardine Run’, which begins in the Eastern Cape and travels up to the north coast of KwaZulu-Natal (Findlay *et al.* 1992). However, sightings of *D. capensis* in KwaZulu-Natal waters have been made in both summer and winter (Findlay *et al.*, 1992).

The aim of the present study was to: (1) provide baseline data on absolute and relative organ weights of three dolphin species incidentally caught in the shark nets along the KwaZulu-Natal coastline of southern Africa; and to (2) explore potential correlations between the relative weight the individual organs contribute to the total body weight and the ecology of the three species examined.

MATERIALS AND METHODS

Sample

For the present study, data for 142 *S. chinensis*, 607 *T. aduncus*, and 640 *D. capensis* were analysed. All data were available from the Graham Ross Marine Mammal Collection at the Port Elizabeth Museum, Port Elizabeth, South Africa, and originate from animals incidentally caught and drowned in the shark nets off KwaZulu-Natal (Fig. 1). No stranded specimens were included in the analyses. All data from carcasses that were noted as either rotten, shark bitten, or pregnant were removed from the dataset. The data analysed included total body weight and length as well as weights for the heart, lung and trachea, liver, kidneys, spleen and testes.

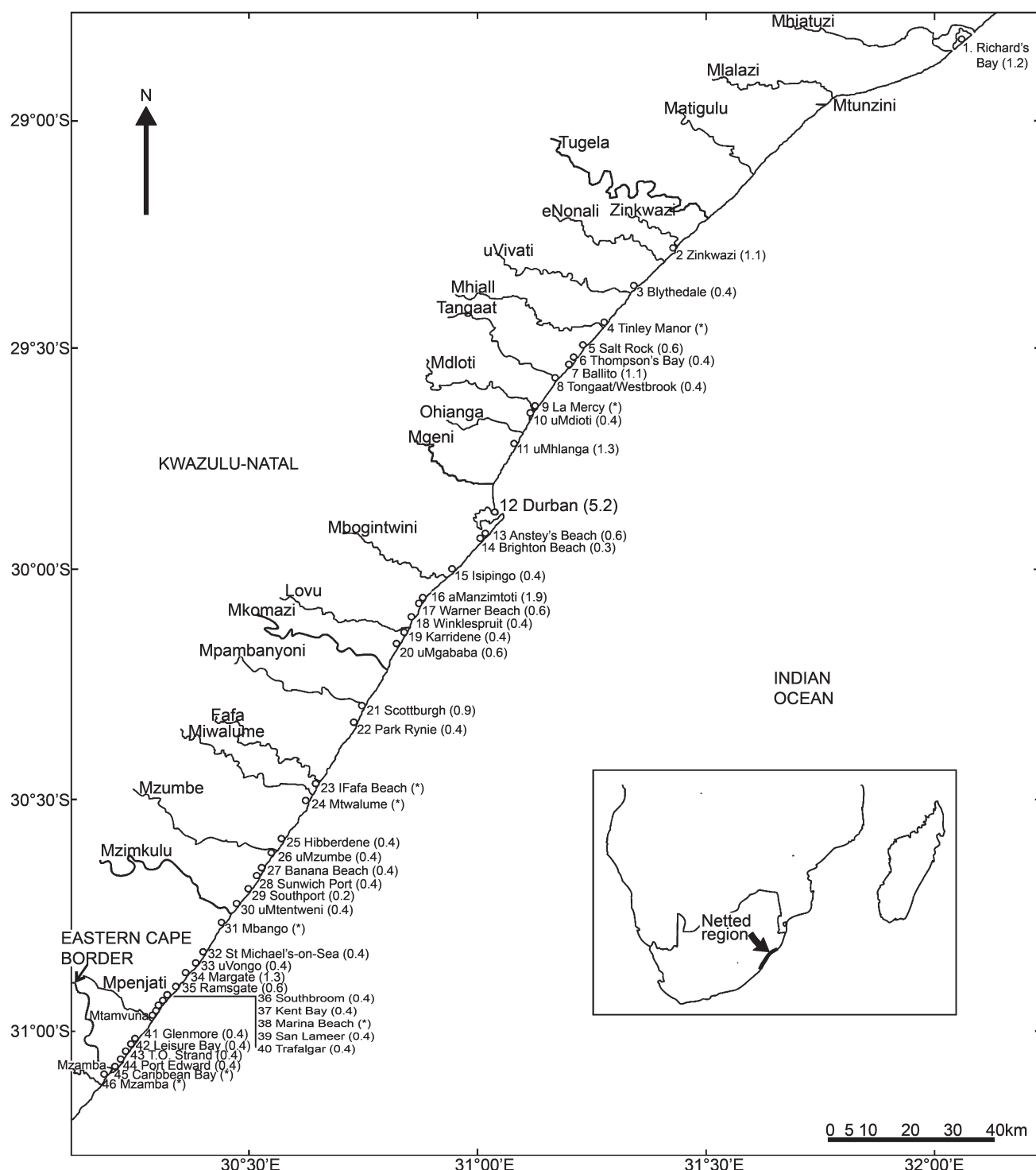


Fig. 1. Shark net installations along the KwaZulu-Natal coastline. Numbers in parentheses show the length of netting in km as of November 2006. Source: KZNSB.

As datasets may not have been complete for each individual, sample sizes vary for the individual organ weights as stated in the text. The time period over which these data were collected for the individual species was as follows: *S. chinensis*: 28 November 1979–29 April 2010, *T. aduncus*: October 1970–11 May 2010, and *D. capensis*: 14 Aug 1974–16 Nov 2009.

Standard body length and weight measurements of the dolphin carcasses were determined as the carcasses arrived at KZNSB. Body length measurements were carried out following the guidelines of Norris (1961). Thereafter the

carcasses were frozen until further analyses were conducted. The carcasses were defrosted prior to systematic necropsies. The heart, lung and trachea were removed together from the thoracic cavity and the heart was separated out by severing the dorsal aorta and all major blood vessels at the entrance to the heart. It was then drained of blood and blood clots were washed out prior to weighing. The lung and trachea (including the larynx) were weighed together, and, in some instances, the lungs were dissected free at the level of the principal bronchus and weighed individually. Organs up to 3kg were weighed to the nearest gram on a digital balance (Nagata). Organs over

3kg were weighed using a hand-suspended Salter balance. The reproductive status of the animals was noted upon necropsy based on macroscopic examinations of the reproductive organs (i.e. presence/absence of sperm in the epididymis, presence of corpora on the ovaries). The epididymides were removed from the testes before a combined testis weight was obtained for each individual.

Total body length-weight relationships were established for all three dolphin species and described by allometric equations of the form $y = ax^b$, where a = y-intercept, b = slope, x = total body weight (kg), and y = total organ weight (g). Relative organ weights were calculated for each individual and expressed as a percentage of body weight. To compare the relative organ weights between the three genera, the percentage data were arc-sine transformed (Zar, 1999) before an ANOVA and *post-hoc* Tukey test were carried out. To examine potential differences between males and females for each of the three species, individual organ weights and body weights were log-transformed and allometric equations generated for either sex for each of the three species. Slopes and y-intercepts were compared using an ANCOVA multiple regression analysis with a predetermined alpha (α) set at 0.05. All statistical analyses were conducted using *STATISTICA* v. 9 (StatSoft Inc.).

To evaluate the contribution the testes made to the overall body weight, the combined testes weights of only mature males of the three dolphin species were analysed. While no previous data on maturity of male *S. chinensis* were available, an increase of combined testes weight was observed at about 223cm body length and 200g combined testes weight in the sample. Thus subsequently only data for animals over 223cm in body length and/or over 200g combined testes weight were used to determine combined testes weight as a percentage of total body weight ($n = 23$).

For *T. aduncus* only males over 225cm in body length and/or over 300g combined testes weight were analysed ($n = 90$) (following Cockcroft and Ross, 1990a), and for *D. capensis* only males over 220cm body length and/or over 200g combined testes weight were analysed ($n = 172$) (following Mendolia, 1989).

RESULTS

Body length-weight relationships

Individual plots of body weight versus length for males, females and sexes combined for all three species are shown in Figs 2, 3 and 4, respectively. Allometric equations for these relationships are provided in Table 1.

Out of 92 male and 50 female *S. chinensis* examined, the shortest animals measured 145cm and 150cm and weighed 43kg and 46kg, respectively. The longest specimens of *S. chinensis* in the present study were a 276cm long male, weighing 280kg and a 251cm long female, weighing 188kg (Fig. 2).

Of 299 male and 308 female *T. aduncus* examined, the shortest animals were a 100cm long male, weighing 9.75kg and a 120cm long female, weighing 19kg (Fig. 3). The heaviest male specimen was 246cm long and weighed 248kg, although the longest male measured 262cm, but only weighed 226kg (Fig. 3). The longest female *T. aduncus* measured 256cm and weighed 190kg (Fig. 3).

For *D. capensis* length and weight data for 328 males and 312 females were available. The shortest male measured 114cm and weighed 18kg, while the shortest female was 107cm long, weighing 21kg (Fig. 4). The longest male was 265cm long and weighed 192kg (Fig. 4). A 252cm long female, weighing 80kg may be considered unrepresentative for animals from this population; thus the longest female measured 240cm and weighed 148kg (Fig. 4).

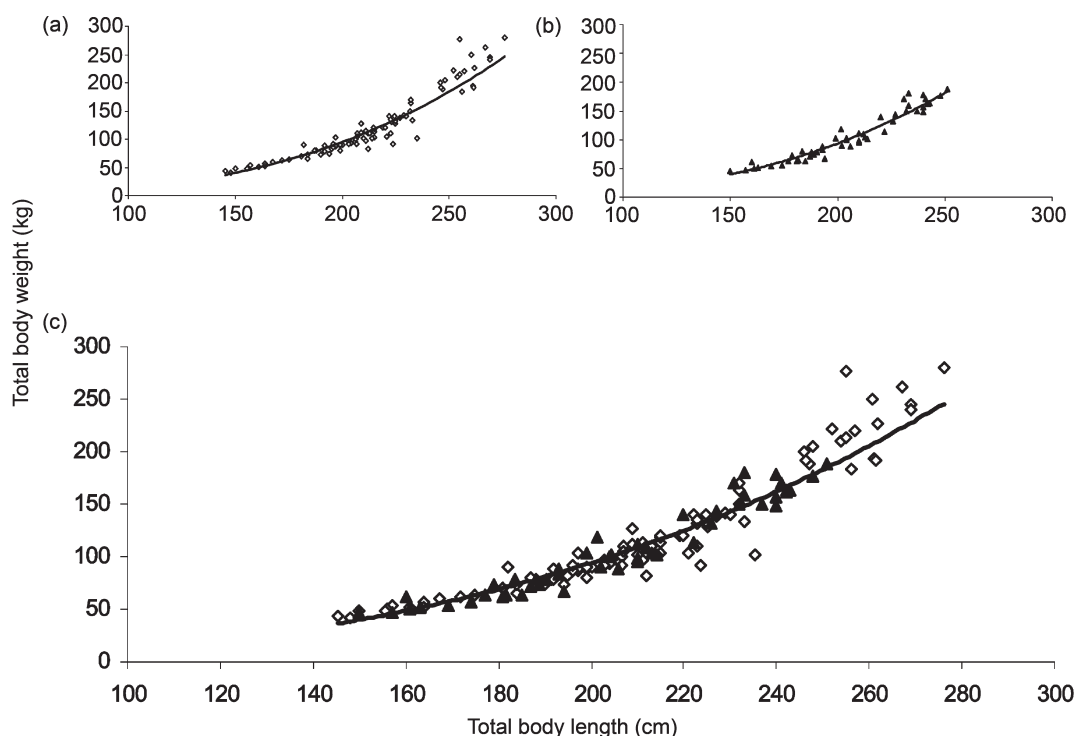


Fig. 2. Body length-weight relationships for (a) male *S. chinensis*, (b) female *S. chinensis*, and (c) both sexes of *S. chinensis* (diamond = males; triangle = females).

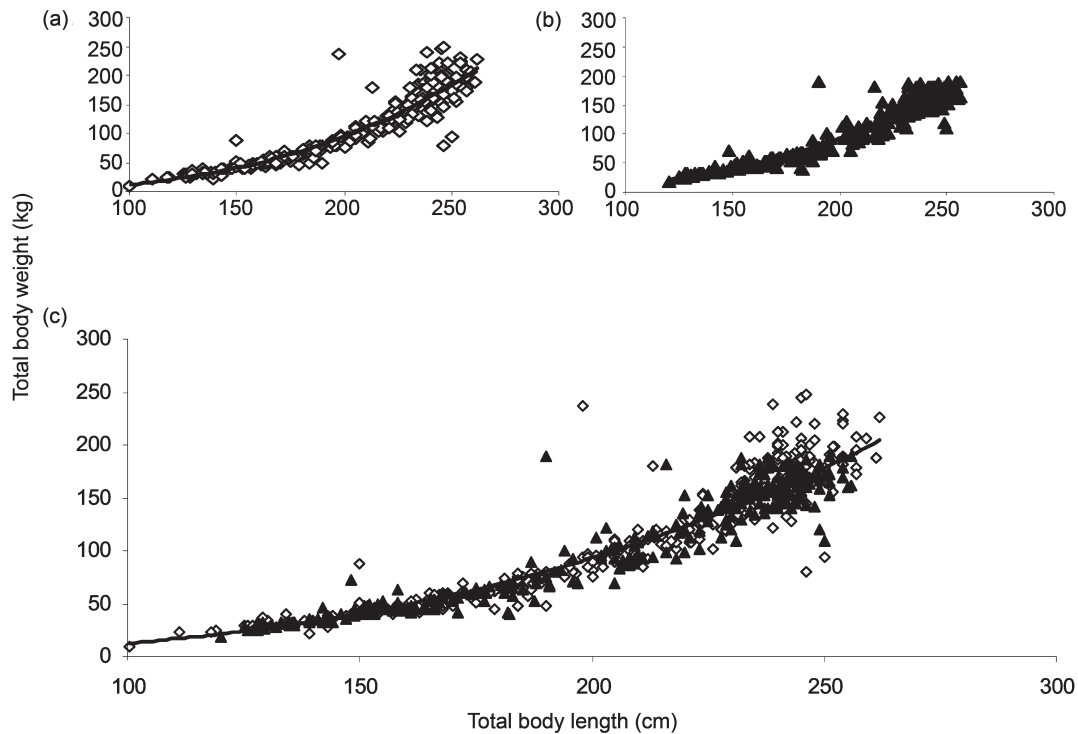


Fig. 3. Body length-weight relationship for (a) male *T. aduncus*, (b) female *T. aduncus*, and (c) both sexes of *T. aduncus* (diamond = males; triangle = females).

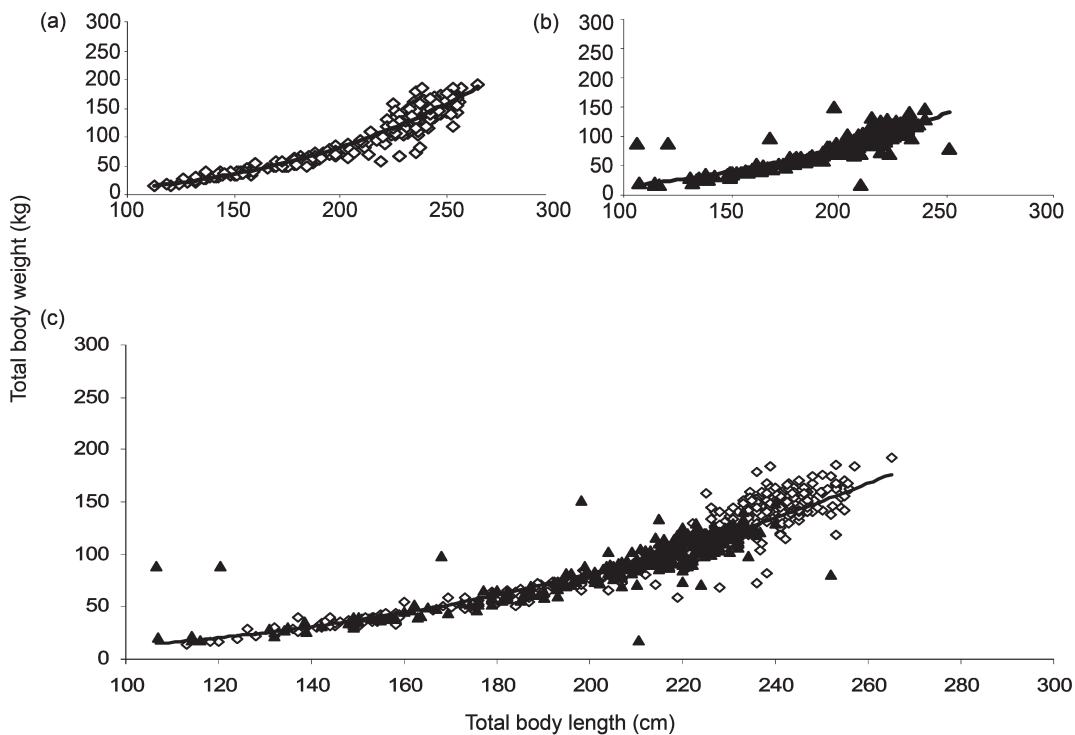


Fig. 4. Body length-weight relationship for (a) male *D. capensis*, (b) female *D. capensis*, and (c) both sexes of *D. capensis* (diamond = males; triangle = females).

These length-weight relationships indicate the differences in body size between the three species (Figs 2, 3 and 4), with the largest *S. chinensis* male being substantially larger (14cm longer and 32kg heavier) than the largest *T. aduncus* male. In females of the two species, however, there was little difference in body size, the largest *S. chinensis* female being 5cm shorter than the largest *T. aduncus* female and weighing 2kg less. Similarly, the difference in body length between

the longest male *T. aduncus* and the longest *D. capensis* male was negligible (262cm vs. 265cm, respectively), but the heaviest *T. aduncus* male was 56kg heavier than the heaviest *D. capensis* male. In females this difference between the species was 16cm and 42kg. The observed difference between *T. aduncus* and *D. capensis* was substantially larger than between *S. chinensis* and *T. aduncus*, indicating that *D. capensis* is considerably smaller than the other two species,

Table 1

Allometric equations for length-weight relationships for all three species of delphinids.

Species	Sex	N	Equation	R ²
<i>Sousa chinensis</i>	M	92	$y = 0.00001x^{2.9692}$	0.9335
	F	50	$y = 0.00001x^{2.9765}$	0.9434
	M & F	142	$y = 0.00001x^{2.9762}$	0.9372
<i>Tursiops aduncus</i>	M	299	$y = 0.00001x^{2.9605}$	0.932
	F	308	$y = 0.00003x^{2.8429}$	0.9468
	M & F	607	$y = 0.00002x^{2.9011}$	0.9379
<i>Delphinus capensis</i>	M	328	$y = 0.00002x^{2.9229}$	0.9538
	F	312	$y = 0.00002x^{2.4169}$	0.7918
	M & F	640	$y = 0.00004x^{2.7408}$	0.8938

with *S. chinensis* being the most robust out of the three species.

Organ weights as a percentage of body weight

The trend in absolute organ weights between the three species of dolphins was such that the largest absolute weights were usually present in *T. aduncus*, followed by *D. capensis*, with *S. chinensis* having the smallest absolute organ weights (Table 2). One exception were the absolute liver weights, which were slightly higher in *D. capensis* than *T. aduncus* (Table 2).

This general trend was reversed in the spleen, which was largest in *S. chinensis* (mean = 94.04g ± 38.52), followed by *D. capensis* (mean = 80.39g ± 55.95), with *T. aduncus* having the smallest spleen in terms of absolute size out of the three species (mean = 66.68g ± 33.28) (Table 2).

If, however, the organ weights are considered relative to body weight of the three delphinid species, a different pattern emerges. The relative heart weights showed the reverse trend observed in absolute body size between the three species as the heart was larger in relation to the overall body weight in *D. capensis* (mean = 0.62% ± 0.11), than it was in *T. aduncus* (mean = 0.6% ± 0.14) or *S. chinensis* (mean = 0.52% ± 0.08). This trend was supported by results from an ANOVA and *post-hoc* Tukey test, which showed that the relative heart weights of *S. chinensis*, *T. aduncus* and *D. capensis* were significantly different from each other (*F*-value = 70830.01, *p* < 0.001).

The same trend of largest relative organ weights in the smallest species was true for the relative weights of liver and kidneys: both made up the larger percentage of body weight in *D. capensis* (mean = 2.47% ± 0.58 and 0.85% ± 0.19, respectively) than in *T. aduncus* (mean = 2.03% ± 0.47 and 0.8% ± 0.19, respectively) and *S. chinensis* (mean = 1.93% ± 0.39 and 0.67% ± 0.12, respectively). This result was supported by the ANOVA analysis and Tukey test, which showed that the relative liver weights of *D. capensis* were significantly larger than those of *T. aduncus* and *S. chinensis* (*F*-value = 32427.98, *p* < 0.001); no significant difference in organ weights was found between the latter two species. Kidney weights proved to be significantly different for all three species, with *D. capensis* having the largest kidneys and *S. chinensis* the smallest ones (*F*-value = 42225.54, *p* < 0.05).

Relative weights for the lungs and trachea combined were larger in *T. aduncus* (mean = 4.33% ± 0.88) than they were

Table 2

Absolute and relative organ weights from three dolphin species incidentally caught in the shark nets off the KwaZulu-Natal coast of South Africa.

Species:	<i>Sousa chinensis</i>	<i>n</i>	<i>Tursiops aduncus</i>	<i>n</i>	<i>Delphinus capensis</i>	<i>n</i>
Heart						
Minimum weight (g)/(%)	240/0.36	131	118/0.23	350	84/0.09	308
Maximum weight (g)/(%)	1,250/0.88		1,550/1.91		1,367/1.11	
Mean weight (g) (±SD)/	591.11 (±219.91)/		637.83 (±311.98)/		635.45 (±256.91)/	
Mean % of body weight (±SD)	0.52 (±0.08)		0.6 (±0.14)		0.62 (±0.11)	
Lungs and trachea						
Minimum weight (g)/(%)	1,550/2.39	131	962/1.43	333	720/1.33	296
Maximum weight (g)/(%)	8,675/6.11		11,050/9.05		8,430/7.27	
Mean weight (g) (±SD)/	4,420.59 (±1808.52)/		4,789.92 (±2,514.66)/		4,227.27 (±1,809.32)/	
Mean % of body weight (±SD)	3.88 (±0.57)		4.33 (±0.88)		4.1 (±0.81)	
Lungs						
Minimum weight (g)/(%)	1,900/2.97	9	1,350/0.78	24	3,050/2.61	7
Maximum weight (g)/(%)	4,700/3.96		8,300/6.14		5,161/4.29	
Mean weight (g) (±SD)/	3,396.11 (±1047.86)/		3,276.49 (±2,037.36)/		4,243 (±745.1)/	
Mean % of body weight (±SD)	3.25 (±0.33)		3.8 (±0.98)		3.7 (±0.62)	
Liver						
Minimum weight (g)/(%)	718/0.77	92	109.9/0.16	323	53/0.19	307
Maximum weight (g)/(%)	6,100/3.2		5,500/3.87		6,512/4.52	
Mean weight (g) (±SD)/	2,290.23 (±1049.47)/		2,356.31 (±1,357.69)/		2,605.25 (±1,224.24)/	
Mean % of body weight (±SD)	1.93 (±0.39)		2.03 (±0.47)		2.47 (±0.58)	
Kidneys						
Minimum weight (g)/(%)	263/0.45	92	160/0.32	312	115/0.34	289
Maximum weight (g)/(%)	2,080/0.96		2,970/2.09		3,250/2.32	
Mean weight (g) (±SD)/	790.64 (±363.93)/		918.97 (±530.96)/		910.3 (±425.23)/	
Mean % of body weight (±SD)	0.67 (±0.12)		0.8 (±0.19)		0.85 (±0.19)	
Spleen						
Minimum weight (g)/(%)	43/0.02	61	11/0.01	181	8/0.01	192
Maximum weight (g)/(%)	211/0.2		192.4/0.2		460/0.33	
Mean weight (g) (±SD)/	94.04 (±38.52)/		66.68 (±33.28)/		80.39 (±55.95)/	
Mean % of body weight (±SD)	0.09 (±0.04)		0.07 (±0.04)		0.08 (±0.05)	

in either *D. capensis* (mean = $4.1\% \pm 0.81$) or *S. chinensis* (mean = $3.88\% \pm 0.57$). If just lung weights were considered, the same trend was observed (*T. aduncus*: mean = 3.8 ± 0.98 ; *D. capensis*: mean = $3.7\% \pm 0.62$; *S. chinensis*: mean = $3.25\% \pm 0.33$). However, sample sizes for lung weights were very small and may therefore not be representative for the species. The ANOVA results using combined lung and trachea weights showed no significant differences between the three species (F -value = 26364.09, $p > 0.05$).

Examining the relative spleen weights between the three species the trend seemed reversed, with *S. chinensis* showing the largest relative weights (mean = $0.09\% \pm 0.04$), followed by *D. capensis* (mean = $0.08\% \pm 0.05$) and *T. aduncus* having the smallest spleen (mean = $0.07\% \pm 0.04$). The ANOVA results confirmed that (F -value = 5077.023, $p < 0.001$).

A summary of the allometric relationships of the various organs with body size in all three delphinids is supplied in Table 3. All organs showed a strong correlation with body size, with the exception of the spleen in all three species (Table 3).

The ANCOVA analysis indicated no significant differences between males and females of *S. chinensis* for the lungs and trachea, liver, kidney and spleen ($p > 0.05$ in all cases), but showed that males had significantly larger hearts than females ($p < 0.05$) (Fig. 5). No significant differences between males and females were found in *T. aduncus* ($p > 0.05$) or *D. capensis* ($p > 0.05$) in all cases (Figs 6 and 7).

Table 3

Allometric equations for organ-weights versus body weight relationships for all three species of delphinids.

Organ	Sex	n	Equation	R ²
<i>Sousa chinensis</i>				
Heart	M	86	$y = 1.8367x^{0.5686}$	0.9002
	F	46	$y = 0.4492x^{1.4913}$	0.9368
Lungs and trachea	M	83	$y = 2.5751x^{0.4779}$	0.883
	F	46	$y = 2.467x^{0.5456}$	0.9338
Liver	M	64	$y = 2.1638x^{0.5981}$	0.8127
	F	28	$y = 2.1432x^{0.6171}$	0.7476
Kidneys	M	62	$y = 1.7207x^{0.7065}$	0.8411
	F	30	$y = 1.6918x^{0.7467}$	0.9088
Spleen	M	42	$y = 1.5096x^{0.3705}$	0.1325
	F	21	$y = 1.6881x^{0.1362}$	0.0278
<i>Tursiops aduncus</i>				
Heart	M	170	$y = 1.8426x^{0.5864}$	0.866
	F	180	$y = 1.7845x^{0.6356}$	0.9102
Lungs and trachea	M	158	$y = 2.5975x^{0.483}$	0.9106
	F	165	$y = 2.5444x^{0.5183}$	0.8978
Liver	M	164	$y = 2.1345x^{0.6202}$	0.7691
	F	159	$y = 2.0885x^{0.6626}$	0.7394
Kidneys	M	151	$y = 1.8233x^{0.661}$	0.8865
	F	161	$y = 1.7612x^{0.7226}$	0.9058
Spleen	M	80	$y = 1.1405x^{0.666}$	0.4399
	F	101	$y = 1.2889x^{0.4458}$	0.2646
<i>Delphinus capensis</i>				
Heart	M	165	$y = 1.7813x^{0.6476}$	0.9148
	F	143	$y = 1.8187x^{0.6136}$	0.7475
Lungs and trachea	M	158	$y = 2.5163x^{0.5165}$	0.9047
	F	136	$y = 2.5367x^{0.5105}$	0.7787
Liver	M	167	$y = 2.1752x^{0.6322}$	0.9134
	F	140	$y = 1.9798x^{0.7858}$	0.7267
Kidneys	M	155	$y = 1.7478x^{0.7303}$	0.9093
	F	134	$y = 1.7045x^{0.7918}$	0.8654
Spleen	M	106	$y = 1.2789x^{0.538}$	0.1789
	F	87	$y = 1.2652x^{0.4842}$	0.1185

Testis weight as a percentage of body weight

The smallest combined testis weight in relation to total body weight was observed in *S. chinensis*, where it constituted on average 0.43% of the total body weight (Table 4). The testes were somewhat larger in *T. aduncus*, where the combined testes weight made up on average 0.64% of the total body weight in mature males. The largest combined testis weight was seen in *D. capensis*, where it constituted on average 2.01% of the total body weight (Table 4). An ANOVA showed significant differences between the three species (F -value = 158.406, $p < 0.001$).

DISCUSSION

Relative organ weights as a reflection of a species' ecology

The data on body size, group size, and distribution range indicate that *S. chinensis* is a robust delphinid that occurs in small groups and has a coastal distribution with a relatively small range (Best, 2007; Karczmarski *et al.*, 2000). Data on travel speeds for the species in South Africa have been reported to be 4.8 km hr^{-1} (Saayman and Tayler, 1979); personal observations support the notion that the species cannot be considered a fast swimmer. In contrast, *T. aduncus* is moderately smaller in body size, occurs in larger groups and has wider distribution range than *S. chinensis*, with faster travel speeds, ranging from 2.8 km/hr^{-1} to 9.9 km/hr^{-1} reported for South African waters (Best, 2007; Cockcroft *et al.*, 1990; Saayman *et al.*, 1972). *D. capensis* is the smallest of the three dolphins considered, but occurs in large schools and is a fast-swimming, oceanic species with a large distribution range (Best, 2007); swimming bursts of $20.5\text{--}32\text{ km/hr}^{-1}$ have been reported for the species (Rohr *et al.*, 2002). The trend in absolute organ weights observed during this investigation with smaller species, such as *D. capensis* having larger organs than the largest species, *S. chinensis*, appears counter-intuitive. Calculation of the relative organ weights in relation to body weight indicated a different trend, which can be explained by the different physiologies and ecologies of the three genera.

The significantly larger relative heart, liver, and kidneys in *D. capensis*, compared to the other two species, may reflect the higher metabolism or 'work rate' in this active, fast-swimming, oceanic species. Heart weight in cetaceans has been the subject of some investigation. Ridgway and Kohin (1995) presented relative heart weights for three genera of small odontocetes and concluded that differences in heart weight are due to differences in physiological and ecological demands. The largest relative heart weights were found in the fast-swimming, offshore species (Dall's porpoise, *Phocoenoides dalli*). The heart weight was intermediate in the slower swimming species (Pacific white-sided dolphin *Lagenorhynchus obliquidens*), and smallest in the most inshore, slowest moving species (common bottlenose dolphin *T. truncatus*) (Ridgway and Kohin, 1995). A similar trend was observed during this study with the fast swimming, offshore, *D. capensis* having the largest heart in relation to body weight. Slijper (1958) reported heart weights for a number of cetacean species and suggested that activity and swimming speed may play a role in the relative size of the heart in relation to the body weight. Bryden (1972)

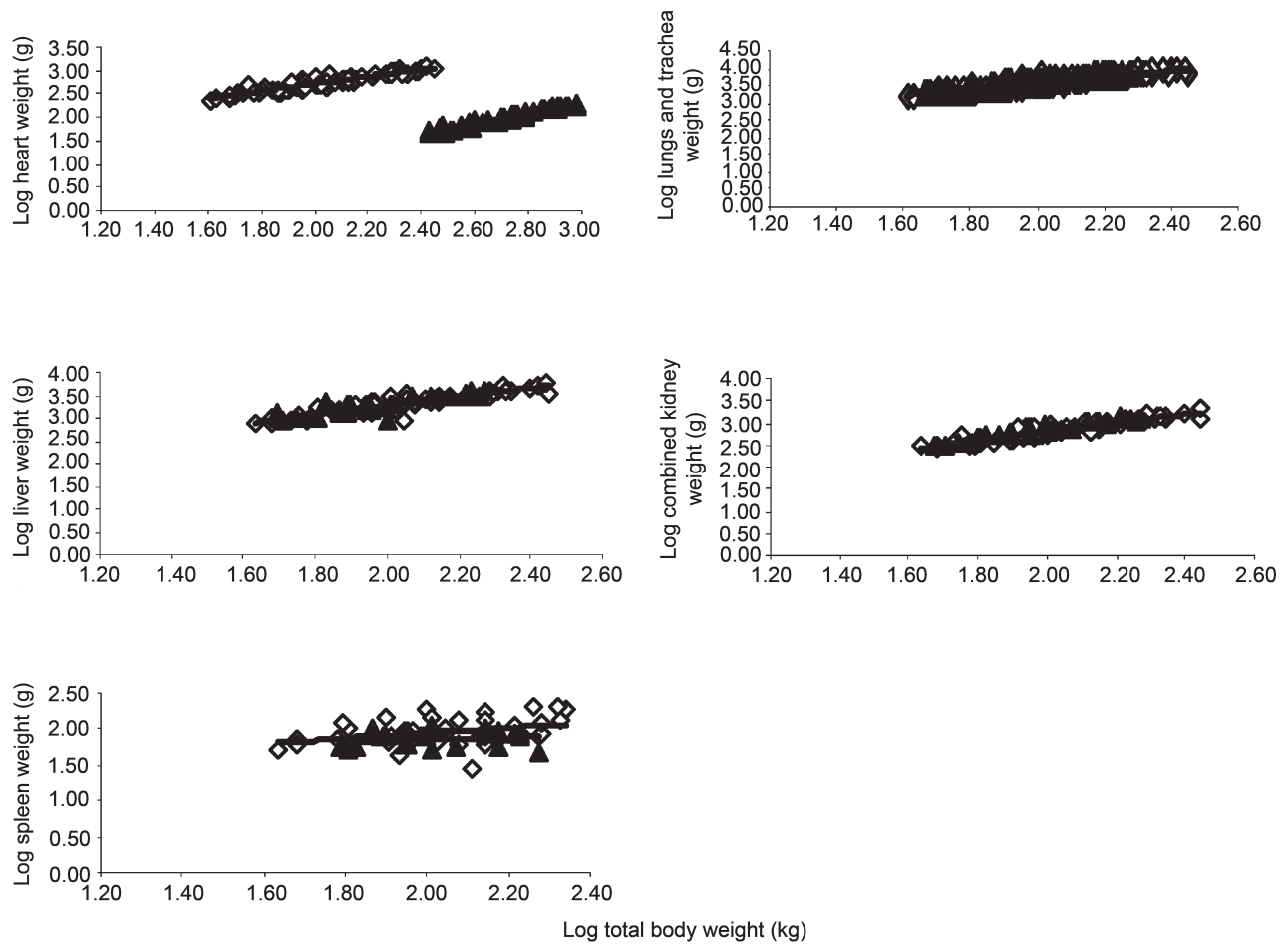


Fig. 5. Log respective organ weight (g) versus log total body weight (kg) for adult male (diamond) and female (triangle) *S. chinensis*.

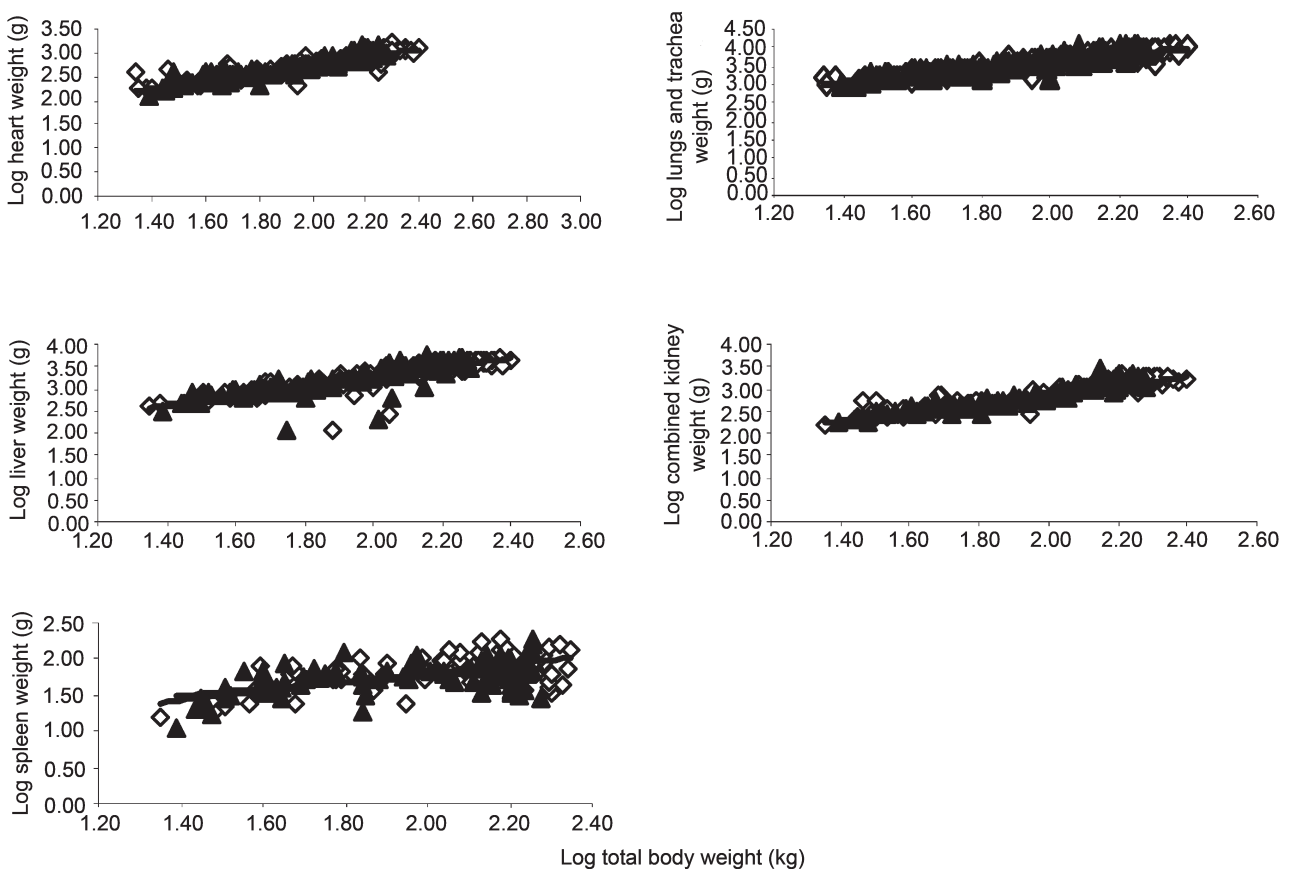


Fig. 6. Log respective organ weight (g) versus log total body weight (kg) for adult male (diamond) and female (triangle) *T. aduncus*.

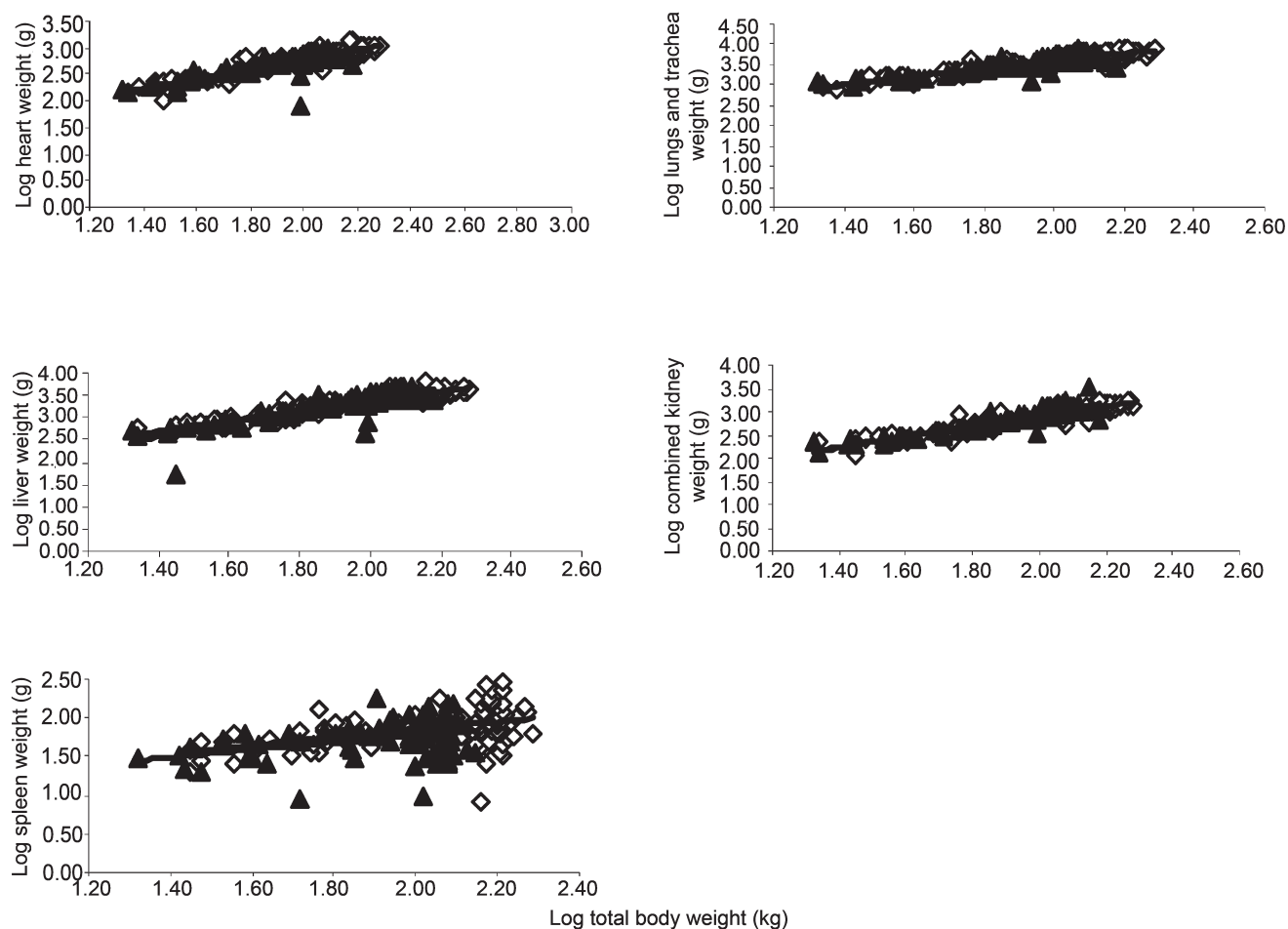


Fig. 7. Log respective organ weight (g) versus log total body weight (kg) for adult male (diamond) and female (triangle) *D. capensis*.

concluded that the relative heart size within different groups of mammals is probably as closely related to activity, speed and other physiological factors as it is to body weight (Bryden, 1972). Greater relative heart weights in pinnipeds have also been explained using increased activity, for example in Ross seals (*Ommatophoca rossi*) as compared to crabeater seals (*Lobodon carcinophagus*; Bryden and Erickson, 1976), and Cape fur seals (*Arctocephalus pusillus*) in comparison to Antarctic fur seals (*A. gazella*) (Stewardson *et al.*, 1999), with the two former species having to dive deeper and feeding on faster prey than the latter.

Relative liver weights previously reported for cetaceans reflect an inverse relationship between body size and relative liver weight, which was also apparent during the present study. Slijper (1958) reported an average weight of liver of 3.22% of body weight for the harbour porpoise *Phocoena phocoena*, 2.20% of body weight for a number of dolphin

species, and 1.20% of body weight for the sperm whale *Physeter macrocephalus*. Perrin and Roberts (1972) reported an average liver weight equivalent to 2.53% body weight for the spotted dolphin (*Stenella graffmani* = *attenuata*) and 1.90% of body weight for the spinner dolphin *S. longirostris*. Prothero (1982) examining liver weights over a large range of mammalian taxa, both aquatic and terrestrial, concluded that there were no differences in relative liver weights between aquatic and terrestrial mammals or between males and females, although he observed that the proportion of the liver tissue contributed to the overall body weight decreases with increasing body weight.

Slijper (1962) commented that the relative weight of the kidneys in small cetaceans in general is exceptionally large, reporting relative weights 0.84% of total body weight for several porpoises, 1.10% of body weight for *T. truncatus*, and 0.93% for *L. obliquidens*. *S. attenuata* show average relative kidney weights of 0.98% and *S. longirostris* of 0.65% (Perrin and Roberts, 1972). An inverse relationship between relative kidney weight to body weight as seen in three species examined in the present study has not been reported previously.

Although a trend in relative heart, liver and kidney weights was observed between the three species examined, surprisingly no significant difference was found in the relative lung and trachea weights. Previous studies on lung mass in cetaceans suggest that the lungs of delphinids and phocoenids are larger than those of similar sized terrestrial

Table 4

Combined testis weight as a percentage of total body weight for mature male animals.

Species	<i>Sousa chinensis</i>	<i>Tursiops aduncus</i>	<i>Delphinus capensis</i>
<i>n</i>	26	90	172
Minimum weight (%)	0.16	0.20	0.07
Maximum weight (%)	0.7	1.12	4.19
Mean % weight ($\pm$ SD)	0.43 ($\pm$ 0.12)	0.64 ($\pm$ 0.20)	2.01 ($\pm$ 0.88)

mammals (Bryden, 1972; Kooyman, 1973; Kooyman and Sinnett, 1979; Piscitelli *et al.*, 2010), while the relative lung mass of deeper diving odontocetes (kogiids, physeterids, and ziphiids) is similar to that of similar sized terrestrial mammals (Piscitelli *et al.*, 2010). Dive depths for the three species off South Africa examined here are non-existent, but available data on stomach content analyses indicate that *S. chinensis* feeds in shallow, inshore, often estuarine habitats (Barros and Cockcroft, 1991; 1999), while *T. aduncus* feeds mainly on coastal reef fishes (Cockcroft and Ross, 1990b) and *D. capensis* on epipelagic shoaling fish (Young and Cockcroft, 1994). As all three delphinids examined can be considered relatively shallow divers, which are 'fast' breathing (meaning high ventilation rate, short ventilation/dive times, and high lung volume exchanged per breath) (Kooyman, 1973; Piscitelli *et al.*, 2010), and thus no differences in lung weight would be expected between the three species. In comparison, the lungs of *S. attenuata* and *S. longirostris* are very similar in size, making up 3.2% of the body weight and 3.3%, respectively (Perrin and Roberts, 1972). In *P. phocoena* the lungs make up 3.5%, in *T. truncatus* 2.87% and 3.59% in *L. obliquidens* (Slijper, 1958).

The significantly smaller spleen found in *T. aduncus* in the present study, compared to that of *D. capensis* and *S. chinensis*, is intriguing, particularly in conjunction with the weak allometric relationship of this organ with body weight found for all three species examined. As the function of the spleen is the creation, storage and filtration of red blood cells as well as involvement in active immune response, no obvious explanation is to date at hand for this observation. Bryden (1972) remarked that the spleen in cetaceans is very small (0.02%) in comparison with that of most terrestrial mammals, where it constitutes around 0.3% of the body weight. Relative spleen weights reported for other odontocetes support this, with average values *S. attenuata* and *S. longirostris* being 0.06% and 0.04%, respectively (Perrin and Roberts, 1972). Interestingly, sexual dimorphism in spleen weights has also been reported for *S. longirostris*. For *P. phocoena* and *T. truncatus*, the spleen constitutes 0.02% and 0.09% of the total body weight (Slijper, 1958). Thus the relative weights of 0.09%, 0.07% and 0.08% of total body weight found for *S. chinensis*, *T. aduncus* and *D. capensis*, respectively, during this investigation are in accordance with relative spleen weights for small cetaceans published previously.

Testis weight and mating system

Cockcroft (1993) hypothesised previously that the combined testis size of these three delphinids in relation to group size and sexual dimorphism within the individual species may give indications as to the mating system. He reported an average relative testes weight of 0.7% for *S. chinensis*, 1% for *T. aduncus*, and 4.2% for *D. capensis* (Cockcroft, 1993). Although the trend of smallest values for average relative testis weight in *S. chinensis* (present study: 0.4%), followed by somewhat larger testes in *T. aduncus* (0.6% of total by weight), with the biggest testes found in *D. capensis* (2%) is also seen in the present study, the values are somewhat lower than those reported by Cockcroft (1993). However, interestingly the maximum values seen in the present study concur with the average values presented by Cockcroft

(1993). Plön and Bernard (2007), in reviewing available data for combined testis sizes in relation to proposed mating systems for cetaceans, concluded that relatively small testes in relation to body weight indicate a monogamous or extreme polygynous mating system. Conversely, relatively large testes are indicative of frequent copulations and sperm competition. In this sense the data from the present study indicate that the small relative testis weight in association with sexual dimorphism and small group sizes seen in *S. chinensis* is representative of a mating system in which a single male has access to a number of females. The somewhat larger testes, reduced sexual dimorphism, and larger group size in *T. aduncus* is indicative of more frequent copulations by males (Connor *et al.*, 2000; Plön and Bernard, 2007). The relatively large testes seen in *D. capensis*, with no sexual dimorphism and large group sizes prevalent in this species are representative of sperm competition (Cockcroft, 1993; Connor *et al.*, 2000; Plön and Bernard, 2007).

SUMMARY

In summary, the results of the present study suggest that the relative size of the major organs in the three genera examined here are a reflection of the differing life histories and ecologies of the species. Absolute organ weight has been shown to have little biological meaning and organ weights need to be considered in relation to body weight. While the above organ weights are in accordance with similar studies carried out previously on other cetacean genera, recent findings on *P. phocoena* suggest that on average 27% of the total body weight in adult animals is made up of blubber (McLellan *et al.*, 2002). The contribution of blubber to the total weight is even higher in juvenile animals (Lockyer, 1993; McLellan *et al.*, 2002; Miyazaki *et al.*, 1981). Unfortunately, contributions of blubber weight to the total body weight could not be taken into account during this study as these measurements were not available for the majority of the carcasses. Thus it is unclear whether this would skew the data in any way, particularly as the contribution of blubber weight to the total body weight appears to vary between species as well between seasons (Lockyer, 1993). However, future studies should aim to account for contributions of blubber weight to total body weight to elucidate these issues.

The baseline data on organ weights in the three genera established in the present study will form the basis of more detailed pathological and health examinations of the carcasses in the future and hopefully contribute to identification of what presents 'normal' organ weights in the three species. These will then be available for comparison with data from strandings or heavily diseased animals.

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A note on observations of cetaceans in the Indian Ocean Sanctuary, Australia to Israel, April 1995

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ABSTRACT

A forty-day voyage from Hobart (Australia) to Haifa (Israel) included a visual and acoustic census for cetaceans in the Indian Ocean Sanctuary. One hundred and sixty-three sightings were made, 156 occurring within the Sanctuary. Twelve species were identified. Sperm whales (*Physeter macrocephalus*) were encountered most frequently (51% of identified encounters), whilst spinner dolphins (*Stenella longirostris*) were numerically dominant. Other species identified included bottlenose dolphins (*Tursiops* spp.), short-beaked common dolphin (*Delphinus delphis*), pan-tropical spotted dolphin (*Stenella attenuata*), rough-toothed dolphin (*Steno bredanensis*), Risso's dolphin (*Grampus griseus*), killer whale (*Orcinus orca*), short-finned pilot whale (*Globicephala macrorhynchus*), false killer whale (*Pseudorca crassidens*), Bryde's whale (*Balaenoptera edeni*) and Cuvier's beaked whale (*Ziphius cavirostris*). The most sightings occurred WNW of the Seychelles, east of Somalia, and in the Gulf of Aden and Red Sea. Half of the sperm whale sightings were to the east of Ras Hafun (Somalia), and included adults, subadults and at least one calf. Thirteen hours were spent listening for cetaceans using a towed array whilst the ship was underway. Cetaceans were detected at 78% of the listening stations, with a possible four species recorded (sperm whale, spinner dolphin, pilot whale, bottlenose dolphin). The survey shows the value of platforms of opportunity for studying the pelagic communities of cetaceans in the Indian Ocean Sanctuary. It highlights the need for further research in the northwestern sector where anthropogenic threats are varied and increasing.

KEYWORDS: INDIAN OCEAN; SPERM WHALE; SPINNER DOLPHIN; PAN-TROPICAL SPOTTED DOLPHIN; BOTTLENOSE DOLPHIN; ROUGH-TOOTHED DOLPHIN; BRYDE'S WHALE; RISSO'S DOLPHIN; COMMON DOLPHIN; PILOT WHALE; KILLER WHALE; CUVIER'S BEAKED WHALE; FALSE KILLER WHALE; SURVEY-ACOUSTIC; SURVEY-VESSEL

INTRODUCTION

Cetacean studies within the IWC's Indian Ocean Sanctuary (IOS) have largely been carried out in coastal waters (including Australia, Sri Lanka, Oman, South Africa and India). Fewer studies have been undertaken offshore, although Mörzer-Bruyns (1971), Keller *et al.*, (1982), Kasuya and Wada (1991), Eyre (1995), Ballance and Pitman (1998), de Boer (2000a) and the Ocean Alliance Odyssey voyage (Ocean Alliance, 2009; Wise *et al.*, 2009) have contributed to our current knowledge of the pelagic cetacean fauna. Acoustic studies of cetaceans to supplement visual observations have been primarily used for sperm whales (Godard *et al.*, 2003; Gordon, 1987; Khan *et al.*, 1993; Whitehead and Gordon, 1986).

The non-government environmental organisation Greenpeace International makes regular oceanic transits with its vessels. Cetacean surveys in the IOS have been undertaken using these vessels in 1993 (Eyre, 1995), 1995 (Eyre, 1997), 1998/99 (De Boer *et al.*, 1999), 1999 (De Boer, 2000a), 1999/2000 (De Boer, 2000b; De Boer *et al.*, 2003) and 2000 (Eyre, 2000).

This paper reports on results obtained during a transit of the Sanctuary during the austral autumn of 1995, originally presented as an unpublished report to the IWC (Eyre, 1997). Subsequent research conducted by other organisations in the locations covered here are briefly mentioned.

METHODS

The survey vessel was the *MV Greenpeace*, a 58m deep-sea salvage tug which averaged 9.9 knots during the transit. A

Furuno GP-500 Navigator provided vessel position, and navigational charts were used for approximate depth in addition to the ship's depth sounder in shallow water. Water temperature was taken from the ship's engine cooling system at a depth of approximately 2.5m, and sea and wind conditions were estimated using the Beaufort scales.

The vessel left Hobart, Australia on 25 March 1995 and entered the IOS on 29 March. The course continued northwest to the northeastern waters of Africa and into the Red Sea, arriving at Haifa, Israel on 3 May 1995. Fig. 1 shows the vessel's cruise track.

Although the principle purpose of the transit was one of vessel delivery, the course or speed was altered to close in on large cetaceans for data collection or to survey areas of interest. An area WNW of the Seychelles which was covered in the 1993 survey (Eyre, 1995) was transited, and the vessel also detoured off Ras Hafun (Somalia) for a day when large numbers of sperm whales were encountered.

Visual survey

Visual observations were conducted during daylight hours and in sea conditions below Beaufort 6 (Fig. 2). Most observations were carried out from a platform 12m above sea level. Searching also occurred from the crow's nest (20m), wheel-house roof (10m) and bridge (8m) depending on environmental conditions.

Two observers were usually present, each searching 180° on each side, with most effort concentrated 90° forward. From 26 April to 3 May, only one observer was present, concentrating search effort 180° forward. The crew on watch

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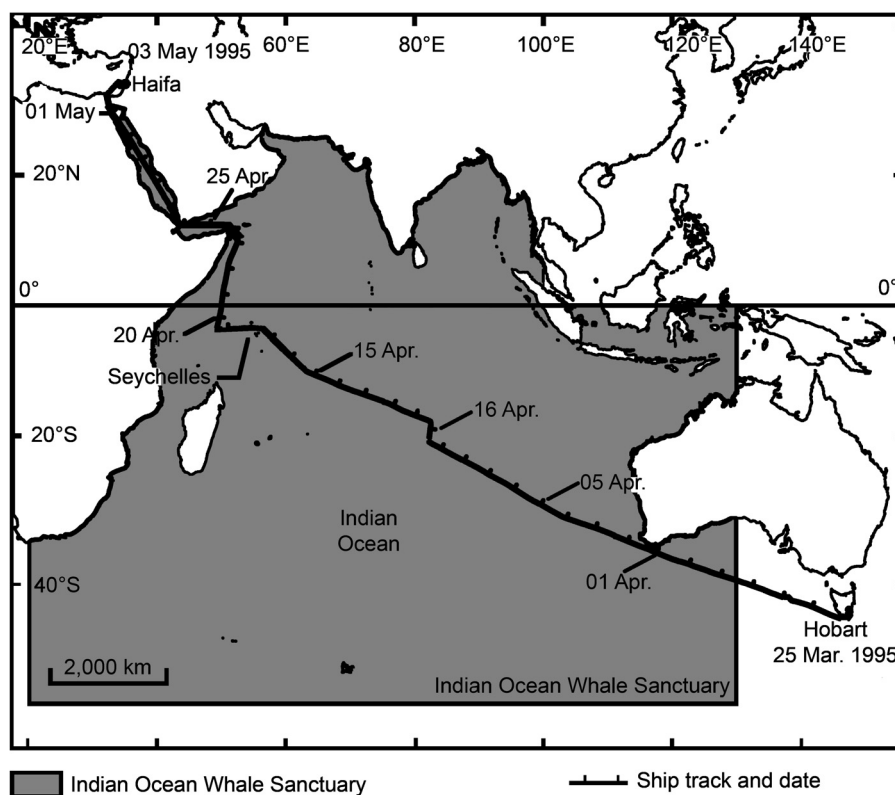


Fig. 1. Vessel cruise track and associated dates.

also assisted during this time. On-effort watchers scanned with the naked eye and used Steiner 7×50 field glasses to search from the vessel out to the horizon.

Effort, ship's course and speed and environmental data were collected hourly or when a sighting was made. School sizes were estimated using low/high/best estimation of numbers of individuals. Photographs were obtained where possible using Pentax and Canon SLR cameras with 50–200mm lenses.

The term 'sighting' refers to cetaceans separated spatially or temporally. It is recognised that sperm whale sightings are likely to be sub-groups of larger aggregations. The methods do not allow abundance to be estimated.

Acoustic survey

Two hydrophone systems were used. One was a single element hydrophone with 12m of cable deployed from a

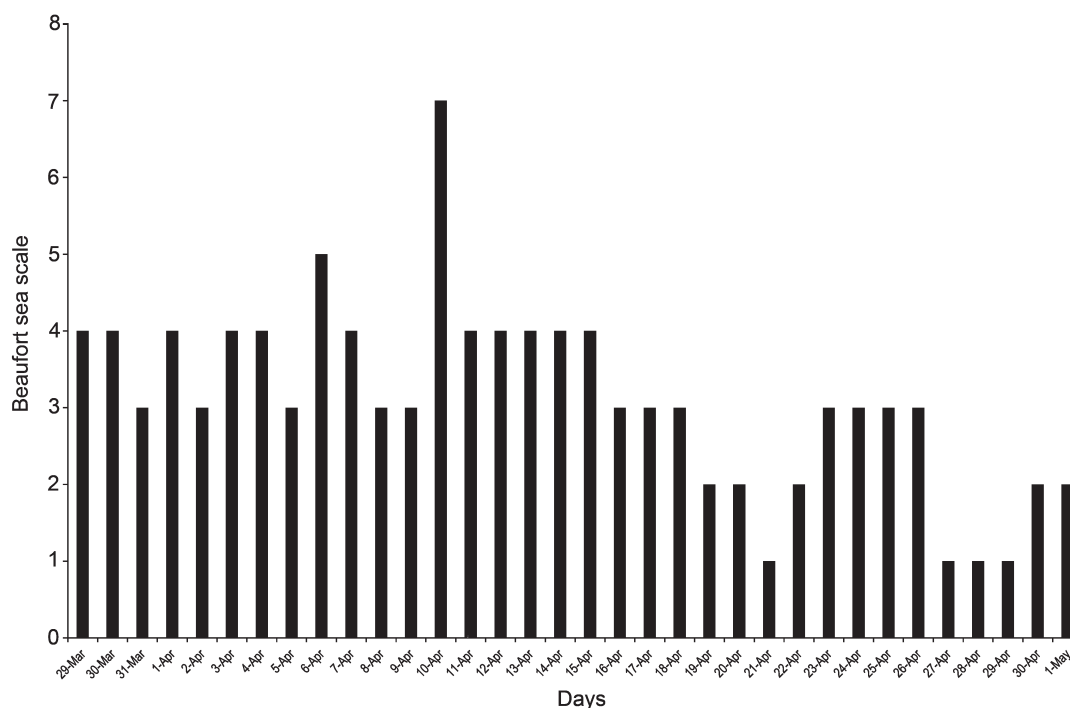


Fig. 2. Average Beaufort sea state during on-effort watching whilst in the Sanctuary (29 March–1 April 1995).

rigid-hulled inflatable. A preamplifier with a range of 20–60dB covering a bandwidth of 50Hz–20kHz was connected to a *Panasonic* SV-250 portable DAT recorder.

The second system was a two element towed array, consisting of 90m of strengthened cable towed approximately 78m behind the vessel and with a rope tail for stability. The array contained two *Benthos* AQ-4 elements with 30dB gain preamplifiers and a frequency response of 200Hz–35 kHz, mounted in a 10m long reinforced polyurethane tube filled with deodorised paraffin oil. The array was connected to a *Sony Pro TCD-D10* DAT recorder. The hydrophone array was developed by the International Fund for Animal Welfare, based on equipment used by Leaper *et al.*, (1992) and had been used by Pierpoint *et al.*, (1997) prior to this survey.

Routine tows were conducted from 17–26 April, between 08:30–09:30 hours. Three evening tows were also conducted during this period (Fig. 3). The ship slowed to 6.5 knots, and the visual survey was maintained during daylight tows. During one hour of listening, recording was done at alternate 10 minute intervals (total 30 minutes recorded). Non-routine tows occurred when cetaceans were in the vicinity and ship schedule allowed.

Recordings were aurally analysed for presence/absence and identification of cetacean sounds and were then sent to the Cetacean Group at the University of Oxford for sperm whale abundance analysis using the ‘Cartwheels’ program (Conservation Research Group, 1989) but unfortunately the quality of the recordings precluded estimates being developed.

RESULTS

Visual

A total 16,688km was covered from Hobart to Haifa, with 14,563km (87.2%) within the IOS. There were 378 hours of effort in total of which 332 hours (87.8%) were in the IOS, giving an average of 9.5hrs per day. Of the 163 sightings made (on 22 of the 40 days) 156 sightings (95.7%) were within the IOS. All but 4 sightings were on effort. On-effort encounter rate was 1.05 sightings/100km within the IOS.

An estimated 2,560 individual cetaceans were sighted, and twelve species identified. Sightings are summarised in Table 1 and locations given in Figs. 3 and 4.

The most individuals sighted were of spinner dolphins ($n = 1,059$) and the most sightings were of sperm whales ($n = 69$).

Four sightings were of mixed species associations. These included pilot whales and bottlenose dolphins (two occasions), Risso’s and rough-toothed dolphins, and spinner and pan-tropical spotted dolphins. Oceanographic conditions within the IOS predictably shifted from cool to warm as the vessel headed northwest (Table 1), with calmer conditions within the Red Sea. Fig. 2 shows the average daily Beaufort sea state whilst on-effort within the IOS. On April 10 the weather intensified and watching conditions deteriorated due to the proximity of Cyclone ‘*Marlene*’.

Acoustic

A total of 14h 14min were spent listening at nineteen stations (Fig. 3), with 8h 47s recorded. Almost 11 hours were

scheduled tows, which covered 134.3km. Non-routine tows occurred on five occasions after cetaceans had been sighted, totalling 2h 3min of listening. On two occasions the single-element hydrophone was used from an inflatable. This included 23 minutes recorded on 23 April in the company of a widely dispersed sperm whale group. No cetacean sounds were heard on the other occasion.

Cetaceans were heard at 78% of the stations. These sounds included sperm whale clicks, as well as odontocete whistles. Whistles could be detected on 50% of recordings, and whilst it was not possible to positively assign whistle series to a species, spinner dolphins were in the vicinity on at least three occasions and a mixed aggregation of pilot whales and bottlenose dolphins were in the area on one occasion. Sperm whales were heard but not seen on two occasions.

SPECIES ACCOUNTS

Short-beaked common dolphin (*Delphinus delphis*)

Two confirmed sightings of this species were made (Table 1, Fig. 2) The first sighting was of a large, widely dispersed group accompanied by seabirds (Australasian gannets, *Morus serrator*), assumed to be engaged in feeding. The animals were in shallow coastal water off Tasmania. The second sighting occurred 4 days later when several large animals bowrode for approximately 11min. No calves were observed.

Spinner dolphin (*Stenella longirostris*)

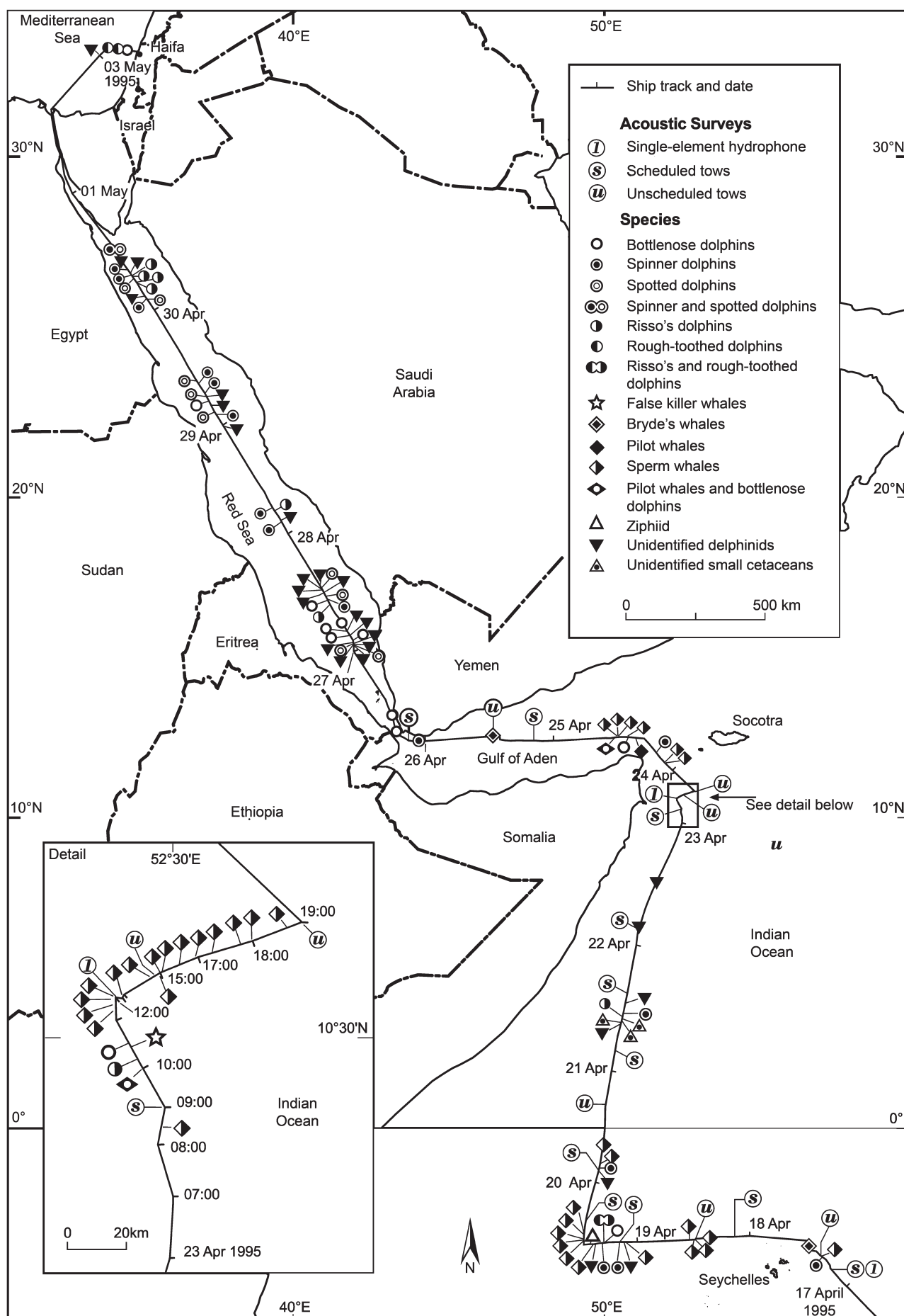
Spinner dolphins were encountered in several locations and conditions (Figs 3 and 4) and in small and large aggregations (Table 1). In mid-ocean, the species was often observed travelling slowly or milling amongst sea birds, presumably feeding. Aerial activity was always seen. Sightings occurred during all daylight hours, with a slight peak near midday. A mother and calf was seen on 28 April in the Red Sea and smaller individuals within pods were seen northwest of the Seychelles and in the northern Red Sea.

Bowriding was only observed in the Red Sea, including a mixed pod with pan-tropical spotted dolphins (Fig. 3).

There was some variation in size and colour pattern amongst the Red Sea animals. A tripartite pattern was common in all animals, but many were dark grey dorsally and on the pectoral fins with a band of the same colour separating the lateral and ventral fields, originating from and enclosing the eye and terminating parallel to the genitals. This band varied in width and shade for individuals (possibly an indication of age) and on larger animals was a very pronounced stripe. Other groups of animals were uniformly smaller and lighter in colour; the flippers were similar in shade to the lateral field; the rostrum was shorter and the dark lateral band was absent.

Pan-tropical spotted dolphin (*Stenella attenuata*)

Spotted dolphins were positively identified in the Red Sea (Fig. 3), but were likely to account for some of the ‘unidentified delphinids’ encountered throughout the survey. Most (70%) of the sightings involved bowriding, including the mixed group with spinner dolphins. Group sizes ranged from 9–70 individuals. Calves were seen in the southern Red Sea.



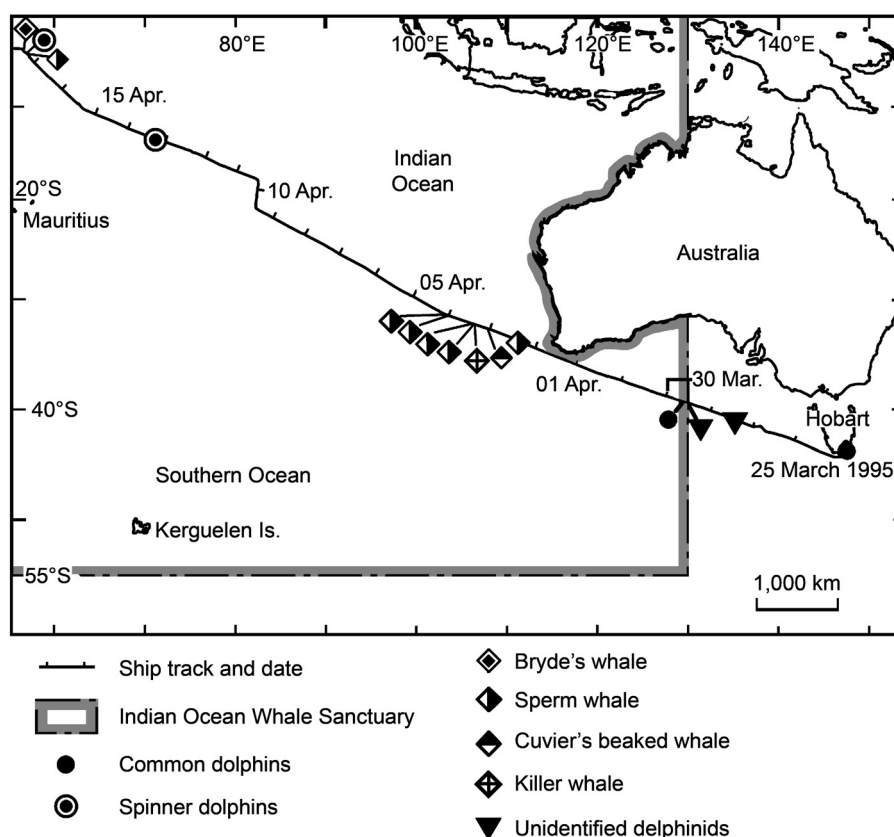


Fig. 4. Vessel cruise track and sightings positions for the eastern sector of the Indian Ocean Sanctuary. Some symbols are for multiple sightings of the same species.

The white rostral tip and dark cape was common to all groups observed, with some groups having distinctive white lips. Larger animals had dark flecks below the cape. Three groups contained a large number of individuals with a dark band extending from the gape, continuing beyond eye patch and ending above the trailing edge of the pectoral fin. Their size was comparable to other individuals without a band.

Bottlenose dolphin (*Tursiops* spp.)

Bottlenose dolphins were seen in different environmental conditions, including clear, deep oceanic waters and shallow, murky coastal waters on the approach to Haifa port (Table 1). The genus was only positively identified in the western part of the Sanctuary, including the Gulf of Aden and Red Sea (Figs 3 and 4).

The largest groups of animals ($n = 60$ and 40) were seen in the company of pilot whales. Most (79%) of sightings involved bowriding, including those associated with pilot whales.

Most of the animals encountered were quite large, robust and with short, blunt rostrums. Colour varied from dark grey (except for the ventral surface), to grey gradation along the flanks. Only three sightings were of lighter and smaller animals identified as Indo-Pacific bottlenose dolphins, *Tursiops aduncus*. One was mid-Red Sea (29 April, Fig. 3) and the other two were off the Horn of Africa (24 April, separate and with pilot whales, Fig. 3).

A mother and calf bowrode on two separate occasions in the Red Sea and the multi-species group in the Gulf of Aden had smaller animals present.

Rough-toothed dolphin (*Steno bredanensis*)

This species was seen on three occasions: once mid-ocean in deep, warm water and twice in the Mediterranean in deep, relatively cool water of 18°C (Table 1, Fig. 3). In the IOS the species was associated with Risso's dolphins and were broken up into units containing 1–4 animals which appeared boat-shy. All animals in the Mediterranean bowrode for an average of four minutes, including one juvenile.

The animals surfaced in synchrony when closely grouped and had a peculiar 'space shuttle' appearance when bowriding by holding their large pectoral fins at right angles to their body.

Risso's dolphin (*Grampus griseus*)

Risso's dolphins were encountered mid-ocean and in the Red Sea (Fig. 3). The largest group ($n = 25$) was associated with rough-toothed dolphins and consisted of young and old animals dispersed throughout the *Steno* groups. This was the only time the species approached to within 10m of the vessel. Group sizes varied from 1–5 animals for other encounters. Smaller animals were seen on three occasions in the Red Sea.

They were often (78%) seen 'sailing', with their flukes held vertically above the water or resting motionless at the surface on days of warm sea and air temperatures ($\geq 24^\circ\text{C}$ and $\geq 25^\circ\text{C}$ respectively).

Killer whale (*Orcinus orca*)

One group (about 10 animals of mixed age and sex) was encountered in cool, deep water in the eastern sector of the

Table 1
Group sizes of identified species, including water depth and temperature.

Total sightings	Total individuals ('best')	Mean group size (SD; range)	Approx depth, m (SD; range)	SST, °C (SD; range)
Pan-tropical spotted dolphin				
10	361	36 (24; 9–70)	657 (378; 178–1,302)	27 (3; 24–30)
Bottlenose dolphin spp.				
14	151	11 (17; 1–60)	912 (1,396; 14–5,000)	29 (3; 19–32)
Risso's dolphin				
9	53	6 (7; 1–25)	1,744 (1,605; 509–5,000)	28 (4; 24–32)
Sperm whale				
69	100	1 (1; 1–4)	2,461 (1,624; 1,000–5,000)	30 (3; 20–32)
Spinner dolphin				
19	1,059	56 (54; 4–250)	2,016 (1,929; 64–5,000)	28 (3; 24–32)
False killer whale				
1	2	2 (0; 2–2)	1,251 (0; 1,251–1,251)	30 (0; 30–30)
Short-beaked common dolphin				
2	310	155 (205; 10–300)	2,684 (3,768; 20–5,349)	15 (0; 15–15)
Bryde's whale				
2	2	1 (0; 1–1)	2,250 (1,768; 1,000–3,500)	30 (1; 30–31)
Killer whale				
1	10	10 (0; 10–10)	3,934 (0; 3,934–3,934)	20 (0; 20–20)
Pilot whale				
3	66	22 (14; 6–30)	1,938 (597; 1,251–2,328)	30 (0.3; 30–30)
Rough-toothed dolphin				
3	31	10 (13; 2–25)	2,708 (1,990; 1,425–5,000)	23 (8; 18–32)
Ziphiids				
2	3	2 (1; 1–2)	4,950 (71; 4,900–5,000)	26 (8; 21–32)

IOS (Table 1, Fig. 4). The animals were travelling fast, and blows were clearly visible 1km away in Beaufort sea state 4. They had a brown rather than black appearance and the saddle patch was faint.

Pilot whale (*Globicephala* spp.)

Pilot whales were encountered in the Somali Basin and the Gulf of Aden (Fig. 3). They were probably short-finned pilot whales (*G. macrorhynchus*) given their position (Leatherwood *et al.*, 1991). Pilot whales were associated with bottlenose dolphins on two occasions, and were noticeable even at a distance by their blows. Large animals appeared in all groups and no calves were seen. Six animals were observed surfing in sea state 4 with a 1.5m swell.

False killer whale (*Pseudorca crassidens*)

One sighting of two animals occurred in an area east of Somalia where a high number of other species were encountered, notably sperm whales (Fig. 3). They appeared disturbed by the vessel's presence, altering course away from the ship and spending little time at the surface,

Ziphiids

Two Cuvier's beaked whales (*Ziphius cavirostris*) were seen in the east of the IOS. Both were brownish grey dorsally, however one was cream-coloured anterior to the dorsal fin in a well-defined demarcation. The skin around the eye was dark and noticeable against the light background, and scarring was not evident on either animal. The whales had sloping melons with short rostrums and the dorsals were large and falcate, positioned well back. The trailing edge of the dorsals were grey. The animals had been

slowly milling at the surface and sounded as the vessel approached.

An unidentified single whale (Fig. 4) was seen in deep water (SST 32°C). It was medium-sized and resting motionless at the surface. A small triangular dorsal fin was positioned over half way along the body. The animal submerged as the vessel approached.

Bryde's whale (*Balaenoptera edeni*)

Two sightings of single animals were made in warm deep water (Table 1, Fig. 3). A large individual was sighted near Mahé (Seychelles). It had a variable swim pattern and submergence times from 1–9 minutes. The ship's course was slowed and altered without causing obvious disturbance to the whale.

The second sighting was in the Gulf of Aden. The whale was only seen briefly and no sounds were detected.

Sperm whale (*Physeter macrocephalus*)

This was the most frequently encountered cetacean species (Table 1). Sightings occurred throughout the IOS (Figs 3 and 4) with the exception of the Red Sea. Concentrations of animals occurred WNW of the Seychelles Group, south east of the Horn of Africa and in the Gulf of Aden.

Group numbers and estimated size of individuals showed a latitudinal pattern, with large, lone individuals (presumably adult males) seen in the south east IOS, in temperate (20–22°C), deep (3,934–5000m) water. Small groups, primarily thought to be subadults, were seen WNW of the Seychelles and south of the Equator, in warm (32°C), deep (2,000–5000m) water. Large, dispersed groups of adults, subadults and at least one occurrence of a calf were observed 10° north

of the Equator, west of Ras Hafun (SST 30.5–31°C, depth 1,200–2,000m). In the Gulf of Aden most animals were adults, either alone or in pairs (SST 30°C, depth 1,000–1,500m).

The highest number of sightings and individuals occurred on 23 April, when the vessel deviated 69km off course, 98km from Ras Hafun (Fig. 3). Sightings were divided roughly into four groups as the track progressed east throughout the day. The first group was of three sightings, totalling five adults encountered early in the morning. The second group consisted of adults, subadults and at least one calf (estimated 5m long) dispersed in subgroups of 1–3 animals, either resting at the surface or diving. Photographs were taken, and 23 minutes of recordings were made using the single element hydrophone deployed from an inflatable boat. Despite considerable surface noise, multiple clicks could be heard. Fifteen minutes prior to joining this group, two noticeably large, lone animals were seen. The group was observed from late morning to early afternoon.

An hour after leaving these whales and continuing east, the next group was encountered. This consisted of mostly large animals, either singly or in pairs. Whilst some rested at the surface, others were active. One pair was observed to roll together whilst swimming underwater, and a single animal with a dorsal fin callus was also seen swimming upside down just below the surface. Another pair of large whales was engaged in lob tailing. The array was towed whilst the vessel slowly circled in the area. At one stage all animals had sounded, but many animals could be clearly heard. One and a half hours were spent with this group mid-afternoon before course and speed were resumed. In the late afternoon, the final group was observed, with whales alone and at the surface.

Of a total 19 listening stations, sperm whales could be heard on five occasions, including three when animals were in view. Sperm whales are most often silent when at the surface (Whitehead and Gordon, 1986), making it probable that more animals were in the area than were seen.

Dorsal fin calluses were seen on 70% of individuals photographed. Dorsal fin calluses are associated with female sperm whales (Arnbom and Whitehead, 1989; Kasuya and Ohsumi, 1966).

Unidentified delphinids and small cetaceans

Some 17% of sightings were animals of dolphin-like appearance for which no species could be assigned. Lack of closure on sightings other than large whales made identification difficult unless animals approached or showed distinctive features or behaviour. Reduced visibility due to sea conditions contributed to unconfirmed identification, as did elusive behaviour. Some sightings made by the crew could not be positively identified.

On 21 April off the east coast of Somalia, five of the seven sightings were of small animals which could not be assigned to species (Fig. 3). This was on a warm, still day. Despite these good sighting conditions where animals could be detected resting at the surface from considerable distance, on approach they would sink below the surface until the vessel passed. It is possible that at least two of these sightings were of *Kogia* sp.

In the Red Sea, 37% of sightings were of indeterminate

species. Many of these sightings were at distances greater than 800m and the behaviour exhibited was either slowly travelling or resting at the surface. Vessel speed had increased and there was only one dedicated watcher present.

DISCUSSION

The Indian Ocean is characterised by monsoon-driven upwelling north of the Equator. The southwest monsoon current flows from late April to October, producing upwelling and nutrient-rich waters off the Somali east coast (Small and Small, 1991; Wyrki, 1973). As a result of this upwelling, influx of nutrients and increased phytoplankton biomass during the southwest monsoon, the NW Indian Ocean is considered a significantly productive ocean basin (Veldhuis *et al.*, 1997). Ballance and Pitman (1998) reported that the southwest monsoon began in late May in 1995, and April is often referred to as an inter-monsoon period. The northward flowing Somali Current commences near 10°S, where a large number of sightings were recorded and many species seen (Fig. 3). Upwelling is significant between 5° and 11°N (Small and Small, 1991), where the highest number of sightings were recorded. The mouth of the Gulf of Aden, where the Somali Current converges with the waters of the Gulf was also associated with a high number of sightings (Fig. 3); Small and Small (1991) present similar data on species, area and time of year for offshore sightings.

Our results confirm the conclusions of previous cruises, Balance and Pitman (1998) and Eyre (1995), that spinner dolphins and sperm whales are probably the most abundant cetacean species in the IOS.

As noted, it is likely that some of the unidentified sightings were spotted dolphins. This species appears to be an important part of the deep water fauna of the Red Sea. Beadon (1991) found that spotted dolphins were the most frequently encountered cetacean species off the southern tip of the Sinai Peninsula, but did not record spinner dolphins in the area. Gilpatrick *et al.*, (1987) and Eyre (1995) note a similar distribution for spinner and spotted dolphins in the Red Sea.

Risso's dolphins and bottlenose dolphins occurred throughout the Red Sea and western portion of the Indian Ocean. Kruse *et al.* (1991) refers to the frequency and distribution of Risso's dolphin sightings in the IOS from a review of available information and Beadon (1991) noted that they were the second most commonly encountered species in the Gulfs of Aquaba and Suez. The tail-up behaviour of Risso's dolphins observed on many of the encounters may be related to thermoregulation and has been observed in the Maldives (Anderson, 2005), Oman (Baldwin, 2003), Indonesia (B. Kahn, pers. comm.) and Papua New Guinea (Mörzer-Bruyns, 1971).

The two reported types of bottlenose dolphin would appear to be consistent with other reports (e.g. Beadon, 1991; Leatherwood, 1986; Mörzer-Bruyns, 1971). The association between *Tursiops* sp. and short-finned pilot whales is not uncommon (e.g. Anderson, 2005; Ballance and Pitman, 1998; Small and Small, 1991).

Pilot whales may have a seasonal distribution in the Gulf of Aden and east of Somalia. Small and Small (1991) recorded sightings from February–May and November and Ballance *et al.*, (1996) recorded them in May. Leatherwood

(1986) and Leatherwood *et al.* (1991) reported sightings in similar months in this area. Eyre (1995) transited this in June/July 1993 and reported no sightings of pilot whales. The lack of reported sightings from May–October may be related to the monsoon periods and associated weather patterns.

The single sighting of killer whales in the southeastern portion of the IOS may have been of Antarctic migrants; the brownish colouration may be attributed to diatoms (R. Pitman, pers. comm.). Unfortunately no photographs were obtained.

Although rough-toothed dolphins have been observed with other cetaceans (Perrin and Walker, 1975), this appears to be the first record of the species associating with Risso's dolphins. The two sightings of *Steno* in the eastern Mediterranean were not aberrant. A specimen was previously collected from Haifa (Watkins *et al.*, 1987) and the species is now considered to be a permanent part of the Mediterranean fauna (Miyazaki and Perrin, 1994). Sightings and strandings have been recorded off Israel and Palestine in March and April 1997, 1998 and 2005 (Goffman *et al.*, 2009; Khalaf, 2008).

The Seychelles is an important cetacean area (e.g. Ballance *et al.*, 1996; Claro and Hergueta, 2002; Eyre, 1995; Hermans and Pistorius, 2008; Kasuya and Wada, 1991; Keller *et al.*, 1982). Survey and whaling records suggest that the Seychelles area is an important region for sperm whales in all seasons (e.g. Wray and Martin, 1983). Townsend's (1935) charts show the Mahé Banks were an important whaling ground. Robineau (1991) notes that sperm whales were the most frequently encountered species around the Seychelles, but does not elaborate on whether the seasonal decline for balaenopterid sightings during April extends to sperm whales.

The only one other reference to large concentrations of sperm whales near the area off Ras Hafun is that of Ballance *et al.* (1996), who recorded over 20 sightings of sperm whales from 7–10 May 1995, in an area slightly east of the present study. No mention was made of group composition. Leatherwood (1986) reported two records of single animals from this region on 24 April 1977. Townsend (1935) and Kasuya and Wada (1991) show concentrations of animals SE of this area during April. The presence of sperm whales in this area is probably seasonal (Berzin, 1971) and related to a breeding and calving season that includes March and April (Klinowska, 1991). The presence of a calf amongst an assumed nursery group and the presence of adult animals engaged in close contact suggests that east of Ras Hafun may be a breeding and nursery site. The Gulf of Aden supports large numbers of sperm whales and 'young' sperm whales were recorded from the area in March and May (Small and Small, 1991). Yukhov (1969) noted females and 'small' whales in the later months of the year.

While there has been increased research effort in some parts of the IOS in recent years (e.g. Feingold and Kerem, 2008; Marsden *et al.*, 2004; Notabartolo di Sciara *et al.*, 2007; Notabartolo di Sciara *et al.*, 2009; Reijnders, 2001; 2002; Wise *et al.*, 2009) it is clear that long-term, year-round dedicated studies are required to obtain necessary information on abundance, distribution, seasonal patterns and behaviour of cetaceans within the IOS to address potential anthropogenic threats. However, this study has

shown that increased use of platforms of opportunity could provide valuable information for relatively little cost.

The identification of areas with high abundance and species diversity supports the implementation of more intense efforts in these areas, ideally combining visual and acoustic techniques. Unfortunately the northwestern sector of the IOS has in recent years become affected by war and piracy, making it difficult to conduct vessel-based research. The apparent dependence of some cetacean populations on areas of high primary productivity within the IOS implies that future management of these regions should be considered with respect to fisheries, pollution and climate change.

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Contents

Editorial	iii
Introduction	v
S. HOLT – Negotiating the Indian Ocean Whale Sanctuary	145
K. ADULYANUKOSOL, S. THAONGSUKDEE AND K. KITTIWATTANAWONG – Cetaceans and mass strandings in Thai waters	151
R.P. KUMARRAN – Cetaceans and cetacean research in India	159
K. SATHASIVAM AND K.S. NATARAJAN – Obtaining distributional information on Indian Ocean cetaceans: suggestions based on an Indian network experience	173
A.D. ILANGAKOON – A review of cetacean research and conservation in Sri Lanka	177
A. DE VOS, R. CLARK, C. JOHNSON, G. JOHNSON, I. KERR, R. PAYNE AND P.T. MADSEN – Cetacean sightings and acoustic detections in the offshore waters of Sri Lanka: March–June 2003	185
A.D. ILANGAKOON AND K. SATHASIVAM – The need for taxonomic investigations on northern Indian Ocean blue whales (<i>Balaenoptera musculus</i>): implications of year-round occurrence off Sri Lanka and India	195
R.C. ANDERSON, T.A. BRANCH, A. ALAGIYAWADU, R. BALDWIN AND F. MARSAC – Seasonal distribution, movements and taxonomic status of blue whales (<i>Balaenoptera musculus</i>) in the northern Indian Ocean	203
R.C. ANDERSON, S.A. SATTAR AND M.S. ADAM – Cetaceans in the Maldives: a review	219
R.A. CLARK, C.M. JOHNSON, G. JOHNSON, R. PAYNE, I. KERR, R.C. ANDERSON, S.A. SATTAR, C.A.J. GODARD AND P.T. MADSEN – Cetacean sightings and acoustic detections in the offshore waters of the Maldives during the northeast monsoon seasons of 2003 and 2004	227
M.A. GORE, M.S. KIANI, E. AHMAD, B. HUSSAIN, R.F. ORMOND, J. SIDDIQUI, U. WAQAS AND R. CULLOCH – Occurrence of whales and dolphins in Pakistan with reference to fishers’ knowledge and impacts	235
O.A. AMIR, P. BERGGREN AND N.S. JIDDAWI – Recent records of marine mammals in Tanzanian waters	249
V. DULAU-DROUOT, J. FAYAN, L. MOUYSET AND V. BOUCAUD – Occurrence and residency patterns of humpback whales off Réunion Island during 2004–10	255
S. PLÓN, K.H. ALBRECHT, G. CLIFF AND P.W. FRONEMAN – Organ weights of three dolphin species (<i>Sousa chinensis</i> , <i>Tursiops aduncus</i> and <i>Delphinus capensis</i>) from South Africa: implications for ecological adaptation?	265
E.J. EYRE AND J. FRIZELL – A note on observations of cetaceans in the Indian Ocean Sanctuary, Australia to Israel, April 1995	277

Editorial

This issue is dedicated to studies from the Indian Ocean. Most of these peer-reviewed papers were presented in some form at the Indian Ocean Cetacean Symposium (IOCS) held in Maldives, 18-20 July 2009 to mark the 30th anniversary of the IWC's Indian Ocean Sanctuary. Special thanks go to

Charles Anderson who has put in an enormous amount of work as guest editor to bring this volume to fruition.

G.P. DONOVAN
Editor

Introduction

The formation of the IWC's Indian Ocean Sanctuary in 1979 stimulated a flurry of cetacean research in the region during the 1980s. This included the voyage of the RY *Tulip*, the burgeoning of cetacean studies in Sri Lanka, as well as other work which was reported to the IWC scientific review meeting held in Seychelles in February 1987 (Leatherwood and Reeves, 1989; Leatherwood and Donovan, 1991; Whitehead, 1989). However, since then there had been no regional gathering of interested scientists. Key aims of the IOCS in 2009 were therefore to bring together cetacean researchers from across the region and to demonstrate the breadth and quality of cetacean research being carried out within the Indian Ocean Sanctuary.

In the event, the IOCS brought together 60 cetacean scientists from some 22 countries. The Symposium was inaugurated by the then Vice President of the Maldives Dr. Mohamed Waheed Hassan Maniku. A report of the symposium (Sattar *et al.*, 2009), including transcripts of opening speeches, abstracts of presentations, a list of participants and other details is available from the website of the Maldivian Marine Research Centre (<http://www.mrc.gov.mv>).

Some 43 presentations were made at the IOCS on a wide variety of topics relating to Indian Ocean cetaceans, under three general headings: regional reports, species reports and conservation and management. Several of those presentations were of works in progress, but just over a third have found their way into this peer-reviewed issue. An award for the best presentation at the IOCS by a coastal country scientist was presented to Muhammad Shoab Kiani (Pakistan), with Kanjana Adulyanukosal (Thailand) receiving a runner-up certificate.

In addition to presenting Indian Ocean research, another aim of the IOCS was to highlight the range of threats being faced by cetaceans within the Sanctuary. Fisheries bycatch emerged as a common problem in many countries, and that is reflected in several of the papers presented here. Other threats identified include ship strikes, oil and gas exploration, as well as pollution and (for coastal species) habitat degradation. The potential economic value of whale and dolphin watching, which is bringing employment and recreation to growing numbers of people around the Indian Ocean was also recognised.

The IOCS participants concluded the symposium with the formulation and adoption of the Lankanfinolhu Declaration¹. That declaration recognised the continuing contribution of the Indian Ocean Sanctuary to cetacean conservation within the region; noted the need for countries and organisations within the region to address issues of bycatch and directed catches of small cetaceans; to ensure appropriate mitigation when seismic surveys are carried out; and to work towards habitat protection, especially for cetacean hotspots and critical habitats. It also supported the

wider adoption of responsible whalewatching guidelines and regulations, and encouraged range states along with the IWC and others to develop a collectively agreed action plan to improve conservation outcomes for Indian Ocean cetaceans.

Other outcomes of the IOCS included: the production of a poster depicting the cetaceans of the tropical Indian Ocean, distributed to participants and to every school in Maldives; a presentation by OBIS-Seamap² demonstrating the possibilities and value of data archiving; two public lectures to schoolchildren by Dr. Michel Vély and Dr. Roger Payne; and this peer-reviewed volume.

The first paper in this issue is based on one of the two key note addresses at the IOCS. In his address, Sidney Holt discussed the background to the formation of the IWC's Indian Ocean Sanctuary. Holt was personally involved in the negotiations leading up to the formation of the Indian Ocean Sanctuary and his paper here provides his fascinating perspective on its origins.

In the second keynote address to the IOCS, Roger Payne described the findings of the five-year (2000–05) round-the-world *Voyage of the Odyssey*, which included two years in the Indian Ocean. (His address is not reported here, but details of the *Voyage* are available in: Ocean Alliance, 2009). Their global survey of sperm whales clearly demonstrated that these near-apex predators are concentrating potentially dangerous levels of toxic pesticides and metals. At the same time, the *Voyage of the Odyssey* provided a platform to survey cetaceans, often in areas where relatively little cetacean research has been carried out before. Reports from two such Indian Ocean areas (Sri Lanka and Maldives) are included here.

But the first of the regional reports published here is that of Adulyanukosal, Thaongsukdee and Kittiwattanawong who review cetaceans in Thailand. They look in particular at mass strandings, reporting on a series of five from the Andaman Sea (west) coast of Thailand involving four different species of odontocetes.

From India, Kumarran reviews cetacean records amassed over the past two centuries. Twenty five species of marine cetacean (plus one freshwater dolphin) are noted, with most records being from strandings and fisheries bycatch. There have been relatively few reports of sightings at sea, but most of those are recent, which suggests a hopeful trend towards more research on live cetaceans within India's extensive EEZ. On the other hand, Kumarran notes the real threat of fisheries interactions to small cetaceans and the poor quality of much existing data. Appropriately enough, in the next paper, Sathasivam and Natarajan outline a voluntary, web-based network being developed in India to improve the frequency and accuracy of data collected from cetacean strandings and bycatch.

¹ http://www.mrc.gov.mv/index.php/news_events/iocs_closing/

² <http://seamap.env.duke.edu>

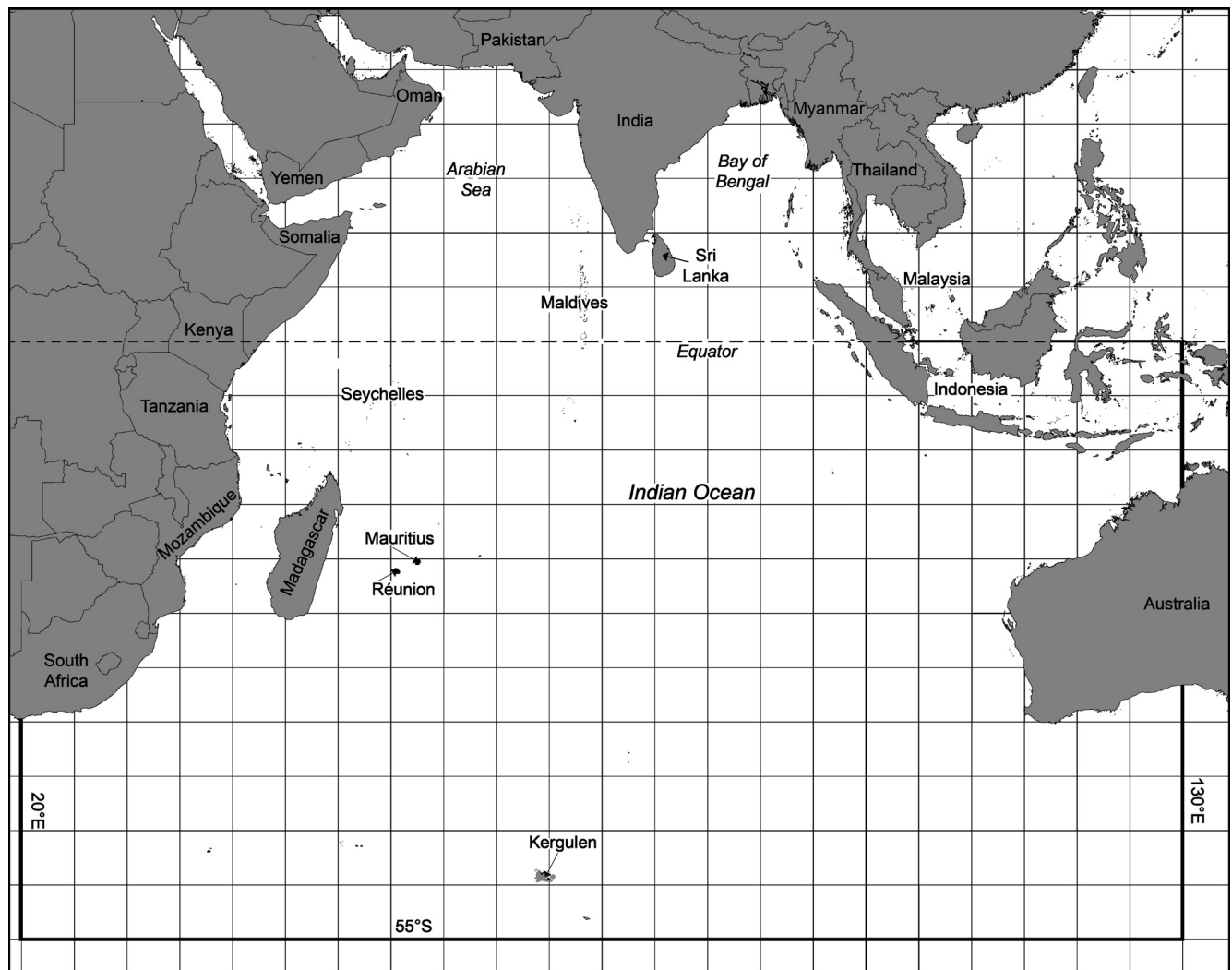


Fig. 1. Map of the Indian Ocean showing extent of the Indian Ocean Sanctuary. This encompasses all Northern Hemisphere waters from the coast of Africa to 100°E, including the Red Sea and the Gulf, and Southern Hemisphere waters from 20°E to 130°E, with the southern boundary set at 55°S.

From Sri Lanka, Illangakoon provides a review of information on and threats to cetaceans around this island nation. She notes that, with 27 species recorded to date (although there are still some unresolved taxonomic issues), Sri Lankan waters are home to a rich diversity of cetaceans. However, small cetaceans are particularly impacted as fisheries bycatch. There are also potential threats to larger cetaceans from shipping and a growing but currently unregulated whale watching industry. Still in Sri Lanka, De Vos *et al.* summarize the observations of the *Voyage of the Odyssey* in 2003. There were sightings of 11 different species, with sperm whales (*Physeter macrocephalus*) being the most frequently sighted and spinner dolphins (*Stenella longirostris*) being the most abundant. Canyons along the continental shelf edge were found to hold especially high concentrations of cetaceans.

Within the wider northern Indian Ocean, but particularly around Sri Lanka, there is growing interest in the local population of blue whale, which is likely a distinct subspecies, *Balaenoptera musculus indica*. Illangakoon and Sathasivam review blue whale records from Sri Lanka and India, confirming their year-round presence and highlighting the need for further taxonomic studies. Taking a broader

view, Anderson *et al.* compiled blue whale catch, sighting, stranding and acoustic data from right across the northern Indian Ocean. They demonstrate that these whales track seasonally shifting peaks in productivity, driven by seasonally shifting monsoon currents. While there is still much to be learnt, Anderson *et al.* successfully predicted and located a previously unknown concentration of blue whales off the south coast of Sri Lanka, which has kick-started significant whale-watching activity there.

From the Maldives, Anderson, Sattar and Adam review information on cetacean sightings and strandings. Recent research has brought the number of species recorded to 23, with the spinner dolphin being the most abundant, as is the case in much of the rest of the tropical Indian Ocean. What is unusual in the Maldives, however, is that the traditional pole and line technique for catching tuna continues to dominate the fisheries sector, and most forms of net fishing (including gillnetting and purse seining) are banned. As a result there is negligible bycatch of cetaceans, and the Maldives is in effect a sanctuary within the Sanctuary. Perhaps as a result of this, Clark *et al.* (who present observations from two visits of the *Voyage of the Odyssey* in 2003–04) recorded cetacean acoustic detections 2.5 times

higher in the Maldives than at other sites visited in the Indian and Pacific Oceans. They also report sightings, with 16 species being recorded during their 72 days at sea in Maldivian waters.

Continuing westwards, Gore *et al.* report on a cetacean research and conservation programme launched in Pakistan in 2004. During boat-based and shore surveys, 11 species were identified. Bottlenose dolphin (*Tursiops* sp.), Indo-pacific humpback dolphin (*Sousa chinensis*) and finless porpoise (*Neophocaena phocaenoides*) occur in good numbers inshore, while spinner dolphin is abundant further offshore. Work with fisher communities identified entanglement in fishing gear and opportunistic exploitation (for food, bait and medicine) as threats to small cetaceans.

From Tanzania, Amir *et al.* review data collected over 10 years, mostly from strandings and incidental fisheries bycatch, together with some dedicated boat-based surveys and incidental sightings. Specimens of 13 different cetacean species were recorded; over 90% were from gillnet bycatch, the remainder being from strandings. From these data, and sightings, Indo-pacific bottlenose dolphin (*Tursiops aduncus*), spinner dolphin and Indo-pacific humpback dolphin were recorded year-round, while humpback whales (*Megaptera novaeangliae*) were only observed during the austral winter, July to November.

Also in the southwest Indian Ocean, humpback whales are the subject of the next paper, by Dulau-Drouot. From boat-based surveys around the island of Réunion she records 724 sightings of humpback whales, with 312 individuals being photo-identified. Most were recorded during July–September, with numbers increasing in recent years. This is consistent with the assessment of the IWC Scientific Committee that Breeding Stock C is recovering from commercial whaling (IWC, 2010) and may be re-occupying its former range.

While most papers in this volume report on surveys of whole animals, the penultimate paper by Plön *et al.* reports on organ weights, from presumed healthy dolphins accidentally entangled in shark nets off South Africa. Three species were studied: Indo-pacific humpback dolphin, Indo-pacific bottlenose dolphin and long-beaked common dolphin (*Delphinus capensis*). The data obtained not only provide a baseline for future pathological examinations, but also illuminate the differing life histories and ecologies of these species.

The final paper in this issue, like the first, covers the entire width of the Indian Ocean Sanctuary. Eyre and Frizell report on a voyage right across the Indian Ocean from Western Australia to the Red Sea. One hundred and fifty six sightings were recorded within the Indian Ocean Sanctuary, with sperm whales being the most frequently sighted and spinner dolphins being the most abundant. This survey highlighted the NW Indian Ocean around the Horn of Africa and the Gulf of Aden as being an area of particular importance for cetaceans. Unfortunately, since that voyage was completed in 1995, this is also an area where such studies are currently restricted by the very real danger of piracy. With the exception of this one area, cetacean research is flourishing across the Indian Ocean, as the papers here demonstrate. Long may it continue.

R. CHARLES ANDERSON
Guest editor

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Fig. 2. Participants at the Indian Ocean Cetacean Symposium, Paradise Island Resort, Lankanfinolhu Island, Maldives, July 2009.

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Negotiating the Indian Ocean Whale Sanctuary¹

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ABSTRACT

This paper provides an overview of the establishment of the International Whaling Commission's Indian Ocean Sanctuary in 1979. The International Convention for the Regulation of Whaling enables the IWC to designate sanctuaries as well as open and closed areas for whaling. The author reflects upon the background to the issue of whale sanctuaries within the IWC and the particular role of the Seychelles Government in the development of the proposal for a sanctuary in the Indian Ocean. He notes the political, scientific and practical factors surrounding the acceptance of the proposal by the IWC and briefly discusses subsequent events.

KEYWORDS: MANAGEMENT; SANCTUARIES; INDIAN OCEAN

INTRODUCTION

The year 2009 represented the thirtieth anniversary of the establishment of the Indian Ocean Whale Sanctuary (IOWS)² by the International Whaling Commission (IWC). In 1979, a truncated form of a proposal by the Republic of Seychelles was adopted and incorporated into the IWC's Schedule³. It was truncated in the sense that the southern boundary of the sanctuary was set at 55°S rather than at the ice-edge of the Antarctic continent as originally proposed. This compromise ensured the requisite three-quarters majority since it allowed Japanese and Soviet pelagic whalers to continue pelagic whaling for Antarctic minke whales in the southern zone of the Indian Ocean. The boundary was effectively moved southward to the ice-edge when the entire Southern Ocean was declared as an IWC Sanctuary in 1994. The IOS was at first a temporary measure with limited existence, but after two reviews (IWC, 2003; Leatherwood and Donovan, 1991), the IWC Schedule was amended to read that 'in 2002 the Commission agreed to continue this prohibition [of commercial whaling] but did not discuss whether or not it should set a time when it should be reviewed again' (Busby and Holt, 2008).

This account derives from a longer study by the author, reviewing the history of the idea and efforts to implement international sanctuaries for cetaceans, especially whales (Holt, 2009a) and a shorter booklet published by IFAW (Holt, 2009b), as well as an earlier account in Holt (1983) and material from a booklet entitled 'Whale Sanctuaries and the South Atlantic' written by Leslie A. Busby, to be published by IFAW during 2012.

The idea of international sanctuaries for whales, on the high seas, was introduced in the League of Nations in 1929 by a committee of international lawyers, led by Sr José Leon

Suárez of Argentina. International whaling conferences in 1938 and 1939 recommended to participating governments that they take powers to establish sanctuaries, particularly in the Antarctic seas, but action was delayed by the Second World War. After the War, an appropriate provision was written into the International Convention for the Regulation of Whaling 1946 (ICRW, Article V (c)) and authority to designate sanctuaries was invested in the IWC.

A sanctuary for baleen whales in the southeastern sector (70°W–160°W) of the Southern Ocean south of 40°S was incorporated into the first IWC Schedule, adopted by the ICRW negotiators in 1946. This was suspended in 1955, after several years of debate, in which Japan, especially, repeatedly sought its abolition. This was understandable; Japan, as an occupied country, was not permitted to attend the 1945 Conference in Washington DC and could not join the IWC until the signature of the Peace Treaty with the USA. The occupying power did however permit – even encourage – Japanese pelagic whaling fleets to resume Antarctic whaling. These fleets entered the Antarctic region via the Pacific in contrast with those from Europe and the USSR that entered that region through the Atlantic and Indian Oceans, thus the sanctuary was considered to put Japan at a disadvantage. However, the reasoning used by those who wished to open the sanctuary to whaling was that this would relieve the whaling pressure in the other Antarctic sectors. The IWC scientists consistently opposed this, recommending instead that the arbitrarily set 'Blue Whale Unit' (BWU) catch limit set for pelagic catching of baleen whales be drastically reduced. Their pleas failed and eventually, in 1955, they reluctantly recommended the suspension of the sanctuary to the Commission as a hard compromise. This was accepted by the Commission notwithstanding the offer of Japan to agree to continuation of protection of a part of the sanctuary area (IWC, 1956a; 1956b).

The suspension was initially for three years with the provision for automatic closure after that time although this did not occur. In subsequent years various proposals for sanctuaries were put forward by groups of interested member states including the Northwest Atlantic, the Northeast

¹ This paper is a shortened and edited version of a presentation to the opening session of the Indian Ocean Cetacean Symposium held in the Republic of Maldives, 18–20 July 2009.

² This abbreviation is used here to avoid confusion with another IWC action – the International Observer Scheme (IOS).

³ The Schedule to the Convention contains the rules that govern the conduct of whaling. It can be amended at meetings of the Commission provided a proposed amendment obtains three-fourths of the votes of those voting for or against.

Pacific, the Mediterranean and Black Seas, the South Atlantic, the Southwest Pacific and – somewhat obliquely – the entire High Seas. To date only the Indian Ocean (in 1979) and Southern Ocean (in 1994) proposals have been adopted by the IWC. Their adoption has involved the general support for the concept, in both regions but especially in the Indian Ocean, of many states that are not members of the IWC or that joined the IWC after the IOWS had been established.

THE BEGINNINGS

In 1965, in a little known Sri Lankan journal, a Sri Lankan scientist, Dr P.E.P. Deraniyagala (Deraniyagala, 1965), suggested that the Indian Ocean between 20°E and 118°E, including the Southern Ocean sector thus bounded, be proclaimed by international agreement as a sanctuary for all cetaceans, as well as for dugongs and marine turtles. The period 1959–1965 was that in which the International Indian Ocean Expedition (IIOE), one of the largest collaborative oceanographic expeditions ever mounted, was organised by the Scientific Committee on Oceanic Research (SCOR) of the International Council of Scientific Unions (ICSU), following the first International Geophysical Year of 1957 which itself led to the negotiation of the Antarctic Treaty. Dr Deraniyagala had several arguments for his suggestion. One was that the requirement for one or two national inspectors to be placed on whaling expeditions was inadequate since in his view the fact that such officials were living with whaling crews for several months reduced the likelihood that they would provide objective reports on their ship-mates' activities. He also stated that a majority of the many dead and dying cetaceans he had studied washed ashore in Sri Lanka, especially the large whales, had suffered from harpoon strikes. He therefore believed that the number of whales that might thereby 'suffer a lingering death' might be equal to or more than the number actually secured and reported as caught. That seemed plausible to many people because the loss rate at the time was known to be substantial although reliable figures were not available. The stranded and wounded whales, especially in Sri Lanka and Southern India to which Deraniyagala referred, included blue, fin, and humpback whales, false killer whales, sperm whales and pygmy sperm whales, beaked whales of the genera *Ziphius* and *Mesoplodon*, although of the toothed whales only the sperm whale was a recognised target for modern whaling at the time, and bycatches of cetaceans in Sri Lankan fisheries are known that could have been responsible for some of the strandings. The author also referred to several specimens of what he knew as the slender *thalmaha* sub-species of minke whale found in tropical waters of the Indian Ocean.

Deraniyagala's paper was generally ignored but in 1978, the newly independent Government of the Republic of Seychelles, which was acquiring a huge Exclusive Economic Zone (EEZ)⁴ as a result of changes in the Law of the Sea, decided to accede to all relevant intergovernmental agreements concerning the ocean. That included the IWC.

Seychelles' decision to join the IWC should be seen in the perspective of the emergence of a broader interest in conservation in the first years of independence of the Republic in 1976, which also had roots in the concern of

British scientists in colonial times for the unique natural history of many of the islands, especially Aldabra⁵ and the birds of the central granitic islands Cousin, Bird and Aride. After the enactment of its EEZ based on UNCLOS principles, a group of Seychellois conservationists facilitated the legal protection of 42% of the new State's land, several marine parks and reserves including entire islands and the surrounding sea areas were created and specific protective legislation enacted for birds, turtles and giant tortoises. The Seychelles National Environment Commission was set up and programmes were run by the International Council for Bird Preservation (now BirdLife International) and the World Wildlife Fund (WWF) to train a new cadre of Seychellois rangers and managers. Thus Seychelles came into the IWC armed with a large array of policy and legal instruments and an advanced conservation ethic.

BACKGROUND TO THE DEVELOPMENT OF THE PROPOSAL

It is perhaps not surprising that in joining the IWC, this new state should do more than just cast its vote for or against the initiatives of others. It had before it the example of Malta that had 'made waves' by launching in the UN General Assembly a vast debate about the reform of the Law of the Sea. Seychelles was not quite so ambitious, although it was one of the main beneficiaries of the new international law. The momentum that began in 1972, with the UN call for a ten-year general moratorium to allow an interim respite from what some saw as virtually uncontrolled commercial whaling and give time for emplacement of better management, had diminished with the 1974 agreement on the Australian proposal for an 'amended moratorium' that came to be called the *New Management Procedure* (NMP) defined by paragraph 10(a–c) of the ICRW Schedule (e.g. see Allen, 1980; Gambell, 1977).

Application of the new rules in the second half of the 1970s had led to the setting of zero catch limits for most baleen whale stocks in the Southern Hemisphere, except that for the Antarctic minke whale (the smallest of the baleen whale species subject to whaling) – large-scale catching of which was begun at the opening of the decade by Japan and the USSR – and the Bryde's whale (which is not found as far south as Antarctic waters). Since the assessments of whale stocks at the time depended on long data series from commercial catches, providing reliable scientific advice on minke whale catch limits was practically impossible as reflected in the reports of the IWC Scientific Committee.

Southern Hemisphere Bryde's whales were partially protected by the prohibition of pelagic whaling in the zone north of 40°S. However, in the late 1970s, Japan had conducted large-scale pelagic whaling for that species under Special Permits allowed by Article VIII of the ICRW, south of Madagascar and on the fringe of the Indian Ocean near Indonesia, as well as near the Solomon Islands in the South Pacific. The Japanese authorities were thought to be considering two ways of opening up these resources for

⁵ The intervention by scientists and conservationists prevented Aldabra – since 1982 a World Heritage Site – from being turned into a US military base in the 1960s, resulting in such interest being turned to Diego Garcia in the Chagos Archipelago.

⁴ The Republic of Seychelles comprises over 100 islands.

systematic exploitation. One was to seek the abolition of the long-standing ban on pelagic whaling for baleen whales in tropical and temperate waters, but that would have been politically difficult, requiring a three-quarters majority in the IWC. The other was to open client land-stations in developing countries, not members of the IWC, in the Indian and Pacific Oceans near the discovered Bryde's whale concentrations – beginning with Madagascar and also Indonesia which had some small-scale 'traditional' (unmechanised) whaling. Bryde's whales in the eastern Atlantic had been taken by so-called 'pirate whalers' operating under flags of convenience to provide frozen baleen whale meat to the Japanese market. The seasonal timing would be such that the factory ships operating in the Antarctic could even pick up the frozen meat on their return journeys to Japan, thus saving transport costs and import-export inconveniences.

In 1979, Japan formally proposed an annual catch limit of 460 Bryde's whales for the putative 'Indian Ocean stock' of this species. However, the IWC's Scientific Committee did not accept the Japanese scientists' estimates of the number of whales from the surveys connected with the Special Permit catches of the previous three years, and so recommended that the Northern Indian Ocean stock be classified as an Initial Management Stock with zero catch limit pending satisfactory estimates of stock size (IWC, 1980b, pp.48–49 and pp.52–53). Two views were expressed within the Committee with respect to the Bryde's whales in the Southern Indian Ocean (including the area south of Madagascar). Most members recommended the same wording as for the Northern Indian Ocean. Others believed that satisfactory estimates of stock size had been obtained and proposed that catch limits should be 95 on the Western side and 282 in the East (where there had been successful Special Permit whaling near Indonesia). Most of the Committee noted that this would require an amendment to the Schedule to open some portion of the area between 40°S and 20°N to pelagic baleen whaling. Subsequently the IWC's Technical Committee (really a 'Committee of the Whole', not at all 'technical') recommended and the Commission Plenary (with no nation dissenting) adopted zero catch limits in both the southern and northern zones of the Indian Ocean (IWC, 1980a).

The ban on pelagic whaling in temperate and tropical waters did not apply to sperm whales. With the decline of baleen catches in the Antarctic the Soviet expeditions had steadily increased their catches of sperm whales – which yielded an industrial oil of strategic importance. Two of the Soviet expeditions were catching sperm whales in effectively unlimited numbers⁶ on their ways to and from the Antarctic via Suez; it was not known at the time how many baleen whales the Soviet expeditions were also killing – illegally and secretly – in these waters (Yablokov, 2000). People in Seychelles believed that sperm whales were far less abundant near the islands than a few decades earlier. While the inclination was to join with those nations that still favoured a general moratorium on commercial whaling, it was thought that it would not have been possible then to

secure the necessary three-fourths majority vote for such a move. Accordingly the Government embraced a strategy and programme including as one element the declaration of the Indian Ocean as a sanctuary, from the northern coastline to the Antarctic ice.

It was also believed within Seychelles in 1979 that 'pirate' operators were preparing two new vessels that might be destined for the Indian Ocean, although the Governments of South Africa and others were now interested in preventing that, particularly by refusing port facilities. The 'pirate' operations in the eastern Atlantic were under threat by the actions of IWC members to impose various types of sanctions against whaling under the flags of non-member countries. Some Commission members were also concerned that if these 'pirate' operations were legitimised by the countries whose flags they flew joining the IWC, this would swing the balance of power back towards the Commission again becoming what it had often been called – 'a Whalers' Club'.

THE 1979 SEYCHELLES INITIATIVE

Early in 1979, a Workshop on Protected Areas for Cetaceans, convened by IUCN in Mexico, with support from UNEP and WWF, had suggested that the eastern Indian Ocean be designated as a protected area. This was made feasible, it was thought, because of the recent decision by the Government of Australia for that country to get out of the whaling business and to work for a world-wide ban on whaling.

The Seychelles proposal was contained in a document entitled the Seychelles Initiative (Anonymous, 1979) and was presented both to the Scientific Committee and the Technical Committee and Plenary by the Alternate Commissioner, Dr L. Watson. I provided further technical information as observer for FAO (Holt, 1979).

The Seychelles' idea was that designation of the *entire* Indian Ocean would at least protect one or perhaps more of the putative Southern Hemisphere populations of all baleen species, as well as of the sperm whale⁷ and the killer whale. Marking experiments had shown that Antarctic minke whales from a particular breeding ground such as that off Brazil could feed at longitudes as much as 54° apart in summer, while other whales also moved across longitudinal boundaries during the same summer feeding season. Individual – visual – recognition of humpback whales in some parts of the Northern Hemisphere had revealed that individuals did not always return to the same breeding area in successive seasons, and it seemed reasonable to assume that this might also be the case for other baleen whale species in the Southern Hemisphere. Nevertheless, the IWC was necessarily dealing with fixed geographical definitions for the purpose of managing whaling and assessing putative whale populations and it seemed reasonable to assume that the various exchanges, mixings and movements that had been noted were exceptions rather than the rule.

It was far from clear to the Seychelles' authorities that a three-fourths majority would be obtainable at the time.

⁶ Catch limits were set by Division in the Southern Hemisphere, i.e. south of the Equator. The Indian Ocean spanned Divisions 3–5.

⁷ Seychelles believed that the NMP was even less adequate for sperm whales than it was for baleen whales and that this species needed global protection, so a second strategic aim was to secure a long-term moratorium on all catching of this species. Its 1979 proposal did not succeed but this aim was realised in 1981.

However, it seemed to be close enough that the balance could be shifted if Indian Ocean coastal states – few of which were yet members of IWC – expressed their support for such an action. Few of them had any special authority or claims under the emerging new Law of the Sea, but coastal states' special interest in areas adjacent to their expanding areas of national jurisdiction was becoming widely accepted. So the Seychelles Government discreetly consulted, at high level, governments of all the Indian Ocean coastal states and found most were favourable to the sanctuary proposal and none opposed it. Several said they would work to bring their countries into the IWC, but that could not practically be done before the 1979 meeting of the Commission. An additional move was the declaration by Seychelles of its own EEZ as a protected zone for all marine mammals and a hope that as many other Indian Ocean coastal states as possible would do likewise. Consideration was given to delaying the proposed action for a year until more Indian Ocean coastal states had joined the IWC but ultimately it was agreed that the element of surprise was very important and it was decided to proceed immediately.

The consultations also led to a suggestion that an Indian Ocean Alliance for Conservation be established, of which the proposals regarding whaling would be a part. In the background to this was the move being led in the United Nations by Sri Lanka to declare the Indian Ocean as a Sea of Peace, from which, *inter alia*, the navies of the superpowers would be invited to withdraw. Although this had support from most of the Non-Aligned Indian Ocean countries it was a practical impossibility. For example, the USA and UK (sovereign of the Chagos Archipelago, including the island of Diego Garcia) saw the Alliance for Conservation as the thin end of a Sea of Peace wedge and strongly opposed it; that initiative was pursued for a while but eventually abandoned.

ADOPTION OF THE SANCTUARY AT THE 1979 IWC MEETING

The IWC's Scientific Committee reviewed the proposal (IWC, 1980b) both in terms of the general concept of sanctuaries and of the Indian Ocean proposal and its boundaries. There were suggestions by some that 40°S or the Antarctic Convergence may be appropriate in particular, but – as the Report of that meeting brusquely says – 'no firm conclusions were reached' (IWC, 1980a, p.27). This was essentially because of the political implications of the discussion and because some mistakenly treated the proposal as if it had been presented more for promoting research than for achieving conservation by cessation of whaling. For example, there was considerable discussion of whether the cessation of commercial whaling in the region would cut short the provision of data coming from whaling activities and which some scientists insisted were needed for setting catch limits. This apparent confusion of objectives has persisted in all later discussions of sanctuaries in the IWC (Zacharias *et al.*, 2006). It arises from Article V.2 of the ICRW which states that regulatory – including conservation – actions to be taken *inter alia* 'shall be based on scientific findings'. Opponents of broad conservation measures (such as sanctuaries and moratoria) have sought repeatedly to

interpret this, erroneously in my view, as meaning that regulatory measures cannot be taken unless they have been proposed or fully supported by the Scientific Committee (which almost never votes and rarely achieves consensus on issues with strong political overtones such as sanctuaries and catching under special permit). In this case as in others, the Commission acted despite a lack of consensus within the Scientific Committee.

Prior to discussions in the decision-making Commission plenary session, the proposal was discussed in the IWC's Technical Committee. It became clear that a three-quarters majority would not be forthcoming without some compromise. The Seychelles delegation amended the original southern boundary proposal to 55°S thereby excluding the major Soviet and Japanese whaling grounds for the Antarctic minke whale from the Sanctuary. Several countries spoke in favour of the proposal. Japan, as it has consistently done, argued against the concept of sanctuaries, stating that individual stock management was preferable and monitoring of populations would be reduced by any pause in whaling. The USSR put forward similar views. Panama and Australia suggested a further amendment to provide for a ten-year review period to allow sufficient time for effects of disturbance and recovery rates of depleted stocks to be followed. The amended proposal was accepted in the Technical Committee by 14 votes to four with five abstentions.

In the Plenary, this was further amended by Seychelles and Australia to provide for a reduced review period (five years) but nevertheless establishing the sanctuary for ten years. This amended proposal was adopted by 16 votes to 3 with 3 abstentions. The Commission also adopted a non-binding Resolution proposed by Denmark instructing the Scientific Committee to look at the type and level of research needed for monitoring within the IOWS as well as to investigate whether it was necessary to initiate additional research simultaneously in areas where exploitation of whales continues, in order to make comparison possible between stocks under the two different regimes; this was a shadow of the pervasive idea that sanctuaries – if established – should be for scientific rather than conservation purposes.

Only part of that work was accomplished. With mainly NGO financing, a research plan for the Indian Ocean sanctuary was developed at a workshop held in the town of Zeist, in The Netherlands (Busby, 1981), and some expanded research on cetaceans was being promoted in several countries in the region, especially by Australia, India and Sri Lanka, where scientific symposia were subsequently held, and also – though on a very limited scale – in Oman, Kenya and Seychelles. However, the financial means to assist this work were not forthcoming either from the IWC or, as had been hoped, from UNEP, and supporters of the Seychelles initiative were subject to criticism by some opponents and skeptics who alleged that promises had not been fulfilled.

In the following years, several more Indian Ocean coastal states did join the IWC (previously only Australia, South Africa and the Seychelles were members): Egypt, India, Oman, Kenya and Mauritius. Sri Lanka, which had been enthusiastic about joining, did not do so, nor did Tanzania;

some thought that these changes of mind, along with Mauritius neither attending meetings nor paying its dues, resulted from external diplomatic pressures. But the influx of non-aligned ‘developing countries’, encouraged and supported by NGOs, began to prepare the IWC for the adoption of a global ‘moratorium’ on commercial whaling, of unlimited duration, which it did in 1982 on the basis of a specific proposal by Seychelles to set all catch limits to zero regardless of existing classifications under the NMP. It had also been envisaged that measures to protect cetaceans (as well as other vulnerable marine species in the region regarding the conservation of which several governments insisted that the IWC did not have legal competence), would be taken by other international institutions, as implied by the original Alliance for Conservation idea, but this happened only to a very limited degree. To this day there is, unfortunately, no comprehensive plan or authority for the conservation and the management of use of the marine life of the region as a whole.

ACKNOWLEDGEMENTS

Many people were directly involved in the action to designate the Indian Ocean as a sanctuary for whales; here only a prominent few can be singled out for special acknowledgement. I begin with Harold Eidsvik, of IUCN, who prepared and steered the IUCN/WWF/UNEP workshop in Baja California, Mexico, in February 1979, which set the sanctuary ball rolling again. Dr Paul Spong was the Rapporteur on that occasion.

The actions later that year, centred on the Republic of Seychelles, were supported vigorously by the then President of the Republic, M. Albert France René and led by the late Dr Lyall Watson, serving as Alternate Commissioner for Seychelles to the IWC. Others on the delegation were the Commissioner, M. Laustau-Lelanne, Ms Cornelia Durrant (Political advisor) and Mr Malcolm Forster (Legal adviser). My superiors in FAO and UNEP allowed me – then in my final year of service with the UN system – to serve unofficially as scientific and technical advisor to the Seychelles delegation.

A small, developing country such as Seychelles could not have pursued this objective successfully without substantial outside help, both financial and personal. This was provided particularly by the Threshold Foundation, which had been established by Prince Shahram Pahlavi-nia, a resident of Seychelles, and the World Wildlife Fund International (WWF), with the dedicated involvement of two of its stars: Sir Peter Scott and Dr Sylvia Earle. Mr Harold Wicks lubricated the pipeline from Threshold, which was headquartered in London. When Threshold ran out of money a few years later, Mr Brian Davies, Founder and CEO of the International Fund for Animal Welfare (IFAW) helped to find ways to continue the necessary financial support for Seychelles’ involvement in cetacean conservation. The Government of Sweden generously gave financial assistance for the convening of the Indian Ocean Alliance consultation, and the vigorous and helpful role of the Commissioner for Sweden, Dr Bertil Hägerhäll, IWC Commissioner for Sweden from when his country rejoined the IWC in 1979, must be acknowledged here.

The workshop held in Zeist, Netherlands, after the 1979 success, was funded by WWF Netherlands on the initiative of its Director, Mr. Niels Halbertsma. I was Convener of the workshop; Ms Leslie Busby organised it and wrote the Report. Halbertsma, after the declaration of the IOS, also supported the voyage of the research yacht *Tulip* to conduct research on sperm whales near Seychelles and Sri Lanka, led by Dr Hal Whitehead, assisted by scientists Dr Vassili Papastavrou and Dr Jonathan Gordon, who both later served with IFAW. Simultaneously Brian Davies arranged for the IFAW twin-engined aircraft to fly to Seychelles to conduct a sperm whale survey there, a project carried out by Mr Ronald Keller; the results of that were published by the IWC (Keller *et al.*, 1982).

Several diplomats based in London at the High Commission offices served as Seychelles Commissioner to IWC in the following years, but the burden of steering the Indian Ocean Sanctuary through the IWC processes to quasi-permanence was borne by Mr Robert Delpech, a brilliant diplomat, sailor and raconteur. For part of that period I served as Alternate Commissioner. After Mr Delpech’s retirement the lead was taken by Dr Nirmal Shah, founder and leader of the very active and successful NGO: *Nature Seychelles*.

Among the neighbouring countries of Seychelles the delegation was perhaps closest, for many years, to the Sultanate of Oman, whose Commissioner, Mr Mohamet Al-Barwani, was particularly supportive during the critical decade after the establishment of the IOWS in 1979. Mr James Carr, who had been helping me in research at the Seychelles High Commission, served for a while on the delegation of Oman. I am indebted to Mr R.P. Kumarran for reminding me, after this paper was written, of the singular contribution made in the 1960s by the Sri Lankan scientist Dr P.E.P. Deraniyagala. Lastly I wish to express appreciation of the work of the Editor for assistance in bringing the words of my Maldives talk into publishable form.

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Cetaceans and mass strandings in Thai waters

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ABSTRACT

A total of 25 species of cetaceans have been recorded in Thai waters from stranding and sighting records. A summary of these, together with details of five mass strandings on the Andaman Sea coast of Thailand, are reported here. The first mass stranding, of nine spinner dolphins (*Stenella longirostris*) was at Talibong Island, Trang Province, in January 1999; six carcasses were examined and three were lost. The second record comprised five spotted dolphins (*Stenella attenuata*) stranded at Ban Ko Kho Khao, Phang-nga, in February 1999; two dolphins were released alive. The third stranding was of eight spotted dolphins at Mai Phai Island, Phang-nga, in March 2006; five animals died and three were released alive. The fourth mass stranding was of 30 false killer whales (*Pseudorca crassidens*) at Racha Yai Island, Phuket, in June 2008; 29 animals were released while one drowned. The fifth record consisted of three rough-toothed dolphins (*Steno bredanensis*) stranded at Nam Bor Bay, Phuket, in July 2008; all three were returned to the open sea. It was difficult to determine the causes of death of the stranded dolphins. However, it was possible that the first two mass strandings were caused by disease. Some strandings were possibly influenced by the landscape of the stranding locations (narrow bay in one case, wide gently sloping beach in another).

KEYWORDS: IRRAWADDY DOLPHIN; INDO-PACIFIC BOTTLENOSE DOLPHIN; FINLESS PORPOISE; FALSE KILLER WHALE; STRIPED DOLPHIN; SPINNER DOLPHIN; PANTROPICAL SPOTTED DOLPHIN; INDO-PACIFIC HUMPBACK DOLPHIN; SPERM WHALE; MASS STRANDING; ANDAMAN SEA; GULF OF THAILAND

INTRODUCTION

Strandings, particularly mass strandings, of marine mammals attract a great deal of public attention. In recent years, the public has generally supported the laboratory investigation of dead animals in order to further scientific knowledge, as well as the return of live animals to the sea (Harwood, 2002; St. Aubin *et al.*, 1996).

Thailand has conducted regular cetacean research since 1993, mostly undertaken by the Phuket Marine Biological Center (PMBC) under the Department of Marine and Coastal Resources (DMCR). Its cetacean research programme was initiated through a collaboration with Danish scientists under the Small Cetaceans in the Gulf of Thailand and the Andaman Sea Project (Chantrapornsyl *et al.*, 1996; 1999; 1991). Information on species distribution and abundance, including biology and behaviour of cetaceans was obtained from interviews, stranding records and surveys under this programme. A stranding network for marine endangered animals (cetaceans, dugong and sea turtles) was set up and has been operated in cooperation with villagers, non-government and government organisations in coastal provinces. This network has worked well, and as a result most data currently available on cetaceans in Thailand were obtained from stranded animals.

Nevertheless, some information is available from other sources. Boat and aerial surveys have been conducted to investigate species distribution, abundance and behaviour (Adulyanukosol and Kittiwattanawong, 2004; Adulyanukosol *et al.*, 2000; Chantrapornsyl, 1996; Chantrapornsyl *et al.*, 1996; 1999; Intongcome *et al.*, 2005a; 2005b; Mahakunlayanakul and Surada, 1999; Ninwat *et al.*, 2008; Thongsukdee and Swangarraraks, 2005; Yamada *et al.*, 2000; 2006).

This report provides updated information on species diversity and distribution of cetaceans in Thailand and on mass stranding events, including details of attempts to rescue live-stranded animals. Other aspects of cetacean biology are not considered here.

MATERIAL AND METHODS

The information on species diversity and distribution of cetaceans in Thailand in this study was compiled from the database of PMBC (1993 to 30 June 2009), together with earlier publications: Anderson and Kinze (1999); Adulyanusokosol (1999); Adulyanukosol *et al.* (2009; 2000); Chantrapornsyl *et al.* (1996; 1999; 1991); Intongcome *et al.* (2005a; 2005b); Ninwat *et al.*, (2008); Sirimontraporn and Sritakorn (1995); Thongsukdee and Swangarraraks (2005); Yamada *et al.* (2000; 2006). The PMBC database includes information from reports of stranded cetaceans as well as details of many specimens which were transferred to PMBC or to other DMCR centres for species identification and necropsy. During necropsy, tissue samples were collected for studies including genetics, parasitology, histology and investigations of both heavy metal and organochlorine pollutants (Harino *et al.*, 2007; 2008). Skeletal material was retained for species identification and osteological examination. With large whales or badly decomposed specimens, the carcasses were examined on-site and buried afterwards.

RESULTS AND DISCUSSION

Species and distribution

Stranding records

Eighteen species of cetaceans were recorded in Thailand up to 1993 (Anderson and Kinze, 1999). Subsequently, an

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additional five species were reported by Chantrapornsyl *et al.* (1999) and Adulyanukosol and Kittiwattanawong (2004). More recently, Yamada *et al.* (2006) studied Thai specimens of balaenopterids, including morphological investigations of skulls and skeletons, and molecular analysis. Prior to that work, all balaenopterid specimens (except one record of fin whale) were identified as Bryde's whale *Balaenoptera edeni*. However, Yamada *et al.* (2006) demonstrated that some of those specimens were in fact Omura's whale *Balaenoptera omurai*. These recent studies brought the total number of cetaceans found in Thai waters to 25 species, belonging to six families: Balaenopteridae (4 species), Physeteridae (1), Kogiidae (2), Ziphiidae (2), Delphinidae (15) and Phocoenidae (1). Twenty-three of these species have been recorded in the Andaman Sea and 18 in the Gulf of Thailand (Table 1 and Fig. 1).

There were a total of 553 stranding records in the PMBC database as of 30 June 2009. Strandings of offshore species and mass strandings occurred only along the Andaman Sea coast, not on the coast of the shallow Gulf of Thailand. Species/groups with more than 10 individuals stranded were: balaenopterids (104), Irrawaddy dolphin *Orcaella brevirostris* (98), Indo-Pacific bottlenose dolphin *Tursiops aduncus* (63), finless porpoise *Neophocaena phocaenoides* (58), false killer whale *Pseudorca crassidens* (45), striped dolphin *Stenella coeruleoalba* (40), spinner dolphin *S. longirostris* (34), pantropical spotted dolphin *S. attenuata* (30), Indo-Pacific humpback dolphin *Sousa chinensis* (25) and sperm whale *Physeter macrocephalus* (13) (Table 1). Among these records, 161 specimens from 20 species were deposited in PMBC. The stored samples of species/group with more than 10 specimens were striped dolphin (28), Indo-Pacific bottlenose dolphin (20), pantropical spotted dolphin (19), spinner dolphin (18), finless porpoise (13), the group of Bryde's and Omura's whales (12), and Irrawaddy dolphin (11) (Table 1).

Sighting records

Cetacean sightings surveys (boat and aerial) have been concentrated in a few areas: the upper Gulf of Thailand (Phetchaburi, Samut Songkhram, Samut Sakhon, Bangkok, Samut Prakan, Chachoengsao and Chonburi Provinces); Trat Province; Chaiya Bay in Surat Thani Province; Khanom Bay in Nakhon Si Thammarat Province; Songkla Lake in Phatthalung Province; Sriboya, Cham and Pu Islands in Krabi Province; Tase village in Trang Province; and Salai Islands in Satun Province. Among the total of 25 species recorded from Thailand, only 13 species were observed during these surveys (Table 2).

Mass strandings

There were five records of mass strandings in the Andaman Sea: one case in Trang Province, two cases in Phang-nga Province and two cases in Phuket Province (Table 3, Fig. 3).

The first stranding, of nine spinner dolphins (necropsy code End 128–136), was at Talibong Island, Trang Province (99°21.7'E, 7°13.9'N), on 25 January 1999. Among the nine carcasses, six were examined and three were lost (Table 3 and Fig. 2). The six carcasses examined were all male, with body lengths of 1.77–1.90m and weights of 37 to 48kg.

Table 1

Species of cetacean recorded in Thai waters, by region. Adapted from Chantrapornsyl *et al.* (1999), Adulyanukosol *et al.* (2004; 2009), Yamada *et al.* (2006) and the PMBC database from 1993 to mid-2009. AS = Andaman Sea, GT = Gulf of Thailand, N1 = Number of stranding records, N2 = Number of skeletons at PMBC, * = sighting record.

Common name	Scientific name	AS	GT	N1	N2
Balaenopteridae					
Fin whale	<i>Balaenoptera physalus</i>	–	•	1	–
Bryde's whale	<i>Balaenoptera edeni</i>	•	•	104	12
Omura's whale	<i>Balaenoptera omurai</i>	•	•		
Humpback whale	<i>Megaptera novaeangliae</i> *	•	–	–	–
Physeteridae					
Sperm whale	<i>Physeter macrocephalus</i>	•	–	13	5
Kogiidae					
Pygmy sperm whale	<i>Kogia breviceps</i>	•	•	8	2
Dwarf sperm whale	<i>Kogia sima</i>	•	–	6	6
Ziphiidae					
Ginkgo-toothed whale	<i>Mesoplodon ginkgodens</i>	•	–	1	–
Cuvier's beaked whale	<i>Ziphius cavirostris</i>	•	–	1	1
Delphinidae					
Killer whale	<i>Orcinus orca</i>	•	•	1	–
False killer whale	<i>Pseudorca crassidens</i>	•	•	45	6
Pygmy killer whale	<i>Feresa attenuata</i>	•	•	4	2
Short-finned pilot whale	<i>Globicephala macrorhynchus</i>	•	•	2	1
Melon-headed whale	<i>Peponocephala electra</i>	–	•	2	–
Indo-Pacific humpback dolphin	<i>Sousa chinensis</i>	•	•	25	7
Indo-Pacific bottlenose dolphin	<i>Tursiops aduncus</i>	•	•	63	20
Rough-toothed dolphin	<i>Steno bredanensis</i>	•	•	8	2
Long-beaked common dolphin	<i>Delphinus capensis</i>	•	•	3	3
Spinner dolphin	<i>Stenella longirostris</i>	•	•	34	18
Striped dolphin	<i>Stenella coeruleoalba</i>	•	•	40	28
Spotted dolphin	<i>Stenella attenuata</i>	•	•	30	19
Fraser's dolphin	<i>Lagenodelphis hosei</i>	•	–	4	3
Irrawaddy dolphin	<i>Orcaella brevirostris</i>	•	•	98	11
Risso's dolphin	<i>Grampus griseus</i>	•	–	2	2
Phocoenidae					
Finless porpoise	<i>Neophocaena phocaenoides</i>	•	•	58	13
Total		23	18	553	161

Parasites were found in the stomachs while cysts were found around the genital areas in all specimens. The stomachs of all specimens were empty.

The second stranding consisted of five spotted dolphins (End 137–139) at Ban Ko Kho Khao, Phang-nga Province (98°15.1'E, 8°53.9'N), on 3 February 1999. Two dolphins were released soon after stranding and three dolphins died. The three carcasses were transferred to PMBC for necropsy. All three carcasses were male, with body lengths of 1.9–2.2m and weights of 57.5 to 81kg (Table 3). Their stomachs were empty, thus it is likely that the dolphins had been ill for some period of time before stranding (see below). However, their tissues have yet to be examined to determine the cause of stranding/death.

The third stranding consisted of eight spotted dolphins (End 403–407) at Mai Phai Island, Phang-nga Province (98°32.5'E, 8°20.0'N) on 24 March 2006. Five dolphins died while three were released. The five dead dolphins comprised three males and two females. Their body lengths ranged from 1.87–2.14m and they weighed 47.5 to 75kg (Table 3 and Fig. 2). Three of the dead dolphins appeared to be healthy. One was assumed to have died from drowning as some water was

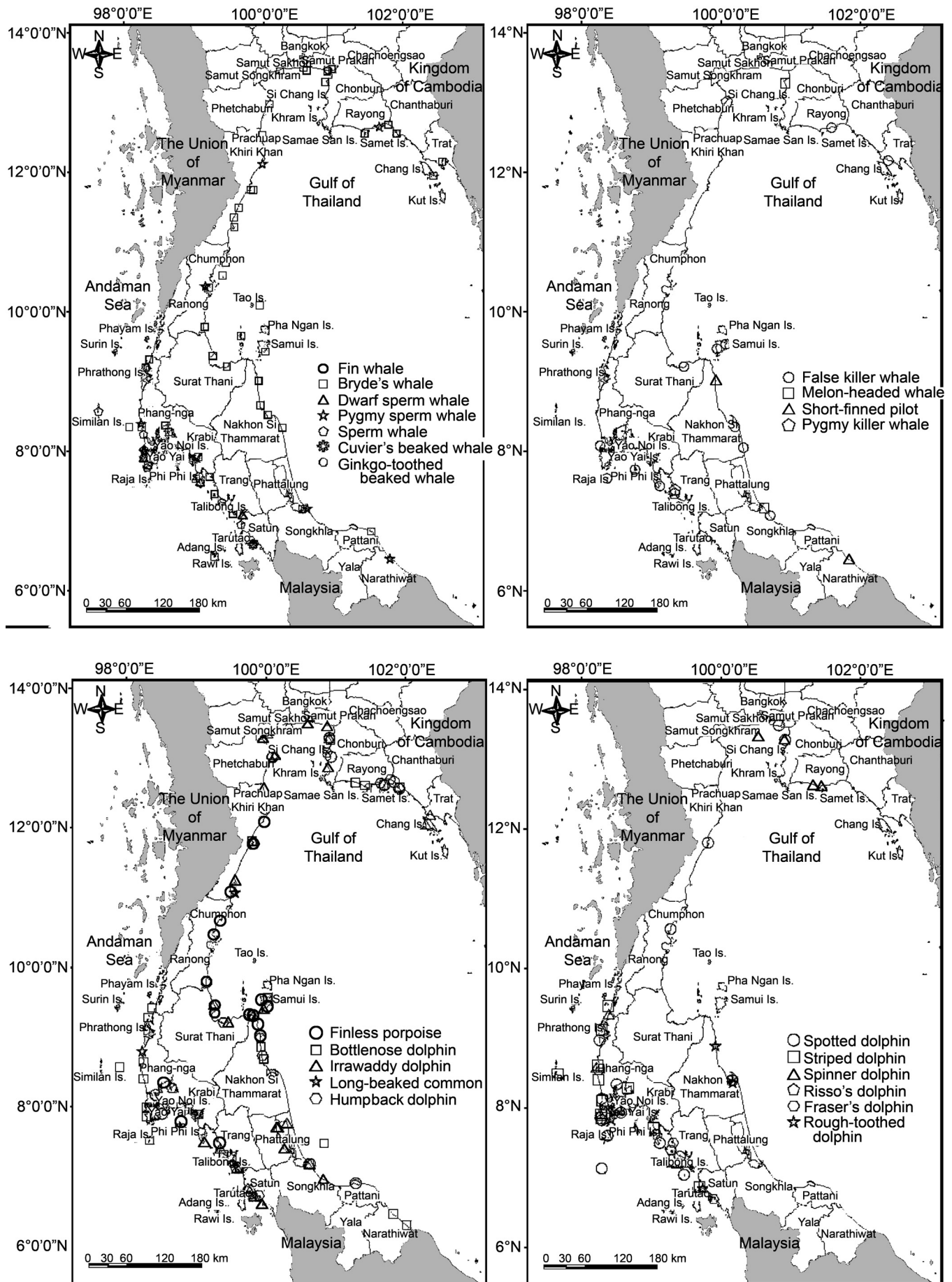


Fig. 1. Locations of cetacean strandings in Thai waters.

Table 2

Summary of records of 13 cetacean species sighted during boat and aerial surveys, including opportunistic sightings. Information collected from 1993 to mid-2009 based on Adulyanukosol *et al.* (2000; 2009); Intongcome *et al.* (2005b); Kiatkarnjanakul (1994); Ninwat *et al.* (2008); Thongsukdee and Swangrerraks (2005); database of PMBC; E. Hines (pers. comm.); A. Intongcome (pers. comm.); S. Man-anansap (pers. comm.); S. Ninwat (pers. comm.); S. Pratip Na Talang (pers. comm.); S. Thongsukdee (pers. comm.); S. Yossundara (pers. comm.)

Species	Location (province)	
	Andaman Sea	Gulf of Thailand
Bryde's whale	N of Phang-nga (2 ind.); Racha Is., Phuket (3–4 ind.); Satun (2 ind.)	Chonburi (4 ind.); Petchaburi (about 5 ind.); Prachuap Khiri Khan (1–3 ind.); Surat Thani (1 ind.); Nakhon Si Thammarat (1 ind.); Songkhla (1 ind.)
Omura's whale	Phuket (4 ind. between Racha Is. and Similan Is.)	–
Humpback whale	E of Phuket Is. (1 ind.)	–
Short-finned pilot whale	W of Phuket Is. (a pod of about 10 ind.)	–
Killer whale	Phuket and Phang-nga (8 times, pod size about 2–30 ind.)	Surat Thani (2 ind. at once)
False killer whale	Similan Is., Phang-nga (A large group of about 50 ind.)	–
Indo-Pacific humpback dolphin	N of Phang-nga (5 ind.); around Sriboya Is. and Krabi Bay, Krabi (5 ind.); Tase village, Trang (30–40 ind.); around Saria Islands, Satun (10 ind.)	Rayong to Trat (15 ind.); Samut Songkhram (5 ind.); Prachuap Khiri Khan to Surat Thani (65 ind.); Khanom Bay, Nakhon Si Thammarat (35 ind.); Sonkhla to Pattani (10 ind.)
Indo-Pacific bottlenose dolphin	N of Phang-nga (10 ind.); Yao Is., Phang-nga Bay (20 ind.); Khai Nok Is., Mai Thon Is-Hae Is, Phuket (20 ind.)	Rayong to Chathaburi (5 ind.); Samui Is, Surat Thani (6 ind.); Nakhon Si Thammarat (10 ind.); Sonkhla (5 ind.)
Spinner, striped, and pan-tropical spotted dolphins	W and S of Phuket (30–40 ind.)	–
Irrawaddy dolphin	Trang (5 ind.); Salai Is., Satun (20–25 ind.)	Trat (> 100 ind.); upper Gulf in Petchaburi, Samut Songkhram, Samut Sakhon, Bangkok, Samut Prakan, Chachoengsao and Conburi (about 100 ind.); Chumphon to Surat Thani (11 ind.); Khanom Bay, Nakhon Si Thammarat (21 ind.); Songkla Lake in Phatthalung and Sngkhla (36 ind.)
Finless porpoise	Inner part of Phang-nga Bay (10 ind.); Sriboya Is., Krabi (10 ind.); Trang (10 ind); Satun (20 ind.)	Petchaburi to Chonburi (25 ind.); Rayong to Trat (20 ind.); Prachuap Khiri Khan to Surat Thani (40 ind.); Khanom Bay, Nakhon Si Thammarat (20 ind.); Songkhla (5 ind.)

found in its respiratory system. One other had been struck by a hard object which presumably contributed to its stranding and eventual death.

The fourth mass stranding, of 30 false killer whales (End 517–527), was at Batok Bay (a small semi-enclosed bay) on Racha Yai Island, Phuket Province (98°22.0'E, 7°36.5'N, Table 3 and Fig. 3), at 16:00h on 26 June 2008. The weather at the time of stranding was stormy with rough seas. Staff and tourists from the Racha Hotel, together with local people, helped push 19 whales towards the open sea before 18:30h. It was decided that the remaining 11 whales should be moved to the more open Ter Bay, some 950m away (Figs 3a and 3b). A team from PMBC (about 22km from Racha Yai Island) arrived at 19:30h and whales were transferred

onto a truck using a backhoe and man power. The bed of the truck was lined with fabric (Figs 3c and 3d). At this stage, a veterinarian applied dexamethasone (anti-inflammatory, 1mg/kg) to relax the whales and disinfected their wounds with gentian violet. Ten whales were released at around 22:00h, with volunteers pushing their heads towards the open sea and helping them balance their bodies as they moved into deep water. By about 22:30h eight whales had been released. However, two whales swam back to the bay twice and a speedboat was used to transport them to deeper water. By the time these two whales were released, it was too dark to observe them. Nevertheless, there was no report of re-stranding. In summary, a total of 29 whales were returned to the sea, with only one death. This was the biggest mass

Table 3

Records of mass strandings in the Andaman Sea. End=field number (necropsy specimens only); n = total number of animals; M = male; F = female; BL = body length; and BW = body weight.

No.	Date	Species	Location	n	BL (m)	BW(kg)	Remarks
1	25 Jan. 1999	Spinner dolphin <i>Stenella longirostris</i> (End 128–133)	Ban Lang Khao, Talibong Is., Trang	9	1.77–1.9 (n = 6, 6M)	37–48	6 were diagnosed and 3 were lost.
2	9 Feb. 1999	Spotted dolphin <i>Stenella attenuata</i> (End 137–139)	Ban Ko Kho Khao, Phang-nga (AS)	5	1.9–2.2 (n = 3, 3M)	57.5–81	2 dolphins were released and 3 died.
3	24 Mar. 2006	Spotted dolphin <i>Stenella attenuata</i> (End 403–407)	Mai Phai Is., Phang-nga	8	1.87–2.14 (n = 5, 3M, 2F)	47.5–75	5 animals died and 3 were released.
4	26 Jun. 2008	False killer whale <i>Pseudorca crassidens</i> (End 517–527)	Batok Bay, Racha Yai Is., Phuket	30	3.52 (F) 2.6–4.2 (n = 10)	346 (End 517 only)	1 whale died, 29 whales were released.
5	5 Jul. 2008	Rough-toothed dolphin <i>Steno bredanensis</i> (End 529–531)	Nam Bor Bay, Phuket	3	2.45–2.6 (n = 3, 1M, 2F)	–	All were released.

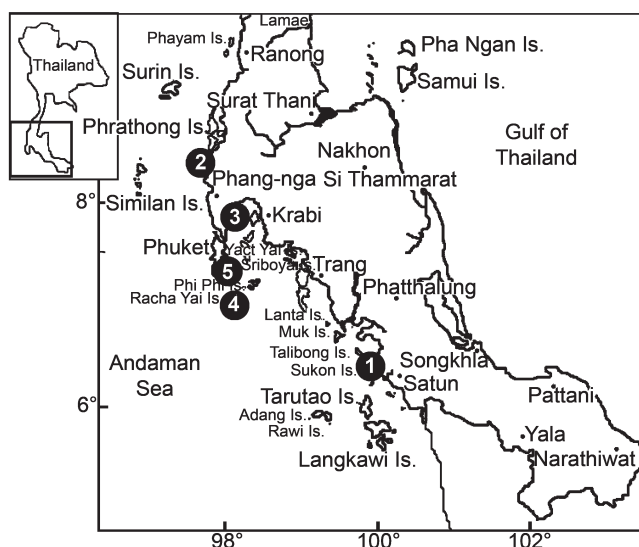


Fig. 2. Locations of the five mass strandings (black circles) in Thailand between 1993 and mid-2009. The number in each black circle corresponds to row number in Table 3.

stranding in our records in terms of the number of individuals. The body lengths of 10 whales ranged from 2.6–4.2m and they weighed approximately 300 to 400kg. The one dead female false killer whale was transferred to PMBC for a detailed examination. The head of this whale was stuck on the rocks when found. It was 3.52m long and weighed 346kg. The necropsy found no sign of diseases, but there was some water in its trachea and a small amount of sand in its

blow hole. It was concluded that this whale died from drowning.

The fifth stranding, of three rough-toothed dolphins *Steno bredanensis* (End 529–531) occurred at Nam Bor Bay, Phuket Province ($98^{\circ}24.1'E$, $7^{\circ}50.8'N$), on 5 July 2008 (Table 3; Figs 2 and 4). Local fisherman saw the dolphins at 05:00h and reported to the Center. PMBC staff arrived at the beach at 07:30h. This bay has a mangrove beach and muddy-sand sea bottom. The dolphins stranded during the low tide period at a distance of approximately 1km from the shoreline, and around 200m apart. Hollows were dug beside each dolphin to allow some sea water to flow underneath in an attempt to reduce stress. The attending veterinarian then applied anti-shock medicine to the dolphins, which were all male. The dolphins were carried to the edge of sea where they were held while waiting for the tide to rise. Later, the dolphins were transported by two speedboats and released in the open sea between Nam Bor Bay and Racha Yai Island. The release was successful; the three dolphins swam out to sea together at 10:30h. Thereafter, PMBC staff patrolled the area by speedboat for approximately 30mins to check for any re-strandings.

It was difficult to ascertain the causes of these mass strandings. The first two strandings were likely caused by diseases since the dolphins involved were thin and their stomachs empty. Some of the animals also had numerous parasites in their stomachs and cysts in their genital areas.

The three dolphins from the third record appeared to be in good health. Nonetheless, one drowned and one was struck by a hard object. Animals from the fourth and the fifth mass

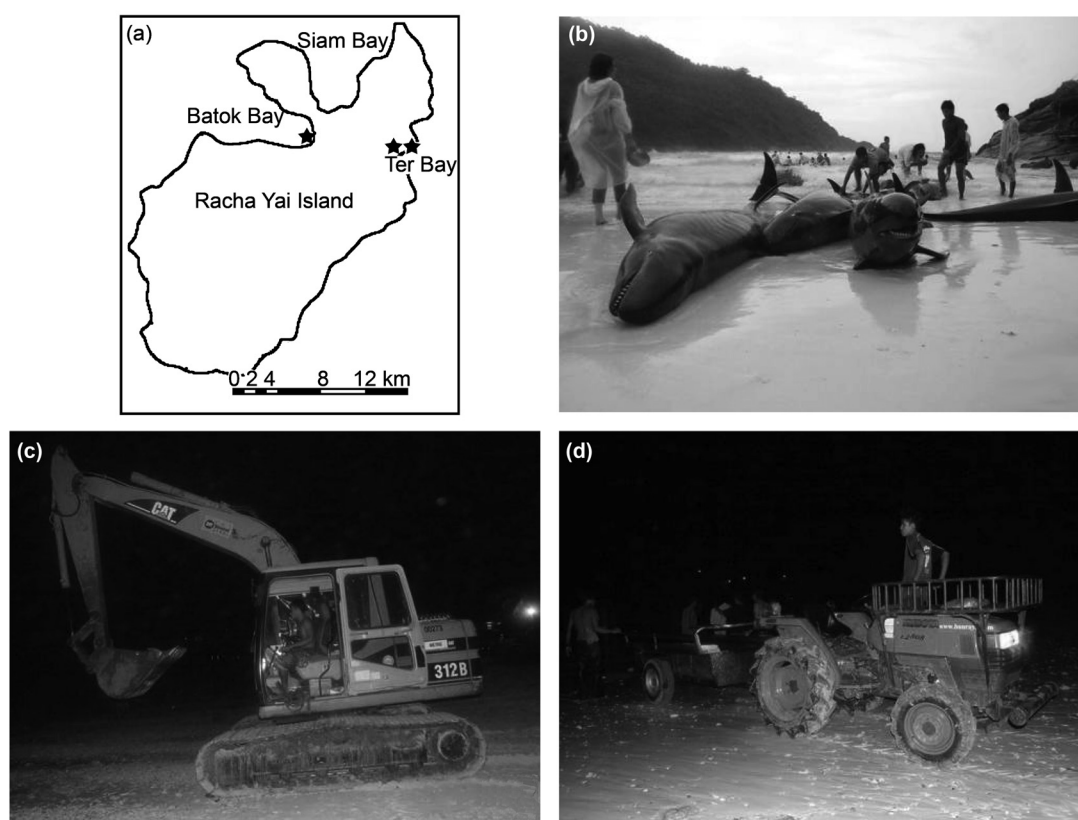


Fig. 3. (a) Map of Racha Yai Island the stranding location (showing Batok Bay) and releasing location (Ter Bay). (b) False killer whales stranded at Batok Bay. (c) A backhoe lifting stranded whales onto a truck. (d) A truck individually transferring 10 whales from Batok Bay to Ter Bay.

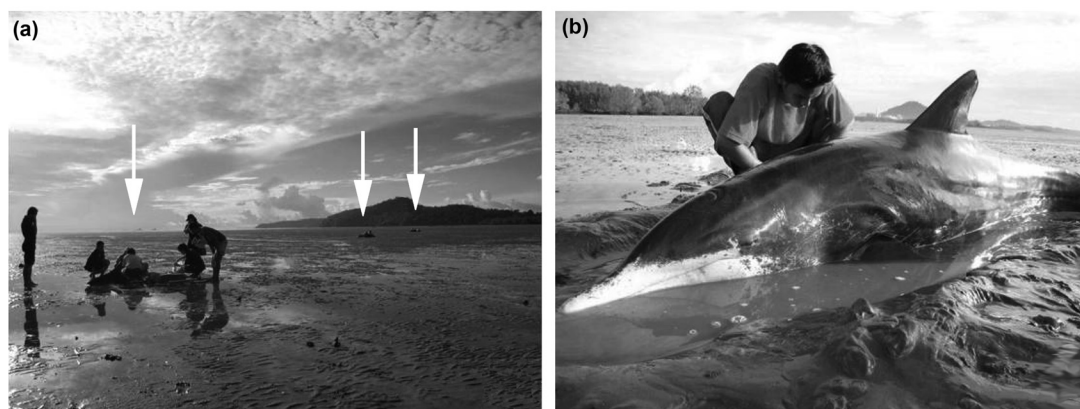


Fig. 4. (a) Three rough-toothed dolphins stranded at Nam Bor Bay, Phuket, on 5 July 2008 (arrows). (b) A hollow was dug beside the dolphin to reduce stress.

strandings also appeared to be in good health. These strandings were possibly the result of mis-navigation, especially given the topography of the stranding locations. In the case of the fourth record, 30 false killer whales swam into a small, narrow bay (Batok Bay, Racha Yai Island). The width at the mouth of the bay is 745m while its length is 925m. The whales possibly lost their way and swam into this semi-enclosed bay when sea conditions were very rough as a result of which they could not swim back to the open ocean. The 10 false killer whales transferred to Ter Bay sustained a few wounds on their bodies, but appeared generally very healthy and strong enough to be released. In the case of the fifth stranding, involving rough-toothed dolphins, Nam Bor Bay in Phuket has a length of 3.7km and a width of 2.1km. It is believed that the gently sloping beach and rapidly falling tide led to a navigational miscalculation by the dolphins causing them to be trapped in a shallow bay (Fig. 4).

In addition to these five mass stranding events, nine Irrawaddy dolphins *Orcaella brevirostris* (End 587–595) were found at Ban Bor Beach, Samut Sakhon Province (100°3.2'E, 13°3.5'N), on 25 March 2009 around noon, at low tide. The dolphins were trapped inside a man-made obstacle, a 'sand sausage', used to reduce coastal erosion. Local people helped return all the dolphins to the sea (Fig 5).

On 3 June 2009, another Irrawaddy dolphin was found stranded inside the sand bags and released. Without human intervention, all the animals would have died during low tide

because most of the area between shore and the sand bags dried out. These structures were purpose built to reduce beach erosion in the upper Gulf of Thailand, but they are clearly a problem for dolphins foraging in these areas. Solutions need to be developed to strike a balance between beach protection and safeguarding the survival of dolphin populations in the area.

CONCLUDING REMARKS

Understanding the consequences of strandings on marine mammal populations is often difficult because baseline data on the size and status of affected populations are often unavailable (Harwood, 2002). Nevertheless, in Thailand, some impacts of human activities on coastal species are evident, particularly from small-scale fisheries. Many cases of dolphin entanglements in gillnets have been documented, i.e. finless porpoises in the inner Gulf of Thailand and Irrawaddy dolphins in Songkla Lake (Ninwat *et al.*, 2008; Sirimontraporn and Sritakorn, 1995; Thongsukdee and Swangarrarak, 2005; Thongsukdee, unpub data) (Figs 6a and 6b).

Marine litter also poses problems. Two cases of cetacean deaths resulted from ingestion of or entanglement in marine litter. The first was a dwarf sperm whale in Phuket which died following ingestion of 1.6kg of plastic bags (Fig. 6c). The second was a bottlenose dolphin that was trapped in a long (45m) piece of discarded fishing net (Fig. 6d). Cetaceans are not the only marine animals affected; in

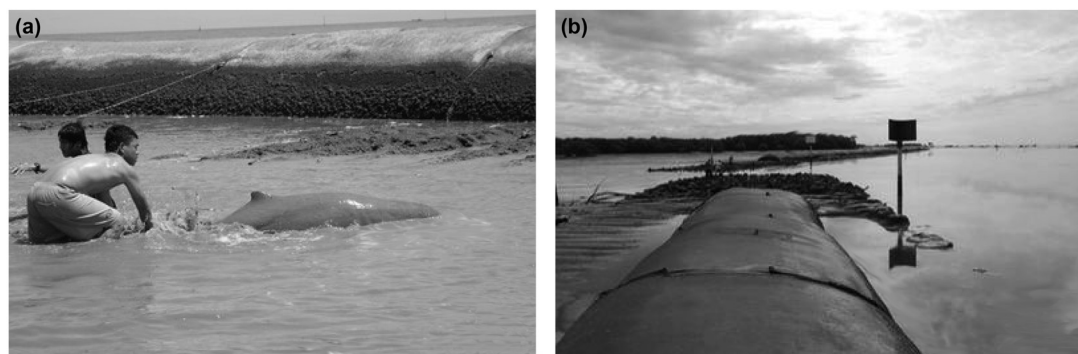


Fig. 5. Irrawaddy dolphins stranded at Ban Bor, Samut Sakhon Province, on 25 March 2009. (a) Local people trying to release the dolphins. (b) Giant sand bags protecting the beach from erosion likely trapped the dolphins during low tide. Each sand bag was about 100m in length and 4m in width with a 50m gap between the two.

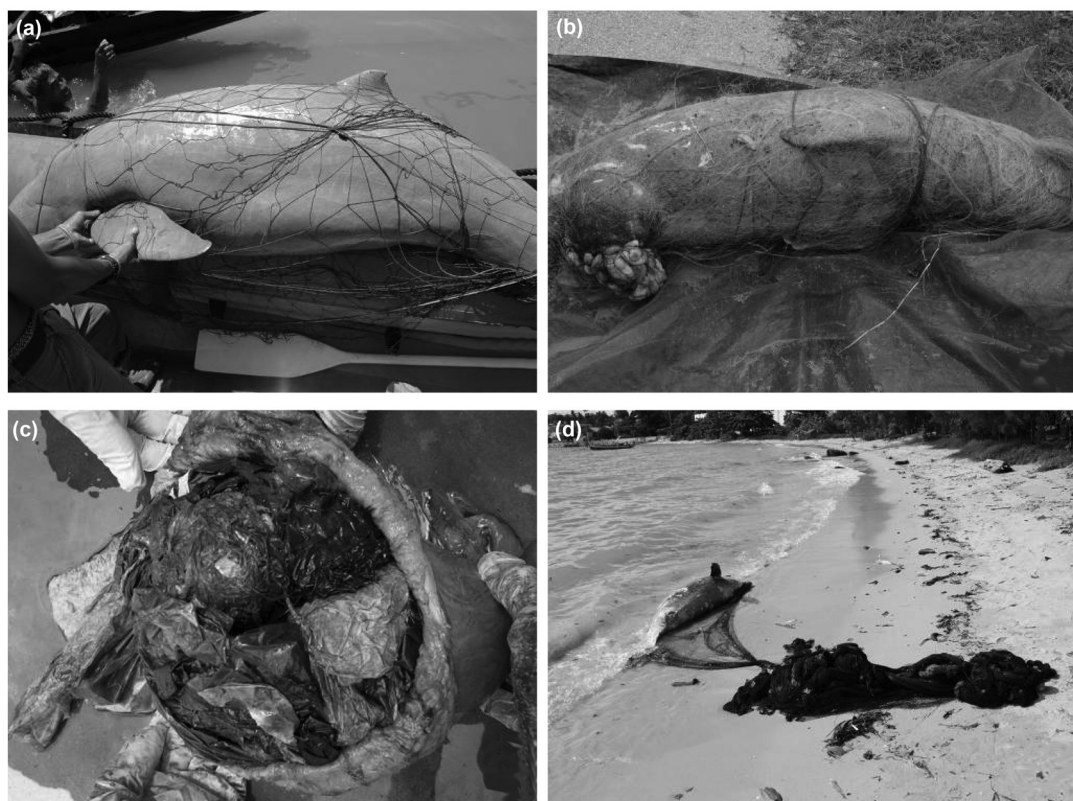


Fig. 6. Photographs illustrating some causes of cetacean death. (a) Irrawaddy dolphin in Songkhla Lake drowned by a large-mesh gillnet for catching giant catfish. (b) Irrawaddy dolphin in Songkhla Lake entangled in a small-mesh gillnet for catching sea bass. (c) Stomach of a dwarf sperm whale stranded in Phuket filled with plastic bags. (d) Bottlenose dolphin in Phuket drowned by a long piece of fishing net. [Photos (a) and (b) courtesy of Mr Santi Ninwat.]

Thailand, 26% of turtle strandings were caused by gillnets and ghost nets (Adulyanukosol and Ruangkaew, 2002).

At present there appears to be a good network for marine endangered animal stranding rescue and response along both coastlines. The DMCR has already developed protected areas for cetaceans using a ‘community based management’ approach in specific locations: (1) Irrawaddy dolphins in Bangprakong river mouth, Chachoengsao; (2) Irrawaddy dolphins in Songkhla Lake; (3) Indo-Pacific humpback dolphins in Khanom Bay, Nakhon Si Thammarat; (4) Indo-Pacific humpback dolphins and bottlenose dolphins in Tase village, Trang; and (5) Irrawaddy dolphins, Indo-Pacific humpback dolphins, and finless porpoises in Sarai Islands, Satun. The large numbers of Irrawaddy dolphins along the coast of Trat near to the Cambodia border should also be protected in a similar way. In that case it would be necessary to collaborate with Cambodia for transboundary conservation. Molecular studies are also important for species identification since some species found in Thai waters seem to be smaller than conspecifics elsewhere, e.g. dwarf spinner dolphins in the Gulf of Thailand.

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Cetaceans and cetacean research in India

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ABSTRACT

The diversity of cetacean species in Indian waters is high, with 25 species recorded so far. Records of cetaceans from India during the last 200 years have provided insights into their spatiotemporal distribution, behaviour, feeding, reproduction, fishery interaction and pollution. The cetacean fauna is dominated by pantropical species, with a relatively high abundance of spinner dolphins, which is similar to other areas studied within the northern Indian Ocean. Historical records were analysed to propose an inventory of cetaceans. Cetacean diversity was highest in the Gulf of Mannar on the southeast coast of India, which with 14 species recorded from a small area can be considered a 'hot spot' for further research. Fishery interactions, domestic consumption, pollution and lack of quality information to inform management are the main threats for successful survival of cetaceans. The status of information regarding cetaceans in India could be classified based on this study as: six species with adequate data; five species where data is restricted to a few geographic locations; four species for which data collection is being initiated; five species with sparse data; and six species which are difficult to observe.

KEYWORDS: INDIA; ARABIAN SEA; BAY OF BENGAL; HISTORICAL DATA; STRANDING; FISHERY INTERACTION; DOMESTIC CONSUMPTION; POLLUTION; DATA QUALITY; INVENTORY; FALSE KILLER WHALE; INDO-PACIFIC BOTTLENOSE DOLPHIN; INDO-PACIFIC HUMPHBACK DOLPHIN; IRRAWADDY DOLPHIN; KILLER WHALE; LONG-BEAKED COMMON DOLPHIN; MELON-HEADED WHALE; PANTROPICAL SPOTTED DOLPHIN; RISSO'S DOLPHIN; ROUGH-TOOTHED DOLPHIN; SHORT-FINNED PILOT WHALE; SPINNER DOLPHIN; STRIPED DOLPHIN; BLUE WHALE; BRYDE'S WHALE; COMMON MINKE WHALE; FIN WHALE; HUMPHBACK WHALE; SEI WHALE; SPERM WHALE; DWARF SPERM WHALE; PYGMY SPERM WHALE; BLAINVILLE'S BEAKED WHALE; CUVIER'S BEAKED WHALE; FINLESS PORPOISE

INTRODUCTION

India has one of the richest diversities of cetaceans within the International Whaling Commission's (IWC) Indian Ocean Sanctuary (IOS). Twenty six species of cetaceans (including 25 marine species and the Ganges river dolphin, *Platanista gangetica*) have been recorded. According to the IUCN¹ Red List (<http://www.iucnredlist.org>) these 26 species are catalogued as Endangered (4 species), Vulnerable (3), Near Threatened (1), Least Concern (8) and Data Deficient (10). In addition, one sirenian (the dugong, *Dugong dugon*, also Vulnerable) is recorded from Indian waters. There is ample scope for cetacean research in India, and research has indeed gained momentum since the declaration of the IOS in 1979.

Mention of cetaceans in Indian literature started as early as 246BC (Table 1), when river dolphins were protected during Emperor Asoka's reign. Current understanding of marine mammals in India developed with the establishment of European colonies and subsequent scientific collections amassed by their museums. Specimens such as skulls, skeletons, internal parasites, sketches and photographs of Indian cetaceans have been curated in various museums in UK, France and USA (Heyning and Perrin, 1994; Leatherwood, 1986). These include type specimens of finless porpoise *Neophocaena phocaenoides* (Cuvier, 1829; Amano, 2002) and dwarf sperm whale, *Kogia sima* (Owen, 1866). Owing to India's largely inland and vegetarian population, the Europeans were not keen on commercially exploiting whales in India. However, aboriginal hunting was not uncommon among island communities in Lakshadweep (Burton, 1941; Manikfan, 1991) and the Andaman and Nicobar Islands (Prater, 1928). Lack of commercial interest, expertise and dedicated research teams have severely limited

basic research on marine mammals in India (Kumaran, 2002).

Nevertheless, there were developments during Victorian times (e.g. Blyth, 1859). The real beginning of marine mammal research in India might be attributed to the collection and transportation (by sea) of a stranded blue whale, *Balaenoptera musculus*, from Mangalore in 1874 for displaying in the government museum at Madras (present Chennai). Since 1876 the skeleton of that specimen has been on display to the public. By the late 19th Century a few British naturalists showed great interest in collecting and cataloguing the flora and fauna of India. Some of those accounts remain of value even today (Blandford, 1888–91; Lydekker, 1903; 1905; Thurston, 1895). Their provisional identifications were in use in India until very recently (Kumaran, 2002), even after those nomenclatures had undergone much taxonomic revision (Perrin *et al.*, 2002; Rice, 1998).

Few species of marine mammals are protected under the Indian Wildlife Act, 1972 (Anon., 1991; Kumaran, 2002) and its subsequent amendments. While this legal protection is welcome, it does make the collection of specimens for research very difficult. Sample collection is mainly dependent on fishery catches for dolphins and porpoise, and occasional strandings for large whales.

Conservation of marine mammals in India requires reliable data on their distribution, reproduction, population characteristics, fishery interactions and pollutant levels. The need to reassess the earlier records in the light of present knowledge was reiterated during two dedicated meetings on marine and fresh water cetaceans in 1985 and 1992 respectively (Table 1). For example, an analysis of stranding records in Europe provided valuable new insights into the distribution of several species of marine mammals (Evans and Hammond, 2004). However, very limited progress has

¹ International Union for the Conservation of Nature.

Table 1
History of major developments in Indian marine mammalogy.

Date	Development	Source
246 BC	Protection of Indian river dolphins in the 'Moral Edicts of King Asoka'	Pilleri (1979)
Between 1483–1530	Reference to the Ganges River dolphins in Baburnama	Pilleri (1979)
1748	Note on two whales, one with unusual length from Pondicherry by Ananthangamramam Pillai	Moses (1947b)
Mar.–Apr. 1761	First record of sperm whale	Leatherwood (1986)
1801	First record of the Ganges River dolphin	Pilleri (1978)
1827	First record of Indo-Pacific humpback dolphin	Leatherwood (1986)
1827	First record of finless porpoise	Leatherwood (1986)
Prior to 1829	First record of long-beaked common dolphin	Blyth (1859)
1848?	First record of blue whale?	Blandford (1888–91); Moses (1947b)
Jul. 1852	First record of short-finned pilot whale first mass stranding	Blandford (1888–91)
Jul. 1852	First record of Irrawaddy dolphin	Blandford (1888–91)
28 Feb. 1853	First record of dwarf sperm whale	Owen (1866)
20 Mar. 1853	First record of Indo-Pacific bottlenose dolphin	Owen (1866)
23 Aug. 1853	First record of melon-headed whale	Leatherwood (1986)
1859?	First record of rough-toothed dolphin	Leatherwood (1986)
1866	First record of pygmy sperm whale	Blandford (1888–91)
1874	First confirmed record of blue whale	Blyth (1859)
1874	Transportation of a stranded blue whale from Mangalore to Chennai by sea	Anon. (1951)
1876	Mounting of a complete skeleton of blue whale	Anon. (1951)
1889	First record of dugong	Thurston (1895)
Prior to 1890	First record of spinner dolphin	Blandford (1888–91)
Prior to 1890	First record of spotted dolphin	Hershkovitz (1966)
14 Feb. 1901	First record of false killer whale	Ferguson (1903)
21 Mar. 1939	First record of fin whale	Moses (1940)
23 Jan. 1943	First record of humpback whale	Mathew (1948)
28 Jan. 1947	First record of sei whale	Jacob and Menon (1950)
Nov. 1935	First record of Risso's dolphin	Burton (1941)
Mar. 1943	First record of killer whale	Moses (1947a)
1949–50	Compilation of stranding records	Moses (1947b)
1950	Successful maintenance of dugongs in captivity	Jones (1959)
24 May 1961	First record of common minke whale	Silas (1964)
26 to 27 Dec. 1961	Transportation of a dugong from Rameswaram to Chennai by road covering a distance of 592km in 13.5hrs. First initiative to create awareness by displaying a live animal at the National Agricultural Fair (1962)	Thomas (1966)
14 Jan. 1971	Second mass stranding of short-finned pilot whale	Alagarwami <i>et al.</i> (1973)
1971	First publication on Eocene cetaceans from the Kachchh district, Gujarat proving archaeocetes reached Indian Ocean during Eocene time	Tandon (1971); Bajpai and Thewissen (1998)
1972	Indian Wildlife Act	Anon. (1991)
2 Jul. 1979	First record of Bryde's whale	Mohan (1992)
1979	Establishment of Indian Ocean Sanctuary by International Whaling Commission (IWC)	Leatherwood and Donovan (1991)
1981	Membership of International Whaling Commission	Donovan (2002)
10 Nov. 1982	First record of Cuvier's beaked whale	Pillai <i>et al.</i> (1981)
1984	Initiation of programme to collect information on stranded/accidental entanglement of marine mammals	Silas (1984)
12–16 Jan. 1985	First seminar on endangered marine animals and parks, Kochi	Silas (1985)
25 May 1989	First confirmed record of striped dolphin	Kumaran (2003)
4 Mar. 1991	Issue of stamps of the Ganges River dolphin and dugong	CMFRI*
18–19 Aug. 1992	Seminar on the conservation of river dolphins of the Indian sub-continent, New Delhi	Reeves <i>et al.</i> (1993)
Phase I – 2002–07 and Phase II 2008–12	First dedicated long-term project on marine mammals	CMFRI*
5 Sep. 2003	First record of Blainville's beaked whale	Said Koya (pers. comm.)

*CMFRI = Central Marine Fisheries Research Institute, Kochi, India.

been made in this direction in India (Blandford, 1888–91; James and Soundarajan, 1979; Moses, 1947b). Major gaps in the data on Indian cetaceans mean that the information available is inadequate to address questions pertaining to their conservation (Kumaran, 2002).

Despite India's large geographical extent, its high cetacean diversity, and its membership of many international conservation efforts (such as IUCN, CITES², CBD³, CMS⁴ and IWC), it has failed to develop a professional approach

to cetacean research. With no direct economic implications, India has been reluctant to pursue serious marine mammal research until recently. However, cetacean research received an impulse from 2002, when a fall in trawl catches prompted the administration to develop an ecosystem-based management strategy which requires information on top predators.

The purpose of the present study is to address two major gaps for effective conservation and management of marine cetaceans in India: (1) to review records of marine cetaceans from 1800 to 2006 in order to prepare a statewide inventory; and (2) to evaluate the current status of cetaceans in the different maritime states.

² Convention on International Trade in Wild Species of Endangered Fauna and Flora.

³ Convention on Biological Diversity.

⁴ Convention on Migratory Species.

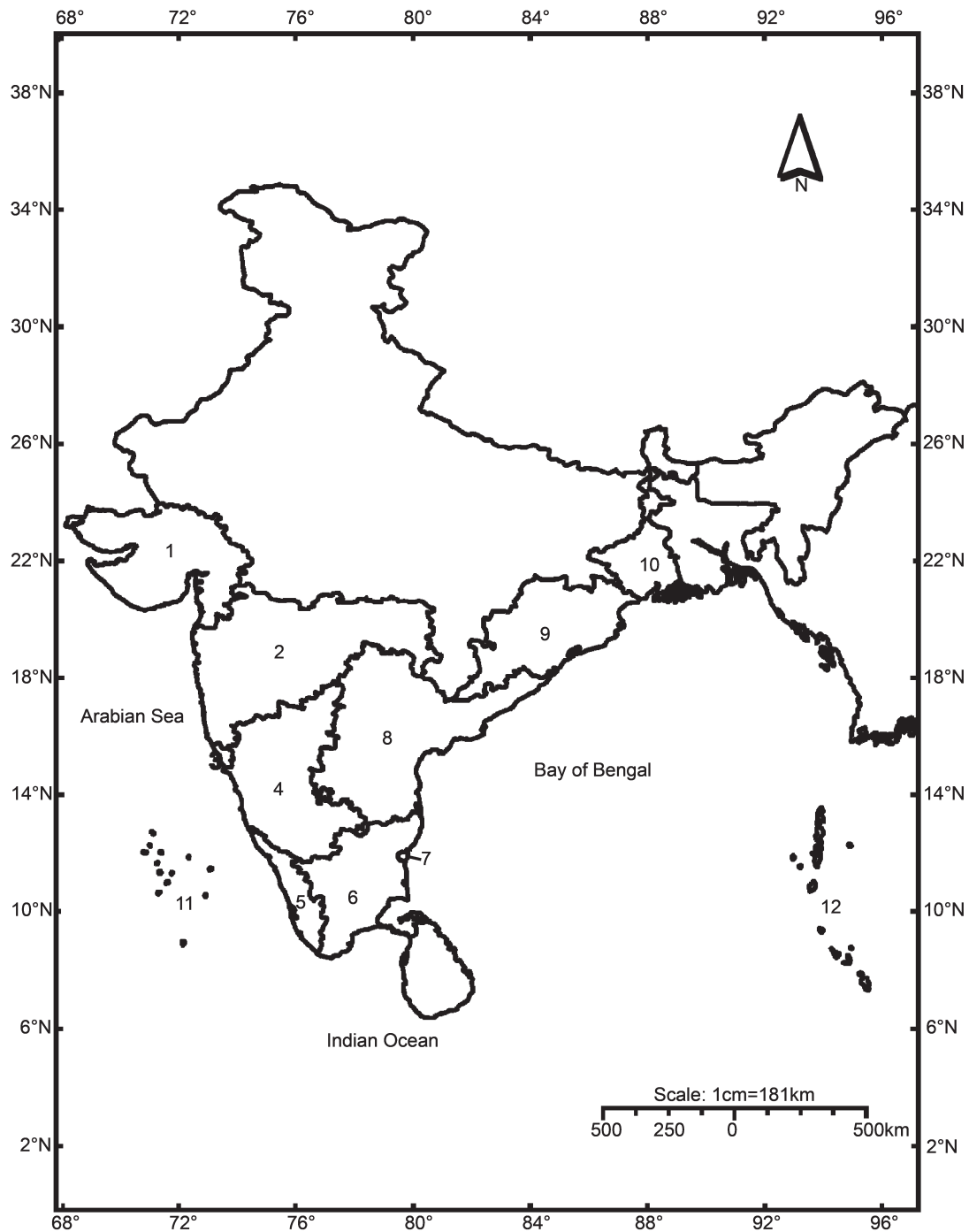


Fig. 1. India map showing the maritime states. Key: 1. Gujarat; 2. Maharashtra; 3. Goa; 4. Karnataka; 5. Kerala; 6. Tamil Nadu; 7. Pondicherry; 8. Andhra Pradesh; 9. Orissa; 10. West Bengal; 11. Lakshadweep; 12. Andaman and Nicobar Islands.

MATERIALS AND METHODS

Study area

India has a coastline of 8,129km (Fig. 1) and an EEZ of 2.02 million km². There are ten maritime states: on the west coast Gujarat (GU), Maharashtra (MA), Goa (GO), Karnataka (KA), Kerala (KE); on the east coast Tamil Nadu (TN), Pondicherry (PO), Andhra Pradesh (AP), Orissa (OR) and West Bengal (WB); and two island groups Lakshadweep (LD) in the Arabian Sea and Andaman and Nicobar Islands (A&N) in the Bay of Bengal. Although small areas of Tamil Nadu and Pondicherry are on the west coast, their administrative capitals and the bulk of their coastlines are on the east coast.

Compilation of records

Reports on the Indian marine mammals published by more than 250 authors in over 220 papers from numerous sources varying from conference abstracts to books during the years 1800 to 2006 (plus one record from 1748) were considered for this analysis. A total of 2,095 records were extracted from the literature and reliable unpublished sources. Nine major sources of cetacean records have been identified (Table 2): fishery interaction (50.2% of records); live stranding (4.4%); washed ashore dead (3.3%); sighting (29%); museum specimen (1.5%); carcass (1%); captivity (0.4%); mass live stranding (8.3%); mass mortality (1.8%); and type unknown (0.1%). Although 29% of the records were from sightings,

Table 2
Major sources of cetacean records in India (values expressed as percentage).

Species	Record sources ($n = 2,095$)										Total
	Fishery interaction (50.2%)	Stranding (44%)	Washed ashore (33%)	Sighting (29%)	Museum specimen (1.5%)	Carcass (1%)	Captivity (0.4%)	Mass stranding (8.3%)	Mass mortality (1.8%)	Type unknown (0.1%)	
Baleen whales	1.5	40	50	—	3.2	10	22.2	—	—	33.3	4.5
Sperm whale	0.6	10.9	11.4	0.2	3.2	—	—	—	—	—	1.2
Pygmy/dwarf sperm whales	0.1	3.4	—	—	6.4	—	—	—	—	—	0.3
Beaked whales	0.1	2.4	1.6	—	—	—	—	—	—	—	0.2
Dolphins	91.4	39	27	99.8	74.3	70	22.2	100	100	33.4	89.3
Porpoise	6.3	—	4.3	—	12.9	20	55.6	—	—	33.3	4.1
Unid. whales	—	4.3	5.7	—	—	—	—	—	—	—	0.4
Total	100	100	100	100	100	100	100	100	100	100	100

the specific identifications of several are questionable owing to the lack of local expertise. Only sightings from reliable sources were considered for comparative analysis.

Among the publications reviewed here, the frequencies of the major species groups considered were: dolphins (55%) > baleen whales (27.4%) > sperm whale (7.5%) > porpoise (7%) > pygmy and dwarf sperm whales (2.6%) > beaked whales (0.5%). Similarly from the total of 2,095 records, the frequencies of the major species groups recorded were: dolphins (89.3%) > baleen whales (4.5%) > porpoise (4.1%) > sperm whale (1.2%) > pygmy and dwarf sperm whales (0.3%) > beaked whales (0.2%). In addition unidentified whales accounted for 0.4% of records; however, the true percentage of unidentified animals will be more, since several unreliable records were not considered in this analysis.

Validation of records

The records considered here are pooled from different sources over a period of 200 years, and so they lack uniformity. This analysis of records does not include duplications, for example (i) in the works of different authors (e.g. Grubh and Pereira, 1965; Kharbari *et al.*, 1966; Kuthalingam *et al.*, 1982; Nammalwar and Thanapathi, 1982; Subramani, 1989; Anonymous, 1988a); (ii) of records by the same author with alterations in species name (e.g. James and Mohan, 1987; Mohan, 1992); and (iii) publication of the same record in different journals (e.g. Dhandapani, 1992; 1995; James, 1984; 1985). When the same work is published more than once (e.g. Kizhakudan, 2002; Kizhakudan and Kizhakudan, 2001), the earliest publication is considered in this study. Dubious records, such as a record including a measurement from tip of the snout to second dorsal fin (Jani and Patel, 1995) and records of deep water species inhabiting shallow waters (Singh, 2003) or vice versa (Sathasivam, 2000; 2004) are ignored. In a few cases, where journal publication was delayed, the reported (i.e. intended not actual) publication date precedes the record date.

Correct specific identification is of key importance to a review such as this. Reports were examined for accuracy of species identification based on Hershkovitz (1966), Jefferson *et al.*, (1993), Perrin *et al.*, (2002) and Rice (1998). Further, whenever possible, these records were verified with personal observations, body measurements, museum collections,

photographs, reports of DNA analysis and other related information from India and abroad.

Specimens reported in the literature as *Delphinus delphis* or *D. tropicalis* (Mohan, 1985a; Thomas, 1983) are considered here to be *D. capensis* (long-beaked common dolphin) based on DNA analysis of a fresh specimen from Andhra Pradesh (Jayasankar *et al.*, 2008). For Indo-Pacific humpback dolphins (*Sousa chinensis*), two different morphotypes have been reported from Indian waters. The animals from the west coast have a prominent hump (Mohan, 1983; Parsons, 1998; Sutaria and Jefferson, 2004), whereas forms without humps are reported from the east coast (Kasim *et al.*, 1994; Kumaran, 1989; 2002; Sutaria and Jefferson, 2004). In this study, the two morphotypes are considered to be the same species; genetic studies are underway and should help clarify the issue. Blue whales reported from India are considered as *B. musculus* for want of more detailed information on possible subspecies. The presence of fin whales (*B. physalus*) (Brownell Jr, 2009) and sei whales (*B. borealis*) (Perrin, pers. comm.) in the northern Indian Ocean has been subject to debate. It is possible that neither species occurs in this region, but until more concrete evidence becomes available the provisional identifications of fin and sei whales from Indian seas are treated as such. Details and limitations on the identification of whales used for this study were published by Kumaran (2002).

Table 3 provides an overview of the literature, by species, subject and state; in cases where species identification has been corrected here, there may be a mismatch between paper titles and assignment in the table. Forty-two keywords were extracted from the publications on Indian cetaceans.

RESULTS AND DISCUSSION

Species composition

The number of cetacean species reported was higher on the east coast with 24 (96% of the 25 species reported nationally) against 21 (84%) on the west coast. On the west coast, eight species accounted for 94.6% of the total records ($n = 1,276$): spinner dolphin (33.4%) > Indo-Pacific bottlenose dolphin (18.4%) = long-beaked common dolphin (18.4%) > finless porpoise (9.4%) > Indo-Pacific humpback dolphin (9%) > blue whale (3.3%) > Risso's dolphin (1.7%) > sperm whale (1.0%). The remaining 13 species combined accounted for 2.8% of records.

Table 3

Review of cetacean study in India. Numbers in parentheses denote the maritime states as follows; (1) Gujarat; (2) Maharashtra; (3) Goa; (4) Karnataka; Kerala; (6) Tamil Nadu; (7) Pondicherry; (8) Andhra Pradesh; (9) Orissa; (10) West Bengal; (11) Lakshadweep; (12) Andaman and Nicobar Islands; and (13) Indian EEZ.

Aspects/subjects	Sources
Blue whale Anatomy (1); capture (6); carcass (6); fishery interaction (6; 8; 5); museum collection (1); oil extraction (5); organ weights (5); osteology (1); stomach contents (1); stranding (1, 2, 3, 4, 5, 6, 10); survey (11); taxonomy (1); washed ashore (1, 2, 3, 4, 5, 6, 8)	Millard (1906); Kinnear (1915); Prater (1915); McCann (1934); Poduval (1938); Moses (1940; 1947b); Devkar (1949–50); Chari (1951); Jones (1953); Rao (1961); Daniel (1963); Nagabhushanam and Dhulkhed (1964); Grubh and Pereira (1965); Venkataraman and Girijavallabhan (1966); Kewalramani (1969); Dhawan (1970; 1972); Bensam <i>et al.</i> (1972); Nagabhushanam and Rao (1972); Karbhari (1973); James and Soundararajan (1979); Venkataramanujam <i>et al.</i> (1983); Marichamy <i>et al.</i> (1984); James and Mohan (1987); Nair and Jayaprakash (1987); Kulkarni <i>et al.</i> (1989); Nammalwar <i>et al.</i> (1989a); Kasim and Balasubramanian (1989); Mohan (1992); Nammalwar <i>et al.</i> (1992b); James <i>et al.</i> (1993); Krishnapillai <i>et al.</i> (1995); Lipton <i>et al.</i> (1995); Mohanraj <i>et al.</i> (1995); Baby (1996; 1999); Tiwari and Varu (2001); Jani (2002); Anoop <i>et al.</i> (2004b); Krishnapillai and Kingston (2004); Afsal <i>et al.</i> (2008).
Fin whale Carcass (4); fishery interaction (6); osteology (4); sighting (2); stomach contents (5); stranding (1, 2, 6); washed ashore (6).	Moses (1940); Grubh and Pereira (1965); Kharbari <i>et al.</i> (1966); Dhawan (1970; 1972); Karbhari (1973); Nammalwar <i>et al.</i> (1983); Kulkarni <i>et al.</i> (1989); Subramani, (1989); Purandhara and Naik (1992); Joel <i>et al.</i> (1996).
Sei whale Capture (5, 6); feeding (1, 5, 6); fishery interaction (1, 5, 6); oil extraction (6); traffic accident (6); skeleton (1); stomach contents (5, 6); stranding (1, 5, 6); washed ashore (1, 6)	Jacob and Menon (1950); Venkataraman <i>et al.</i> (1973); James and Soundararajan (1980); James and Mohan (1987); Anon. (1988a; 1988b); Venkataramanujam <i>et al.</i> (1988); Kasim and Balasubramanian (1989); Nammalwar <i>et al.</i> (1992b); Noble <i>et al.</i> (1992); Jani and Patel (1995); Balasubramanian (2000; 2001b); Gandhi and Kasinathan (2002); Nair <i>et al.</i> (2004).
Bryde's whale Stranding (2, 6); washed ashore (5)	Kinnear (1915); Mohan (1992); Baruah (2000); Jayasankar <i>et al.</i> (2008).
Common minke whale Attacking crew (6); captivity (8); fishery interaction (6, 8); rescue (6)	Silas (1964); Rao (1991); Kasinathan (2002a).
Humpback whale Fishery interaction (5); oil extraction (5); stranding (6); washed ashore (5)	Mathew (1948); Muthiah <i>et al.</i> (1988); Sathasivam (2002).
Sperm whale Captivity (6); capture (5, 6, 11); fishery interaction (5, 6, 11); museum collection (6); oil extraction (6); osteology (6); sighting (11, 12); skull (6); stomach contents (6); stranding (1, 6, 8, 11); washed ashore (4, 6, 7, 11); foetus (11)	Blandford (1888–91); Raja and Pai (1973); Bande <i>et al.</i> (1980); James and Manivasagam (1980); James and Soundararajan (1980; 1981); Kuthalingam <i>et al.</i> (1982); Nammalwar and Thanapathi (1982); Rao, 1983; Leatherwood (1986); Sivadas <i>et al.</i> (1987) Venkataramanujam <i>et al.</i> (1987); Nammalwar <i>et al.</i> (1992a; 2002a; 1989b); James and Panicker (1990a; 1990b); Tiwari and Varu (2001); Kasinathan and Gandhi (2002); Murugan and Khan (2003); Afsal and Rajagopalan (2007); present study.
Pygmy sperm whale Fishery interaction (8); parasites (5); stranding (5)	Blandford (1888–91); Gibson and Harris (1979); Leatherwood (1986).
Dwarf sperm whale Museum collection (8); stranding (5)	Blandford (1888–91); Leatherwood (1986).
Cuvier's beaked whale Fishery interaction (6); organ weights (6); skeleton (11); stomach contents (6); stranding (6, 11); washed ashore (6, 11)	Pillai <i>et al.</i> (1981); Kumaran (1989); present study.
Blainville's beaked whale Washed ashore (11)	Said Koya (unpublished records).
Irrawaddy dolphin Carcass (9); museum collection (8, 10); stranding (6, 10); survey (9); washed ashore (9)	Blandford (1888–91); Leatherwood (1986); James <i>et al.</i> (1989); Dhandapani (1992); Mohan (1994); Karunakaran (pers. comm.).
Killer whale Museum collection (12); stranding (1); survey (11)	Moses (1947a); Nagabhushanam and Rao (1972); Leatherwood <i>et al.</i> (1991).
Short-finned pilot whale Anatomy (6); captivity (6); fishery interaction (6); mass stranding (6, 10); museum collection (2); oil extraction (6); pollution (6); school composition (6); sighting (11); skeleton (6); stomach contents (6)	Blandford (1888–91); Leatherwood (1986); Alagaraswami <i>et al.</i> (1973); Nammalwar <i>et al.</i> (1989a).
False killer whale Age determination (5); biochemical composition (5); captivity (5, 6); capture (6); fishery interaction (5, 6, 12); monitoring (13); museum collection (1); sighting (6, 11); stomach contents (5, 12); stranding (5, 6, 12); taxonomy (5)	Ferguson (1903); Lydekker (1903); Silas and Pillay (1960); Sivaprakasam (1980); Thiagarajan <i>et al.</i> (1984); James (1984); Silas (1984); James (1985); Mohan <i>et al.</i> (1984); Mohan (1995; 1985a; 1994); Alling (1986); James and Mohan (1987); Rao <i>et al.</i> (1989); Leatherwood <i>et al.</i> (1991); Kasim <i>et al.</i> (1993); Nammalwar <i>et al.</i> (2002b).

Aspects/subjects	Sources
Melon-headed whale Fishery interaction (6); museum specimen (6, 8, 12); sighting (8)	Blandford (1888–91); Townsend (1935); Leatherwood (1986); Leatherwood <i>et al.</i> (1991); Karuppiiah <i>et al.</i> (1998).
Indo-Pacific humpback dolphin Age determination (5); captivity (5); carcass (9); fishery interaction (1, 2, 5, 6, 8); foetus (5, 6); mass mortality (6); museum collection (1, 5, 8); organ weights (6); poaching (6); pollution (6); rescue (6); skeleton (1); skull (5); sighting (1, 3, 5, 8); stomach contents (4, 6); stranding (1, 3, 6, 9); taxonomy (5); washed ashore (2, 6)	Blandford (1888–91); Sinclair (1894); Lydekker (1903; 1908); Joglekar <i>et al.</i> (1975); Mohan (1982; 1983; 1995; 1985a; 1985b); Leatherwood (1986); Anon. (1988b); Krishnapillai and Kasinathan (1988); James <i>et al.</i> (1989); Kumaran (1989); Krishnapillai <i>et al.</i> (1991); Arumugam <i>et al.</i> (1995; 1992); Tanabe <i>et al.</i> (1996; 1993); Kasim <i>et al.</i> (1994); Jayaprakash <i>et al.</i> (1995); Lipton <i>et al.</i> (1995); Jadhav and Rao (1998); Parsons (1998); Balasubramanian <i>et al.</i> (2000); Jani (2004); Sutaria and Jefferson (2004); Gandhi (2005); Anoop <i>et al.</i> (2008); present study.
Rough-toothed dolphin Fishery interaction (12); museum collection (12); washed ashore (4)	Blandford (1888–91); Leatherwood (1986); Afsal <i>et al.</i> (2008).
Risso's dolphin Aboriginal hunting (11); anatomy (6); captivity (6); capture (6); fishery interaction (5, 6, 11); sighting (6); stomach contents (6); stranding (6)	Burton (1941); Rajagopalan <i>et al.</i> (1984); Alling (1986); Thiagarajan <i>et al.</i> (1999); Balasubramanian and Easterson (2000); Thiagarajan and Krishnapillai (2000); present study.
Indo-Pacific bottlenose dolphin Aboriginal hunting (11); age determination (5); anatomy (6, 8); captivity (6); commercial exploitation (8); fish bait (8); fishery interaction (5, 6, 8, 11); foetus (5); human consumption (8); museum collection (5, 8); organ weights (6); osteology (6); pollution (6); rescue (6); sighting (6); stomach contents (4, 5, 6); stranding (5, 6); taxonomy (5); washed ashore (5, 6, 10); xenobalanus (6)	Blandford (1888–91); Ferguson (1903); Lydekker (1903; 1905; 1908); Burton (1941); Mohan (1982; 1995; 1985a); Silas <i>et al.</i> (1984); Natarajan and Rajaguru (1985); Rajaguru and Natarajan (1985); Leatherwood (1986); James and Mohan (1987); Krishnapillai and Kasinathan (1987; 1988); Rao (1998); Kumaran (1989); Kannan (1990); Rajaguru and Shantha (1992); Rao and Rao (1993); Rao and Venkataramana (1994); Jayaprakash <i>et al.</i> (1995); Kar (1996); Tanabe <i>et al.</i> (1996; 1993); Lipton <i>et al.</i> (1995); Chandrakumar (1998); Venkataramana and Achayya (1998); Thiagarajan <i>et al.</i> (1999); Joel and Ebenezer (2000); Balasubramanian (2001a); Krishnapillai (2002); Mohamed <i>et al.</i> (2006); present study.
Pantropical spotted dolphin Fishery interaction (6, 8); museum collection (13); organ weights (6); sighting (11); stomach contents (6); pollution (4)	Alling (1986); Leatherwood (1986); Sekhar <i>et al.</i> (1993); present study.
Spinner dolphin Age determination (5); anatomy (6); behaviour (5); fishery interaction (1, 5, 6, 8, 11); human consumption (11); organ weights (6); pathology (1); pollution (6); sighting (5, 11); stomach contents (1, 4, 6); skull (5); washed ashore (6); xenobalanus (6)	Blandford (1888–91); Mohan (1989; 1990; 1995; 1985a; 1985b); Natarajan and Rajaguru (1985); Rajaguru and Natarajan (1985); Alling (1986); Leatherwood (1986); James and Mohan (1987); Anon. (1988c); Kumaran (1989); Krishnapillai <i>et al.</i> (1989); Rajaguru and Shantha (1992); Rao and Rao (1992); Tanabe <i>et al.</i> (1996; 1993); Rao and Chandrashekar (1994); Velayutham <i>et al.</i> (1994); Jayaprakash <i>et al.</i> (1995); Lipton <i>et al.</i> (1995); Kizhakudan <i>et al.</i> (1998); Joel and Ebenezer (2000); Balasubramanian and Selvarani (2001); Krishnapillai (2002); Kasinathan <i>et al.</i> (2005); Anoop <i>et al.</i> (2008); Yousuf <i>et al.</i> (2010); present study.
Striped dolphin Fishery interaction (6); organ weights (6); sighting (11); stranding (1)	Kumaran (2003); Rodriguez (pers. comm.); Said Koya (pers. comm.).
Long-beaked common dolphin Age determination (5); capture (6); feeding (5); fishery interaction (2, 3, 5, 6, 8, 12); human consumption (2); parasites (6); sighting (5, 8); skull (5); stomach contents (2, 4, 6); stranding (1, 2); survey (12); washed ashore (6)	Blandford (1888–91); Balan (1961); Nagabhushanam and Rao (1969; 1972); Hamsa and Nammalwar (1978); Daniel <i>et al.</i> (1979); Sivaprakasam (1980); Silas <i>et al.</i> (1984); Mohan (1989; 1990; 1995; 1985a; 1985b); Leatherwood (1986); Krishnapillai and Kasinathan (1987); Karbhari <i>et al.</i> (1985); Pillai and Chandrangathan (1990); Jayaprakash <i>et al.</i> (1995); Krishnapillai and Lipton (1996); Jadhav and Rao (1998); Rao (1998); Thathayya and Achayya (1998); Jani (2004); Anoop <i>et al.</i> (2008).
Finless porpoise Age determination (5); capture (3); carcass (9); commercial exploitation (3); distribution (5); embryo (4); foetus (3); fishery interaction (1, 2, 3, 4, 5, 6); museum collection (2, 5); parasites (3); stomach contents (1, 4); taxonomy (5); washed ashore (4, 6); xenobalanus (4)	Blandford (1888–91); Lydekker (1908); Dawson (1959); Devaraj and Bennet (1974); Balan (1976); Thomas (1983); Hafeezullah (1984); Mohan (1995; 1985a); Leatherwood (1986); Anon. 1988a; James <i>et al.</i> (1989); Ganapathy (1992); Kumaran and Subramanian (1993); Nammalwar <i>et al.</i> (1994); Jayaprakash <i>et al.</i> (1995); Muthiah (1995); Bose (2000); Kizhakudan and Kizhakudan (2001); Kasinathan (2002b); Bose and Palanichamy (2003); Josekutty (2003); Anoop <i>et al.</i> (2004a); Anoop <i>et al.</i> (2008); present study.

On the east coast, spinner dolphins were still relatively well represented in the literature, but less frequently than on the west. On the east coast, twelve species accounted for 91.5% of records ($n = 819$): spinner dolphins (21.9%) > Indo-Pacific humpback dolphin (19.0%) > Indo-Pacific bottlenose dolphin (17.0%) > sperm whale (7.8%) > finless porpoise (6.2%) > blue whale (5.3%) > false killer whale (4.1%) > long-beaked common dolphin (3.7%) > Risso's dolphin (2.5%) > Irrawaddy dolphin (1.6%), fin whale (1.2%) = common minke whale (1.2%). The remaining nine species contributed 7.4%. The relative contribution of

unidentified baleen whales was 1.8% and 0.8% for the west and east coast respectively.

Species composition on both coasts is dominated by pantropical species, and is comparable to results from other regional studies (Anderson, 2005; Ilangakoon, 1997; Leatherwood *et al.*, 1984; Leatherwood and Reeves, 1989). The data reviewed here can only give the most crude measure of relative abundance, and so such differences, for example the occurrence of more species of beaked whales in Maldives than India (Anderson, 2005), are not unexpected. Even within the Indian EEZ, some species (such as pygmy

and dwarf sperm whales, rough-toothed dolphin, killer whales and Blainville's beaked whale) are hard to see or may occur relatively far offshore, making them less likely to strand or to be caught in coastal fisheries. They are therefore likely to be under-represented in this review. As a considerable amount of the information here comes from fishery interactions, the distribution and nature of the fishing gear used plays a major role in influencing this review. For instance, finless porpoise records are more frequent on the west coast, probably owing to the relatively high use of shore-seines in Karnataka. Shore-seine is more detrimental to finless porpoise than any other gear on the west coast of India, although as pointed out in earlier studies (Jefferson and Curry, 1994) gillnets do also take some finless porpoise (Bose, 2000; Kasinathan, 2002b; Kumaran and Subramaniam, 1993; Mohan, 1995; Nammalwar *et al.*, 1994). The apparent distributional gap for finless porpoise along the east coast probably reflects the limited extent of shore-seine operations on that coast. In contrast, the apparently greater diversity of species on the east coast might be attributed to the presence of large scale gillnet operations in the southeast of India. In that area there are as many as 520 small fishing hamlets involved in gillnet fishing (Anon., 2005a) and therefore the probability of accidentally netting different species is relatively high.

Nevertheless, the data reviewed here do reflect some genuine trends. For example, the Irrawaddy dolphin is distributed all along the east coast of India on the Bay of Bengal side with not a single record from the west coast on the Arabian Sea side. Also, sighting surveys in the Indian EEZ revealed the spinner dolphin as being the most abundant species in both the Arabian Sea and Bay of Bengal (Anon., 2007).

Based on body length data and others factors (such as the presence of foetuses, lactating mothers and un-weaned calves) it is likely that the following ten species use Indian waters as their calving/nursing grounds: blue whale, sperm whale, finless porpoise, short-finned pilot whale, spinner dolphin, pantropical spotted dolphin, Risso's dolphin, Irrawaddy dolphin, Indo-Pacific humpback dolphin and Indo-Pacific bottlenose dolphin. Accidental capture in fishing gear and other strandings of smaller sized blue whales (600, 630cm), sperm whales (366, 371cm) and Cuvier's beaked whale (234cm) support this view.

Producing an inventory

Indian states have the responsibility of implementing the Indian Wildlife Act of 1972. Historical records and recent sightings confirm that the distributional range for many cetacean species transcend the political boundaries of maritime states. Exploitation of some species may be strictly monitored or protected in a particular state but not in the adjacent state. The differences in implementation of the Wildlife Act between maritime states could be attributed to differences in their priorities. Many of the conservation programmes require a state level inventory of the floral and faunal compositions before taking specific actions. Earlier attempts at preparing an inventory of marine mammals in India were restricted in scope and never went beyond brief compilations (James and Soundarajan, 1979; Moses, 1947b). In the present study an attempt has been made to summarise the total 2,059 records

to propose an inventory by state. Inventory of cetaceans by state is a prerequisite for evolving regional action plans as there is no uniform approach towards conservation of cetaceans in India.

Publications in English (publications in regional languages are excluded) on the marine cetaceans from different states were considered when making this inventory. The numbers of publications for each state are plotted against the cumulative number of species to understand the relationship between the research efforts and species diversity (Fig. 2). The total number of publications for the Arabian Sea was 103 and the number of species recorded was 21. The number of publications from Bay of Bengal was 127 with 24 species. Assessment of published records by maritime states has clearly brought out the relationship between effort and expansion of species inventory (Figs 2a and 2b). Pondicherry recorded a single species, the sperm whale and hence is not represented in Fig. 2b. Earlier studies in most of the states were either on coastal species or on large whales. With the increased use of gillnets in the last 40 years and the development of multiday fishing there is an increase in offshore and deep water species composition (Table 1) and in the number of records.

The inventory of marine cetaceans by maritime states of India based on confirmed reports is presented in Table 4.

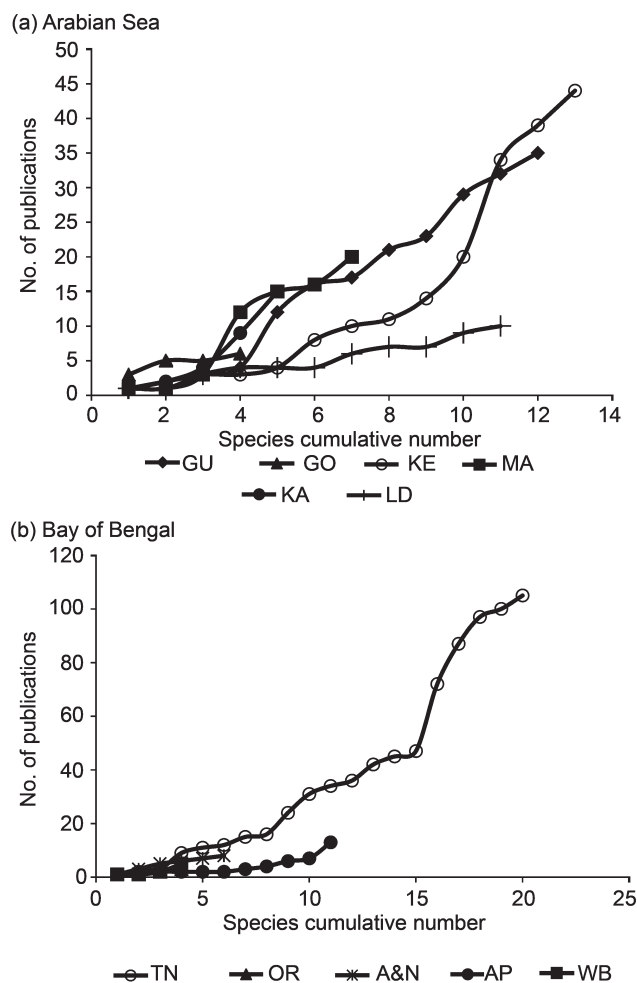


Fig. 2. Cumulative number of species for each maritime state (names mentioned in the text) is plotted against the number of publications from the respective state. (a) Arabian Sea and (b) Bay of Bengal.

Table 4

Inventory of cetaceans by maritime states in India based on the published and confirmed records. IUCN status are given in parentheses: Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC) and Data Deficient (DD).

Species	Maritime states												Indian EEZ
	GU	MA	GO	KA	KE	TN	PO	AP	OR	WB	LD	A&N	
Blue whale (EN)	•	•	•	•	•	•	–	•	–	•	•	–	–
Fin whale (EN)	•	•	•	•	•	•	–	–	–	–	–	–	–
Sei whale (EN)	•	–	–	–	•	•	–	–	–	–	–	–	–
Sperm whale (VU)	•	–	–	•	•	•	•	•	–	–	•	•	–
Irrawaddy dolphin (VU)	–	–	–	–	–	•	–	•	•	•	–	–	–
Finless porpoise (VU)	•	•	•	•	•	•	–	–	•	–	–	–	–
Indo-Pacific hump-backed dolphin (NT)	•	•	•	•	•	•	–	•	•	–	–	–	–
Cuvier's beaked whale (LC)	–	–	–	–	–	•	–	–	–	–	•	–	–
Common minke whale (LC)	–	–	–	–	–	•	–	•	–	–	–	–	–
Humpback whale (LC)	–	–	–	–	•	•	–	–	–	–	–	–	–
Melon-headed whale (LC)	–	–	–	–	–	•	–	•	–	–	–	•	–
Pantropical spotted dolphin (LC)	–	–	–	•	–	•	–	•	–	–	•	–	•
Striped dolphin (LC)	•	–	–	–	–	•	–	–	–	–	•	–	–
Rough-toothed dolphin (LC)	–	–	–	•	–	–	–	–	–	–	–	•	–
Risso's dolphin (LC)	–	–	–	–	•	•	–	–	–	–	•	–	–
Bryde's whale (DD)	–	–	–	–	•	•	–	–	–	–	–	–	–
Pygmy sperm whale (DD)	–	–	–	–	•	–	–	•	–	–	–	–	–
Dwarf sperm whale (DD)	–	–	–	–	•	–	–	•	–	–	–	–	–
Blainville's beaked whale (DD)	–	–	–	–	–	–	–	–	–	–	•	–	–
Short-finned pilot whale (DD)	–	•	–	–	–	•	–	–	–	•	•	–	–
Killer whale (DD)	•	–	–	–	–	–	–	–	–	–	•	•	–
False killer whale (DD)	•	–	–	–	•	•	–	–	–	–	•	•	•
Indo-Pacific bottlenose dolphin (DD)	–	–	–	•	•	•	–	•	–	•	•	–	–
Spinner dolphin (DD)	•	–	–	•	•	•	–	•	–	–	•	–	–
Long-beaked common dolphin (DD)	•	•	•	•	•	•	–	•	–	–	•	•	–
Total number of species	11	6	5	10	15	20	1	12	3	4	13	6	2+

Apparent gaps in species distribution are mainly due to lack of research effort, and there is much scope for improvement. The number of species recorded in a maritime state increases with the amount of research effort and subsequent publications. However, for the state of Tamil Nadu the possibility of adding new species is relatively low because already its present inventory is close to the number of known species from the northern Indian Ocean. Inventories alone are inadequate for conservation.

However, based on 47 publications and the number of species recorded (14 including dugong), a 'hot spot' for the study of marine mammals is the Gulf of Mannar, an area within Tamil Nadu state on the southeast coast between India and Sri Lanka. The number of species reported for the Gulf of Mannar is higher than any other maritime state except Kerala (14). The depth gradation is very pronounced within a limited area providing habitat for many coastal, offshore and deep water species. Furthermore this area has been declared a national 'Marine Protected Area'. Another contributing factor to the high species richness here may be the consistent effort in the region to collect data over many years, and its density of gillnet operations is among the highest in the country (Anonymous, 2005b).

Areas of research interest on Indian cetaceans

Relatively little cetacean research was published in the 19th and early 20th centuries. Most of the publications reviewed here (87%) are from after 1950. Since that date, the major contribution towards cetacean research in India has been from fishery biologists (Kumaran, 2002). The scope of their publications was generally limited to a few measurements and some photographs or figures. Although the quality of

such publications is not high, they provide much needed information on the distribution of several species along the Indian coast. Most publications are in local journals, but there have been some publications from Indian authors in international journals dedicated to marine mammal research such as *Investigations on Cetacea* (Kuthalingam *et al.*, 1982; Venkataramanujam *et al.*, 1988; 1983; 1987), *Marine Mammal Science* (Natarajan and Rajaguru, 1985), *Fishery Bulletin* (Rajaguru and Shantha, 1992), *Aquatic Mammals* (Sutaria and Jefferson, 2004) and the *Journal of Cetacean Research and Management* (Afsal *et al.*, 2008). Besides this there have been few other international publications on Indian cetaceans (Anoop *et al.*, 2008; Jayasankar *et al.*, 2008; Karuppiyah *et al.*, 2005; Tanabe *et al.*, 1996; Tanabe *et al.*, 1993; Yousuf *et al.*, 2008). When classified according to the IWC recommended list of keywords, it can be seen that research on cetaceans in India has focussed on the following nine major areas: behaviour (4.7%); environment (4.7%); exploitation (26.2%); feeding (4.7%); health (7.3%); population assessment (9.5%); stock identity (9.5%); techniques (7.3%); and reproduction (4.7%). Other subject matters contributed to 21.4%. With 'exploitation' being the topic discussed most frequently in the literature, it is worth reiterating the necessity for more detailed studies on cetaceans in Indian waters.

The number of publications and the number of species recorded are greater on the east coast than on the west coast of India. However, the west coast scores better than the east coast when it comes to the diversity of research topics studied. This may be a more meaningful measure of the value of information for management purposes than simply the total number of species recorded.

Threats

Fishery interaction

Fishery interaction is a major threat that needs immediate attention. In India, 19 species (75% of the national total) have been recorded as accidentally taken in different gears. Different species of dolphins, porpoise and small whales form a large proportion of the bycatch. The major fishing gears in India are trawl (44%) > seines (19.2%) > gillnets (18.4%) > bag nets (11%) comprising together 92.6% of the total gears (Anon., 2005a). The numbers of cetacean species recorded as entangled in these four gears are 3, 4, 14 and 1 respectively. Twelve species of cetaceans are reported as fishery bycatch without mentioning the actual gear involved. The impacts of other gear on cetaceans needs to be documented. As many as 98% of the trawls operated in India are benthic, which may be less lethal to cetaceans than pelagic trawls (Fertl and Leatherwood, 1997). Indeed only three species of cetacean are recorded as entangled in trawls in India. However, gillnets are a major threat to cetaceans. Gillnets are a popular gear with many indigenous innovations. Low operating costs and the ability to operate from different vessel types make it a favourite choice among fishermen. Gillnets support the livelihoods of the poorest fisherman, who have no access to more expensive crafts and gears. Regulating mesh sizes, let alone restricting or banning gillnets altogether, would be difficult to implement or monitor in India.

Even though 50.2% of all records in the present study are from fishery interactions, there has been little regular monitoring or mitigation studies. The few studies on the impact of fisheries on cetaceans have been from the southwest coast (Jayaprakash *et al.*, 1995; Mohan, 1985a; Pillai and Chandrangathan, 1990; Silas *et al.*, 1984), the southeast coast (Kumaran, 1989) and recently by Yousuf *et al.* (2008) from three different landing centres (one on the west coast and two on the east coast). Apart from this there are no reliable data on the species or quantity of cetaceans landed, or on the extent of utilisation of cetacean meat as baits in hook and line shark fisheries.

Domestic consumption

A few species, notably finless porpoise, have a niche market along the west coast of India. For instance observations at three different locations (Goa, Malpe in Karnataka and Trivandrum in Kerala) revealed that there is an open market for cetacean meat (Dawson, 1959; Thomas, 1983; present study). At Malpe a conservative estimate is that 2,000 cetaceans are caught per year for human consumption (present study). There is also a market for juvenile dolphins on the west coast. A dedicated study on the species composition and numbers taken for domestic consumption would bring information on consumer choice and utilisation of dolphin meat.

Pollution

The number of cetacean species studied for pollutants, and the diversity of the pollutants studied in Indian waters are reasonable when compared to other aspects of cetacean research. Tissues of spinner dolphin, pantropical spotted dolphin, long-beaked common dolphin, Indo-Pacific humpback dolphin, Indo-Pacific bottlenose dolphin, short-

finned pilot whale, Risso's dolphin and finless porpoise were studied for pollutants such as DDTs⁵, HCHs⁶, enantiomers of α -HCH, chlordane compounds, HCB⁷, PCBs⁸ and for trace metals such as Mn, Ni, Cu, Zn, Pb, Al, Cr, Fe, Co, Cd, Hg (Alagarswami *et al.*, 1973; Karuppiiah *et al.*, 2005; Prudente *et al.*, 1997; Tanabe *et al.*, 1996; Tanabe *et al.*, 1993; Velayuthum *et al.*, 1994; unpublished records). The results obtained to date are comparable to those from any developing country with no specific elevation to any particular group of chemicals. However, continuous monitoring is recommended for different pollutants for those cetaceans that are near the top of the food chain.

Lack of quality information

In India, recently, cetaceans are of interest to the media. Successful networking between the different media and the scientific community could prove useful in collecting much biological information on stranded animals when they are relatively fresh. With almost 440 television channels and hundreds of regional and national newspapers in several languages in India, most stranding events should be covered. While such reports do record many strandings, they may not recover all available information, and in particular specific identification may be unreliable. Nevertheless, such reports are frequently incorporated into regional reviews. As time passes, the secondary documents become the source of information as the older literature becomes untraceable. When the originals are not consulted it is difficult to ascertain the species identity or related information. In the case of original misidentification, the secondary sources help to establish the initial reports more firmly. A classic example is the report of a southern right whale from the northwest coast of India in 1944. Moses (1947a) originally reported this stranding, which has been included in subsequent reviews (Bensam and Menon, 1996; de Silva, 1987; James and Mohan, 1987; James and Soundarajan, 1979; Mohan, 1999; Leatherwood, 1986; Menon, 2003; Moses, 1947b; Sathasivam, 2000; 2004). This despite the fact that the identification error of Moses (1947a) was corrected, as a blue whale, by Devkar (1949–50) and the skeleton has been displayed for the public in the Baroda Museum for the past 60 years. Incidents like this continue even today. For instance a dedicated website for marine mammals of India⁹, has listed Risso's and bottlenose dolphins as finless porpoises without verifying the original source (Burton, 1941). There is no quality control to verify the publications and regrettably the Government of India's reports on issues concerning marine mammals are prepared with equal negligence. The report submitted by the Indian government to the CMS in 2008 had many errors and inconsistencies and underrepresents the ongoing research on marine mammals in India (Kumarran, 2009). The habit of citing work without verifying the original sources is a source of misinformation and thus a potential threat to cetacean conservation in India. Since joining the IWC in 1981 only one representative from India has produced peer reviewed publications on cetaceans. The

⁵ Dichlorodiphenyltrichloroethanes.

⁶ Hexachlorocyclohexanes.

⁷ Hexachlorobenzene.

⁸ Polychlorinated biphenyls.

⁹ <http://www.marinemammals.in/marine-mammal-sightings-strandings>.

need for quality research is indispensable to conserve cetaceans in Indian waters as well as to fulfil India's obligations to international treaties. This calls for sensitisation of different government agencies at both national and state levels.

CONCLUSIONS

Historical data can provide valuable insights into the abundance and diversity of cetaceans. For example, it is possible to estimate the geographical extent of a particular species within Indian waters; to aid in identifying major threats; and to highlight the quality of research required for developing and implementing effective conservation and management plans. However, this requires a certain standard of reporting, with accurate species identification being of particular importance.

The status of current knowledge of different species of cetaceans based on this study might be categorised as: (1) species where data are adequate (blue whale, sperm whale, finless porpoise, spinner, bottlenose and humpback dolphins); (2) species where data are restricted to a few geographic locations (Cuvier's beaked whale, short-finned pilot whale, striped, spotted and Irrawaddy dolphins); (3) species for which data collection is being initiated (sei whale, false killer whale, common and Risso's dolphins); (4) species for which data are sparse (melon-headed whale, humpback, minke, fin and Bryde's whales); and (5) species with less than five records in the last 50 years and therefore considered difficult to see (Blainville's beaked whale, pygmy and dwarf sperm whales, killer whale and rough toothed dolphin).

In the last few years there has been steady progress in systematic data collection on different species and this will reassign the scale for different species. Cetacean research in India in the last few years has qualitatively improved after the initiation of a long term study on marine mammals of India in 2002 (Anoop *et al.*, 2008; Jayasankar *et al.*, 2008; Kumarran, 2009; Yousuf *et al.*, 2008). Conventional approaches to the study of cetaceans in India rely heavily on the funds and infrastructure with less emphasis on data quality. National priorities for biodiversity studies cannot be adequately addressed by merely importing or modifying research methodologies from different countries. A good database on the available information is indispensable for developing suitable action plans for India.

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Obtaining distributional information on Indian Ocean cetaceans: suggestions based on an Indian network experience

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ABSTRACT

The understanding of the occurrence and distribution of cetaceans in the Indian region is largely based on information that has been incidentally obtained from strandings and bycatches. An attempt was made to compile such data systematically. The resultant database has been made widely accessible by hosting it on the internet. To improve the quality of information collected, identification aids were published on the same website. A stranding booklet was also created, mainly for the use of individuals and organisations with limited access to the internet. The 'spare capacity' of individuals and organisations was used to gather information and also to prepare the website and booklets, so that little or no expense was incurred. Recommendations are made regarding the collection of distributional data from the Indian Ocean.

KEYWORDS: INDIAN OCEAN; STRANDINGS; CONSERVATION; MONITORING

INTRODUCTION

Little is known about the distribution or populations of marine cetaceans occurring in Indian waters. India has a coastline of 7,500km, an exclusive economic zone (EEZ) of 2.3 million km² and millions of citizens rely on marine resources for their livelihoods and nutrition. Remarkably few sightings surveys have been conducted in Indian waters (Afsal *et al.*, 2008; Alling, 1986) and nearly all the information that is available has come from just a few hundred records of strandings and fisheries bycatch (James and Soundarajan, 1980; Lal Mohan, 1994; Leatherwood, 1986; Moses, 1940; 1947; Pillay, 1926; Sathasivam, 2000; 2004; Yousuf *et al.*, 2008). There is no regular national data collection scheme and the information accumulated over the past one and a half centuries can be considered scanty. The information that is available relating to the cetaceans of India is almost entirely based on incidental observations and a large number of the specimens have not been identified to the species level.

THE VALUE OF INCIDENTAL INFORMATION

The number of cetaceans stranded, cast ashore and incidentally caught along the Indian coast annually is believed to be great. Given the experiences of other countries it was thought that much information of value could be obtained from records of such specimens. For example, in Australia numerous strandings have been documented, giving considerable insights into species composition, demographics and population variability (e.g. Evans *et al.*, 2005; Kemper *et al.*, 2005). Closer by, much has been learnt from relatively modest recording programmes in the Maldives and Oman (Anderson *et al.*, 1999; Collins *et al.*, 2002).

In India, even a basic record of stranding location, date and species would be very useful. Additional information on sex, whether juvenile or adult, condition and obvious causes,

if any, of stranding or death might also be collected relatively easily. If these data were collected systematically, then over time the resulting database would be sufficiently large to provide a useful reflection of the status of cetaceans in the Indian seas. The species diversity, demographic constitution, spatial distributional patterns, temporal variations including migrations, causes of mortality and population trends might all be inferred in due course. These are essential for understanding the conservation requirements of these animals. A database was developed guided by the following criteria:

- (1) easily available to all interested parties;
- (2) would be a collaborative effort by those who made the observations;
- (3) created in conjunction with efforts to increase awareness about cetacean identification, diversity, abundance and habitats. This would ensure that the data collected were of the best scientific quality possible. It would also reduce the proportion of unidentified records;
- (4) provide as much detail as available, including photographs.

With assistance from the Whale and Dolphin Conservation Society (WDCS, UK), the Indian Marine Mammal Conservation Network (IMMCN) was established in 2008, creating a website (<http://www.marinemammals.in>) which incorporated the database described above.

SPARE CAPACITY

Marine mammal science is typically expensive and laborious to pursue. This hurdle can be overcome by using 'spare capacity' to collect information, at little or no expense. Essentially, spare capacity refers to the opportunities, manpower and facilities available to individuals and existing organisations through their infrastructure and regular

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activities. This idea has been described more fully elsewhere (Sathasivam and Natarajan, In press); in the present context the spare capacity available for studying cetaceans is referred to.

It is intended that the IMMCN will grow through the spare capacity and voluntary efforts of those individuals and organisations in India involved with the marine environment. Many already possess diverse data on marine mammals (cetaceans and the dugong) and some could gather more in the course of their work and contribute it to the community at large, particularly to an open-access data storage and distribution system such as the IMMCN. These individuals and groups include members of fishing communities, defence and law enforcement agencies, the media, naturalists and conservationists. They are well placed to acquire data on marine mammals in the course of their daily activities.

One of the important aspects of the IMMCN is that it is web-based. The internet is widely accessible and India has a very large and rapidly growing online population (<http://www.internetworldstats.com/stats3.htm#asia>). Not only does the IMMCN rely on spare capacity for gathering data, it also used it in creating its own website: many of the website's pages were created through the voluntary effort of cetacean enthusiasts.

However, reaching out to communities who do not have internet access is a challenge. With this in mind, a printable stranding booklet has been created for distribution to such groups through organisations and individuals who work with them (also available from 'Dealing with a Stranding' in the website). It is anticipated that these organisations and individuals have a key role. Voluntary effort, or spare capacity, was again used in translating the stranding booklet. India is a multilingual country and there are many languages used along the coast. A particular cetacean species has a different name in each language. Thus the booklet needs to be produced in each of these languages. Members of the IMMCN have translated the booklet into Tamil and Gujarati, two of the most widely used languages of the coastline. Another member has undertaken to translate it into Bengali.

RECOMMENDATIONS

There are many outstanding questions relating to the taxonomic diversity, distribution and migratory movements of cetaceans within the Indian Ocean, as highlighted by papers in this issue of the *Journal of Cetacean Research and Management*. Even as more rigorous scientific surveys are undertaken, the collection of incidental data still has a significant role, particularly when performed at minimal expense. The following guidance should be given to all national and local efforts to collect distributional information on cetaceans in the Indian Ocean.

(1) The internet can be used not only to receive and display records, but also to disseminate information. This will permit easy information exchange in the region. An electronic mail discussion group linking cetologists across the region would serve as a single point where the answers for all technical questions could be obtained. The IMMCN has such a forum; the *marinemammalsofindia* Yahoo group.

- (2) The value of national and local networks will depend to a large extent on the reliability of the data they accumulate. Accurate species identification is critical. The provision of identification aids as on the website and in the stranding booklet of the IMMCN; the ability to store all available information, including photos, on the database; and the periodic scientific scrutiny of all records are all important.
- (3) Low-cost solutions are required because of the limited availability of financial resources. The use of spare capacity, such as 'platforms of opportunity' for offshore surveys is encouraged (Perera and Ilankoon, 2009; Rowat, 2009). The regular ferry services to the Lakshadweep and Andaman Islands are examples of such platforms. In the same vein, when necropsies are performed regularly on stranded cetaceans, samples could be sent, for instance for molecular analyses, to existing facilities in India or a nation in the region rather than creating new institutions or sending the samples farther away.
- (4) Innovative solutions should be sought for any problems encountered rather than following the usual protocols.

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A review of cetacean research and conservation in Sri Lanka

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ABSTRACT

Sri Lanka is a developing island nation in the northern Indian Ocean. Travellers and historians have documented whales in the waters around the island as far back as the 14th century but the first scientific records of live cetaceans from vessel-based research observations were documented only in the early 1980s. Sri Lanka's waters have high cetacean species richness with 27 species recorded to date and year-round abundance. Small cetaceans are however increasingly threatened due to the developing fisheries industry, with bycatch being a major cause for concern. Other identified threats include increasing shipping traffic and unregulated marine tourism. Cetaceans are protected by national legislation but implementation of the relevant laws and conservation measures is hampered by resource constraints. The prevailing gaps in knowledge are also due to a lack of resources to carry out dedicated long-term research on cetaceans in a developing country with more immediate human development priorities. Therefore strengthened law enforcement and finding adequate resources for sustained systematic research that can inform management decisions are priorities in Sri Lanka.

KEYWORDS: CONSERVATION; INDIAN OCEAN; INCIDENTAL CATCHES; SPERM WHALE; BLUE WHALE; BLAINVILLE'S BEAKED WHALE; INDO-PACIFIC HUMPBAC DOLPHIN; SPINNER DOLPHIN; COMMON BOTTLENOSE DOLPHIN; RISSO'S DOLPHIN; PANTROPICAL SPOTTED DOLPHIN; FRASER'S DOLPHIN; ROUGH-TOOTHED DOLPHIN; SHORT-FINNED PILOT WHALE; FALSE KILLER WHALE; PYGMY KILLER WHALE; KILLER WHALE; MELON-HEADED WHALE; COMMON DOLPHIN; CUVIER'S BEAKED WHALE; BLAINVILLE'S BEAKED WHALE; GINKGO-TOOTHED BEAKED WHALE; LONGMAN'S BEAKED WHALE; SOUTHERN BOTTLENOSE WHALE; PYGMY SPERM WHALE; DWARF SPERM WHALE; FIN WHALE; COMMON MINKE WHALE; HUMPBAC WHALE; BRYDE'S WHALE

INTRODUCTION

Sri Lanka (5°–9°N, 79°–81°E) is a developing island nation in the northern Indian Ocean (Fig. 1) with a long tradition of fisheries around her shores. Travellers and historians have referred to whales around Sri Lanka (previously referred to as Serendib, Taprobane or Ceylon) as far back as the 14th century (Tennant, 1859). Records of stranded whales and museum specimens were first reported from the 1850s (Blyth, 1859; Deraniyagala, 1945; 1960; Fernando, 1912; Kelaart, 1852) and interactions between cetaceans and fisheries from the 1880s (Lantz and Gunasekera, 1955; Nevill, 1887). Scientific records of live cetaceans were not documented until as recently as the early 1980s and present knowledge remains limited due to a lack of dedicated research.

After the International Whaling Commission (IWC) established the Indian Ocean Sanctuary in 1979, cetaceans and cetacean research in Sri Lanka became an area of focus both nationally and internationally (Ilangakoon, 2002; Leatherwood and Reeves, 1989). Further impetus was added with the convening of the first Symposium on Indian Ocean Marine Mammals, held in Colombo in 1983. In the early 1980s, the World Wildlife Fund sponsored 'Tulip Expedition' studied sperm whales (*Physeter macrocephalus*) in the waters around Sri Lanka and brought the occurrence of large numbers of sperm whales and blue whales (*Balaenoptera musculus*) close to land in northeastern waters to the attention of cetacean researchers around the world (Alling *et al.*, 1991; Whitehead, 1989; Whitehead *et al.*, 1983). Consequently, the first national marine mammal research programme in Sri Lanka was initiated by the National Aquatic Resources Research and Development Agency (NARA) in 1984. The initial focus of that programme was on large whales, but early efforts indicated that Sri Lanka was a 'hotspot' in terms of diversity and abundance of cetaceans in general. Soon the

scope of the programme expanded to include small cetaceans, as the threat posed by incidental bycatch in fishing gear was recognised early in the project. With this awareness, a further multi-pronged national research programme was initiated in 1985 with funding from the United Nations Environment Programme (UNEP). These national efforts continued for the next decade and since the mid-1990s individual researchers and international Non-Governmental Organisation (NGO) funded projects have continued sporadic research in Sri Lankan waters. Much of what is known about cetaceans around Sri Lanka today is a result of these varied projects and research efforts (Ilangakoon, 1989; 1997; 2002; 2006c; 2009; Ilangakoon *et al.*, 2000a; Ilangakoon and Perera, 2009; Ilangakoon *et al.*, 2000b; Leatherwood and Reeves, 1989; Ocean Alliance, 2003).

This paper summarises the current state of knowledge on cetaceans in Sri Lankan waters, focuses attention on current and potential threats, and highlights future research and conservation priorities.

RESULTS AND DISCUSSION

Three decades of research, even though sporadic and discontinuous, has resulted in the collection of some valuable information on cetaceans around Sri Lanka. It has also resulted in a small but growing national consciousness about an important aspect of marine biodiversity that was largely unknown before. The present state of knowledge can be examined in relation to what is known about cetaceans in these waters, the threats they face, legal aspects, conservation, research, information gaps and future priorities.

Species diversity and relative abundance

The waters off Sri Lanka are inhabited by a rich diversity of cetaceans, with apparent year-round abundance (Ilangakoon,

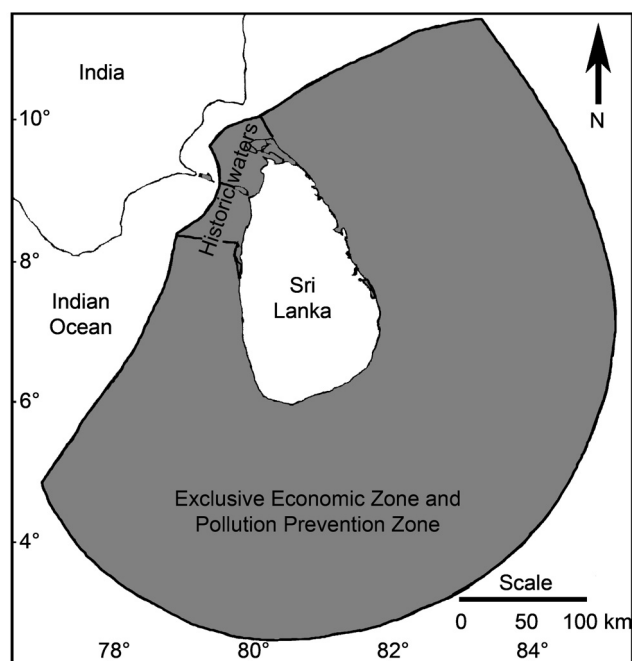


Fig. 1. Location map of Sri Lanka and surrounding waters.

1997; 2002; 2006a; 2006c; Ilangakoon *et al.*, 2000b; Leatherwood and Reeves, 1989). Based on current taxonomy 27 species of cetaceans under the two sub-orders Mysticeti and Odontoceti and placed within the six families of *Balaenopteridae*, *Physeteridae*, *Kogiidae*, *Ziphiidae*, *Delphinidae* and *Phocoenidae* have been recorded from the

waters around the island (Table 1). This species list is based on specimens obtained from strandings on the coastline (Deraniyagala, 1945; Deraniyagala, 1948; Deraniyagala, 1960; 1965; Ilangakoon, 2002; 2006c; Leatherwood and Reeves, 1989; Pearson, 1931), specimens from the fisheries bycatch and direct take (Dayaratne and Joseph, 1993; Ilangakoon, 1989; 1997; 2002; Ilangakoon *et al.*, 2000a; Ilangakoon *et al.*, 2000b; Leatherwood, 1990; Leatherwood and Reeves, 1989; Prematunga *et al.*, 1985) and sightings from offshore surveys (Afsal *et al.*, 2008; Alling, 1986; Alling *et al.*, 1991; Ballance and Pitman, 1998; Ilangakoon, 2002; 2005; 2006a; 2009; Ilangakoon *et al.*, 2000a; Leatherwood *et al.*, 1984; Leatherwood and Reeves, 1989; Ocean Alliance, 2003). It is likely that this species list is still incomplete, as dedicated research has been limited and new species continue to be added. One such example is the addition of Blainville's beaked whale (*Mesoplodon densirostris*) in 2002, based on a specimen identified in fisheries bycatch (Ilangakoon, 2002; 2003).

The continental shelf around Sri Lanka, except in the north and northwest, is relatively narrow, with deep waters being found quite close to the shore around most of the island's coastline (Wijeyananda, 1997). Cetaceans are distributed all around the island. Although no specific abundance estimates have yet been made for any species, bycatch studies (Dayaratne and Joseph, 1993; Ilangakoon, 1989; 1997; Ilangakoon *et al.*, 2000b; Leatherwood and Reeves, 1989) and limited vessel surveys (Afsal *et al.*, 2008; Bröker and Ilangakoon, 2008; Ilangakoon, 2002; 2005; 2006a; 2006c; 2009; Ilangakoon and Perera, 2009) demonstrate that the

Table 1
Cetacean species recorded in Sri Lankan waters.

Species	Based on			Key references
	Si	St	Ca	
Blue whale (<i>Balaenoptera musculus</i>)	X	X	–	Deraniyagala (1948); Leatherwood and Reeves (1989); Ilangakoon (2002)
Fin whale* (<i>Balaenoptera physalus</i>)	–	?	X	Deraniyagala (1965); Leatherwood and Reeves (1989)
Bryde's whale* (<i>Balaenoptera brydei/edeni</i>)	X	X	–	Leatherwood and Reeves (1989); Ilangakoon (2002); Herath (2007)
Minke whale (<i>Balaenoptera acutorostrata</i>)	X	X	–	Deraniyagala (1963); Leatherwood and Reeves (1989); Ilangakoon (2002)
Humpback whale (<i>Megaptera novaeangliae</i>)	X	X	–	Deraniyagala (1965); Leatherwood and Reeves (1989); Ilangakoon (2002)
Sperm whale (<i>Physeter macrocephalus</i>)	X	X	X	Deraniyagala (1965); Leatherwood and Reeves (1989); Ilangakoon (2002)
Pygmy sperm whale (<i>Kogia breviceps</i>)	–	X	X	Pearson (1931); Leatherwood and Reeves (1989); Ilangakoon (2002)
Dwarf sperm whale (<i>Kogia sima</i>)	X	X	X	Leatherwood and Reeves (1989); Ilangakoon (2002; 2006b)
Spinner dolphin (<i>Stenella longirostris</i>)	X	X	X	Phillips (1935); Leatherwood and Reeves (1989); Ilangakoon (2002)
Pantropical spotted dolphin (<i>Stenella attenuata</i>)	X	–	X	Alling (1986); Leatherwood and Reeves (1989); Ilangakoon (2002)
Striped dolphin (<i>Stenella coerulescens</i>)	X	–	X	Alling (1986); Leatherwood and Reeves (1989); Ilangakoon (2002)
Common bottlenose dolphin (<i>Tursiops truncatus</i>)	X	X	X	Phillips (1935); Leatherwood and Reeves (1989); Ilangakoon (2002)
Indo-Pacific hump-backed dolphin (<i>Sousa chinensis</i>)	X	X	X	Deraniyagala (1945); Ilangakoon (2005; 2006b)
Rough-toothed dolphin (<i>Steno bredanensis</i>)	X	–	X	Leatherwood and Reeves (1989); Ilangakoon (2002)
Common dolphin* (<i>Delphinus capensis</i>)	–	–	X	Alling (1986); Leatherwood and Reeves (1989); Ilangakoon (2002)
Fraser's dolphin (<i>Lagenodelphis hosei</i>)	X	–	X	Leatherwood and Reeves (1989); Ilangakoon (2002)
Risso's dolphin (<i>Grampus griseus</i>)	X	–	X	Alling (1986); Leatherwood and Reeves (1989); Ilangakoon (2002)
Short-finned pilot whale (<i>Globicephala macrorhynchus</i>)	X	X	X	Alling (1986); Leatherwood and Reeves (1989); Ilangakoon (2002)
Melon-headed whale (<i>Peponocephala electra</i>)	X	–	X	Leatherwood and Reeves (1989); Ilangakoon (2002; 2005; 2006b)
Pygmy killer whale (<i>Feresa attenuata</i>)	X	–	X	Leatherwood and Reeves (1989); Ilangakoon (2002; 2009)
False killer whale (<i>Pseudorca crassidens</i>)	X	X	X	Pearson (1931); Leatherwood and Reeves (1989); Ilangakoon (2002; 2009)
Killer whale (<i>Orcinus orca</i>)	X	–	X	Ilangakoon <i>et al.</i> (1992); Leatherwood and Reeves (1989); Ilangakoon <i>et al.</i> (2010)
Cuvier's beaked whale (<i>Ziphius cavirostris</i>)	X	X	X	Deraniyagala (1965); Alling (1986)
Ginkgo-toothed beaked whale (<i>Mesoplodon ginkgodens</i>)	–	X	–	Deraniyagala (1965); Moore and Gilmore (1965)
Blainville's beaked whale (<i>Mesoplodon densirostris</i>)	–	X	X	Ilangakoon (2003; 2006a)
Longman's beaked whale (<i>Indopacetus pacificus</i>)	X	X	X	Pitman <i>et al.</i> (1999); Anderson <i>et al.</i> (2006); Afsal <i>et al.</i> (2009)
Finless porpoise* (<i>Neophocaena phocaenoides</i>)	?	–	X	Phillips (1935); Leatherwood and Reeves (1989)

Notes: Si = sightings; St = strandings; and Ca = catch.

Species in relation to which there are uncertainties, revisions and clarifications in the main text are marked with an * in this table.

spinner dolphin (*Stenella longirostris*) is by far the most common species around the island. This species appears to be evenly distributed throughout both coastal and offshore waters. Other commonly encountered species of small cetaceans include the common bottlenose dolphin (*Tursiops truncatus*) and Risso's dolphin (*Grampus griseus*) (Alling, 1986; Ilangakoon, 1989; 1997; 2006a; 2006c; Ilangakoon and Perera, 2009; Ilangakoon *et al.*, 2000b; Kruse *et al.*, 1991).

A small population of Indo-Pacific humpback dolphins (*Sousa chinensis*) was identified in nearshore waters centered on the Puttalam lagoon in the northwest of Sri Lanka as recently as 2004 (Bröker and Ilangakoon, 2008; Ilangakoon, 2005; 2006a; 2006c). Although a museum specimen of a skull of this species from Mannar further to the north (Blanford, 1891) and a probable sighting in Dutch Bay during an aerial survey in the early 1980s (Leatherwood *et al.*, 1984) existed, it remained unconfirmed until regular sightings were made during cetacean surveys in 2004/05. Other small delphinids recorded as sightings (Alling, 1986; Ilangakoon, 2002; Leatherwood and Reeves, 1989; Ocean Alliance, 2003) and/or bycatch (Dayaratne and Joseph, 1993; Ilangakoon, 1989; 1997; 2002; Ilangakoon *et al.*, 2000b; Leatherwood and Reeves, 1989; Prematunga *et al.*, 1985) from around Sri Lanka include pan-tropical spotted dolphin (*S. attenuata*), striped dolphin (*S. coeruleoalba*), rough-toothed dolphin (*Steno bredanensis*), Fraser's dolphin (*Lagenodelphis hosei*) and common dolphin (*Delphinus capensis*). The original records of bycaught specimens of common dolphin were thought to be *D. delphis* are listed as such in the literature, based on knowledge available at the time (Dayaratne and Joseph, 1993; Ilangakoon, 1997; 2002; Leatherwood and Reeves, 1989). However, following the review of Jefferson and Van Waerebeek, (2002) it is more likely that these are *D. capensis tropicalis*.

Five species commonly referred to as 'Blackfish' have been recorded in Sri Lanka's waters, but none appears to be common. Short-finned pilot whale (*Globicephala macrorhynchus*), false killer whale (*Pseudorca crassidens*), pygmy killer whale (*Feresa attenuata*), melon-headed whale (*Peponocephala electra*) and killer whale (*Orcinus orca*) have been recorded as bycatch around the island (Ilangakoon, 1997; 2002; Ilangakoon *et al.*, 2000b; Ilangakoon *et al.*, 1992; Leatherwood *et al.*, 1991; Leatherwood and Reeves, 1989). Most sightings of these species around Sri Lanka have been in continental shelf waters that are not very deep (Bröker and Ilangakoon, 2008; Ilangakoon, 2002; 2005; 2006a; 2009; Ilangakoon *et al.*, 2010) though these are all species that are thought to be usually more common in pelagic waters.

Four species of Ziphiid have been recorded in strandings and bycatch (Dayaratne and Joseph, 1993; Deraniyagala, 1965; Ilangakoon, 2002; 2003; Leatherwood and Reeves, 1989) but sightings (Alling, 1986) are rare. The four species recorded are Cuvier's beaked whale (*Ziphius cavirostris*), Blainville's beaked whale (*M. densirostris*), ginkgo-toothed beaked whale (*M. ginkgodens*) and Longman's beaked whale (*Indopacetus pacificus*). Specimens of the latter species had earlier been referred to as southern bottlenose whales (*Hyperoodon planifrons*) (Alling, 1986; Dayaratne and Joseph, 1993; Ilangakoon, 2002). However, following the studies of Pitman *et al.* (1999) and Dalebout *et al.* (2003),

Anderson *et al.* (2006) referred the Sri Lankan specimens to Longman's beaked whale. Subsequently there has been a confirmed sighting of this species reported from southeast of Sri Lanka by Afsal *et al.* (2009).

Both the pygmy sperm whale (*Kogia breviceps*) and dwarf sperm whale (*K. sima*) have been recorded in low numbers (Bröker and Ilangakoon, 2008; Chantrapornsyl *et al.*, 1991; Deraniyagala, 1960; Ilangakoon, 1989; 1997; 2002; 2005; 2006a; 2006c; Ilangakoon *et al.*, 2000b; Leatherwood and Reeves, 1989; Pearson, 1931) around Sri Lanka.

Among the larger cetaceans, the sperm whale is one of the most commonly encountered and widely distributed in Sri Lankan waters. In the 1980s sperm whales were recorded as being abundant in the waters off the northeast coast, especially in association with the Trincomalee canyon, where very deep water occurs close to the coast (Gordon, 1991; Leatherwood *et al.*, 1984; Whitehead *et al.*, 1983). Subsequent surveys off the south, southeast, west and northwest of Sri Lanka have also regularly sighted this species (Ilangakoon, 2002; 2006a; 2009; Ilangakoon *et al.*, 2000b; Leatherwood and Reeves, 1989; Ocean Alliance, 2003). Sperm whale strandings are also documented from all coastal areas (Deraniyagala, 1948; 1960; Ilangakoon, 2002; 2006b).

Five species of large *Balaenopterid* whales have been recorded around Sri Lanka with blue whales and Bryde's whales being the most common and widely distributed. Blue whales were first sighted in abundance in the northeastern waters near Trincomalee canyon (Alling *et al.*, 1982; Leatherwood *et al.*, 1984; Whitehead *et al.*, 1983) during the 'Tulip Expedition' in the early 1980s. These early records were followed by sightings off the south, southeast, west and northwest (Ilangakoon, 2002; 2006a; 2009; Ilangakoon *et al.*, 2000b; Leatherwood and Reeves, 1989; Ocean Alliance, 2003) indicating widespread occurrence around the island. Blue whale strandings are also documented from all coastal areas other than the northern coastline (Deraniyagala, 1948; Deraniyagala, 1960; Ilangakoon, 2002; 2006b).

Bryde's whales have been frequently sighted all around the island by most surveys undertaken thus far (Ilangakoon, 2002; 2009; Ilangakoon and Perera, 2009; Leatherwood *et al.*, 1984; Leatherwood and Reeves, 1989; Ocean Alliance, 2003) though strandings of this species are rare (Ilangakoon, 2006b). The taxonomic status of this species in Sri Lankan waters is uncertain. Mitochondrial DNA analysis of tissue samples from a Bryde's whale killed off the west coast by a ship strike in 2003 (Herath, 2007) suggested that it was a specimen of *B. brydei*. It is possible that *B. edeni* also occurs but this remains undetermined at present.

The other baleen whales recorded are fin whale (*B. physalus*), minke whale (*B. acutorostrata*) and humpback whale (*Megaptera novaeangliae*). There is considerable uncertainty regarding the occurrence of the fin whale in the tropical northern Indian Ocean, with no recent sightings or strandings. Since occurrence in Sri Lanka is based mainly on old and poorly documented stranding records (Deraniyagala, 1948) and just one more recent net entanglement (Leatherwood and Reeves, 1989) there is a possibility that these may have been misidentifications. Minke whales appear to occur mainly in the shallower northwestern waters of the Gulf of Mannar, based on recorded strandings (Deraniyagala, 1963) and sightings

(Bröker and Ilangakoon, 2008; Ilangakoon, 2006a). Humpback whales, while not common in Sri Lankan waters, have stranded sporadically on the west coast (Deraniyagala, 1948; Ilangakoon, 2002; Leatherwood and Reeves, 1989; Reeves *et al.*, 1991) and their songs have been recorded in northwestern waters (Leatherwood and Reeves, 1989; Whitehead, 1985). These animals are probably part of the Arabian Sea population but their stock affinities are as yet undetermined.

The only species of porpoise recorded from Sri Lanka is the finless porpoise (*Neophocaena phocaenoides*). Phillips (1935) reported sightings of this species off the east coast but no details were given and there have been no reported sightings since then. One specimen in the Harvard Museum of Comparative Zoology was reported in earlier literature (Ilangakoon, 2002; Leatherwood and Reeves, 1989) as having been caught by a Smithsonian Carangid Survey team on the Wadge Bank (Indian waters), but it is catalogued in the Museum collection as coming from Kuru Nagar, Jaffna in northern Sri Lanka (Charles Anderson, pers. comm.). The collector of the specimen has confirmed (Tyson Roberts, pers. comm.) to Charles Anderson that the fresh dead specimen was purchased by him at a fish landing site in Jaffna and handed over to the Museum of Comparative Zoology.

Threats

Cetaceans throughout the world's oceans face a multitude of threats due to increasing human activities, and those around Sri Lanka are no exception. The primary threat to small cetaceans around Sri Lanka is the fishing industry. Interactions between cetaceans and fisheries were first mentioned in the literature in 1887 (Nevill, 1887) but were documented in more detail in the 1950s (Lantz and Gunasekera, 1955). Although the island has a long history of artisanal fishing, traditional nets were made of natural fibers and posed little threat to cetaceans, which could usually break through unharmed if accidentally entangled. Development of modern fisheries began in the late 1940s and with this came the adoption of synthetic fibre gillnets. These gillnets are now widely used, and accidental bycatch has become a major problem, causing the mortality of thousands of small cetaceans each year (Dayaratne and Joseph, 1993; Ilangakoon, 2002; Leatherwood and Reeves, 1989).

Although direct hunting is not as widespread as bycatch in Sri Lanka, the use of a hand-held harpoon to kill small cetaceans has been documented off the south coast (Ilangakoon, 1989; 1997; 2002; Ilangakoon *et al.*, 2000b; Leatherwood and Reeves, 1989). Within the past two decades this practice has spread to other areas on the west and southwest coast and the numbers of small cetaceans being killed annually in this manner continue to increase (Ilangakoon, 2002; 2007; Ilangakoon *et al.*, 2000b).

At present, fisheries cause both targeted and accidental mortality of cetaceans, and both forms of take are indiscriminate in relation to species, sex and size, with rare species, pregnant and lactating females and young animals being taken among others (Ilangakoon, 1989; 2007; Ilangakoon *et al.*, 2000a; Kruse *et al.*, 1991). The availability of dolphin flesh originally derived from accidental bycatch, has led to a newly acquired taste for this non-traditional

source of protein, for some parts of the human population (Breiwick and Tsunoda, 1987; Ilangakoon, 1989; 2002; 2007; Ilangakoon *et al.*, 2000a). This demand-driven market for dolphin flesh is now fed by a growing direct take (Ilangakoon, 2006c; 2007).

Some cetacean catch studies indicate that spinner dolphins comprise more than 50% of the total recorded catch in Sri Lanka (Dayaratne and Joseph, 1993; Ilangakoon, 1989; 1997; 2007; Ilangakoon *et al.*, 2000b). This high rate of bycatch is possibly a result of the association of this species with the tuna that are targeted by fishermen (Ilangakoon, 2006a). The spinner dolphin's natural behaviour of frequently bow-riding with boats also makes it an easy target for direct take using hand-harpoons (Ilangakoon, 1989; 2002; Ilangakoon *et al.*, 2000b). Spinner dolphins could therefore be at particular risk in Sri Lanka's waters, but as no population estimates are available it is difficult to assess the impact.

Sri Lanka is located on a major international shipping route across the Indian Ocean. Increased shipping traffic is a threat that affects all marine mammals, but appears to be more of a direct threat to large whales in the waters around the island. Recent stranding records show evidence of several large whales being killed by ship strikes (Herath, 2007; Ilangakoon, 2006b; 2006c), with some dead animals being pushed along by container vessels into Colombo harbour. Increased shipping traffic also increases the risk of marine pollution, both acoustic and chemical, that can be harmful to cetaceans (Norris, 1994; Sousa-Lima and Clark, 2008; Wise *et al.*, 2009).

Habitat degradation due to destructive fishing practices and pollution of coastal waters from land-based and marine-based sources also poses a threat to cetaceans in Sri Lanka. This may be particularly severe for those species that are restricted to coastal waters. Based on current knowledge, the range of the Indo-Pacific humpback dolphin in Sri Lanka is restricted to a small, nearshore area, off the northwest of the island, including the Puttalam lagoon, which is extensively used for human activities (Bröker and Ilangakoon, 2008; Ilangakoon, 2006a; 2007). This area is also currently earmarked for tourism development. Disturbance and pollution could become a threat to the long-term viability of this population. Anthropogenic impacts on other coastal species have not yet been studied, documented or assessed.

A recent and growing activity around Sri Lanka is marine tourism, notably whale and dolphin watching off the southern coast (Ilangakoon, 2009; Ilangakoon and Perera, 2009). This may become a threat to cetaceans if unregulated. Although cetaceans are legally protected in Sri Lanka, there are no specific regulations in place to control or monitor whalewatching. With only a few seasons of such activities having taken place from 2007 onwards, problems in the form of harassment of large whales have already been documented (Ilangakoon and Perera, 2009). Even if regulations were framed to control such activities under the existing law, enforcement would be difficult due to constraints faced by the authorities. These constraints include the lack of trained personnel and basic equipment, such as boats for monitoring activities at sea. Elsewhere in the world, where whale and dolphin watching is a well-developed part of the tourism industry, adverse impacts have become evident, especially

on species and populations of small cetaceans inhabiting coastal waters (Constantine *et al.*, 2004; Lusseau, 2003) and some large whales (Au and Green, 2001; Gordon *et al.*, 1992; McCauley and Cato, 2001). Such impacts have taken place even where strict regulations are in place (Garrod and Fennell, 2004) and this is now a cause for concern in Sri Lanka.

Legal status and conservation

All cetaceans are protected under national legislation in Sri Lanka. They are afforded blanket protection as a group, under the Fauna and Flora Protection Ordinance, as amended in 1993. Cetaceans are also protected under the Fisheries Act of 1996. While this legislation is in theory adequate to provide protection for all species of whales and dolphins, implementation and enforcement of these laws are negligible at present. As a result, small cetaceans continue to be landed as bycatch and direct take, while the flesh from these animals is openly sold for human consumption, in violation of existing laws (Ilangakoon, 2002; 2006c). Under both sets of legislation it is not only a punishable offence to kill or harm cetaceans, but it is also an offence to sell or have possession of any part of such an animal. Being protected under two sets of legislation also causes some confusion and loopholes in enforcement, because the penalties differ under each legislative instrument (Ilangakoon, 2006c).

Sri Lanka has an extensive network of terrestrial protected areas, but Marine Protected Areas (MPAs) have not been given priority in the protected area system of the country (Ilangakoon, 2006c). Presently there are only six MPAs around the island, four of which were created with the priority aim of protecting coral reefs, while the other two were designated for fisheries management (Perera and De Vos, 2007). Cetacean occurrence and distribution has only been assessed in one of these MPAs, and that too, long after its boundaries were demarcated (Bröker and Ilangakoon, 2008; Ilangakoon, 2006a; 2007). No protected area has yet been created for the express purpose of protecting cetaceans, or important cetacean habitat. Some cetacean species, such as the Indo-Pacific humpback dolphin that is dependent on shallow nearshore waters, could benefit from well-managed protected areas declared specifically for their protection. However, even in the existing Marine Protected Areas (MPAs), enforcement and management are almost non-existent, for reasons including lack of resources and trained personnel (Ilangakoon, 2006c).

Research gaps and constraints

There has been little dedicated, long-term research on cetaceans in Sri Lanka. During the past three decades, several short-term research projects and studies have been conducted when external funds were available and data have also been collected using platforms of opportunity when possible. Therefore, research on cetaceans has been sporadic and discontinuous making results obtained from these surveys difficult to compare. Such data are not conducive to deciphering cetacean life histories, long-term population trends or impacts of human activities. Land-based studies, such as those on fisheries bycatch and direct take, have been more extensive and thorough than boat-based surveys on live animals. This is mainly due to a lack of resources for at-sea

research surveys, which are expensive and often unaffordable for small developing countries like Sri Lanka with more immediate human development priorities. The work already undertaken has helped develop baseline data including a national species list, while temporal and spatial distribution patterns of some of the more common species are only now being unravelled through on-going work. Little however is known about the distribution of other species, migration patterns, population trends or species/populations at particular risk. Even the ecological needs of many of the coastal small cetaceans are currently not clearly understood in Sri Lanka, making it difficult to assess the impacts of human development activities.

Likewise, no molecular biological studies to determine stock affinities or population structures have ever been carried out, with species identifications having been primarily based on morphological characteristics. These research gaps have also resulted in taxonomic uncertainties, especially in relation to some of the large baleen whales. For example, although Bryde's type whales are common around Sri Lanka, the recent splitting of the species (Wada *et al.*, 2003) has created uncertainty as to which species occur(s) around the island. Likewise, there is uncertainty about the movements and population affinities of blue whales. While feeding aggregations of this species including mother-calf pairs have been recorded off the north-east (Alling *et al.*, 1991) and south (Ilangakoon, 2009) coasts, at least some animals are present in Sri Lankan waters throughout the year, raising the possibility of a resident population (Ilangakoon, 2002; 2006c; Leatherwood and Reeves, 1989).

In terms of spatial coverage, Sri Lanka's northern waters have been totally neglected in relation to cetacean research, due to the civil unrest and terrorism which prevailed in the area for the past 25 years. The uncertain security situation made the area inaccessible to researchers. While almost nothing is known about cetacean occurrence and distribution in these northern waters, the cessation of hostilities in 2009 presents opportunities for future research activities.

Research in the past three decades resulted in several publications specifically on cetaceans in Sri Lanka (Ilangakoon, 2002; Leatherwood and Reeves, 1989) and a number of scientific papers, reports and articles. These however, have not been adequate to raise awareness among management authorities, law enforcement personnel, tourism authorities or the general public within the country. There is still a large gap in awareness about cetaceans in the waters around the island, their ecological needs and conservation status, due to a dearth of information and non-scientific literature on the subject.

CONCLUSION AND RECOMMENDATIONS

There is a diversity of cetacean species, inhabiting both coastal and offshore waters around Sri Lanka. This understanding is however based on limited research. There is a need to expand the research base, and to cover more areas, including the north and offshore waters. Likewise, it is desirable that long-term and consistent research activities are initiated in order to assess population trends, ecological needs and the conservation status of cetacean populations in these waters. While it is important to carry out research on all aspects of cetaceans in Sri Lanka's waters, priority needs

to be given to management and conservation-oriented research. Information that is crucial for management purposes includes population trends and immediate and growing threats. More detailed, long-term studies on species and behavioural aspects should be undertaken, along with continuous monitoring of all cetacean related human activities, as and when resources become available.

Sri Lanka has good potential for the development of non-consumptive activities like commercial whale and dolphin watching. At present cetaceans remain a potentially important but underutilised resource that could, through careful management, become economically beneficial to the country. Such activities can benefit underprivileged coastal communities that presently view small cetaceans only as a source of food or supplementary income. Benefits of activities like whale and dolphin watching would be an incentive for these local communities to realise the value of live animals in their waters, as opposed to the exploitation that takes place at present. In developing these activities, baseline data and continuous monitoring are important for long-term sustainability.

It is also important to raise awareness regarding cetaceans and cetacean conservation within the country. Data from scientific studies should therefore be used to create awareness among management authorities as well as the general public. It is only through this kind of heightened awareness and understanding at a local level, especially among coastal communities, that long-term conservation and rational management goals can be achieved.

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Cetacean sightings and acoustic detections in the offshore waters of Sri Lanka: March–June 2003

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ABSTRACT

The Indian Ocean Sanctuary was established in 1979 in an effort to allow exploited stocks of whales to recover from whaling and to facilitate benign research. Further information is required to establish comprehensive management and conservation measures for species within these waters. The current study took place in the offshore waters of Sri Lanka in early 2003. During three research cruises conducted between 29 March and 17 June 2003 the *R/V Odyssey* covered a total track line of 4,480km around the island resulting in 52 confirmed group sightings of 11 species from three cetacean families. As the tracklines were designed to locate sperm whales (*Physeter macrocephalus*) for tissue sampling, they accounted for the greatest number of sightings. Only two species of balaenopterids, the blue whale (*Balaenoptera musculus*) and the Bryde's whale (*Balaenoptera edeni*), were recorded with the blue whale being the most frequently sighted species. Spinner dolphins (*Stenella longirostris*) were the most dominant species in terms of numbers. Some small odontocetes such as the common bottlenose dolphin (*Tursiops truncatus*), striped dolphin (*Stenella coeruleoalba*) and Fraser's dolphin (*Lagenodelphis hosei*) were observed in mixed-species groups, while one group of melon-headed whales (*Peponocephala electra*) was seen associating with a group of sperm whales. Risso's dolphins (*Grampus griseus*) were frequently sighted throughout the research cruise, with one unusual record of a large mating group. Many sightings were made in the vicinity of the numerous submarine canyons around Sri Lanka's coastline highlighting their potential role in enhancing productivity in the offshore waters. It is concluded that Sri Lankan offshore waters hold a rich, but little surveyed cetacean fauna that warrants further studies and implementation of conservation measures to protect these populations.

KEYWORDS: INDIAN OCEAN; BLUE WHALE; SPERM WHALE; FALSE KILLER WHALE; PANTROPICAL SPOTTED DOLPHIN; SPINNER DOLPHIN; BRYDE'S WHALE; BOTTLENOSE DOLPHIN; STRIPED DOLPHIN; FRASER'S DOLPHIN; RISSO'S DOLPHIN; MELON-HEADED WHALE; MONITORING; SURVEY-COMBINED; CONSERVATION; INCIDENTAL CATCHES

INTRODUCTION

Sri Lanka lies in the heart of the Indian Ocean Sanctuary (area north of 55°S), which was proposed by the Seychelles in its first year as a member of the International Whaling Commission (IWC) in 1979 (Leatherwood and Donovan, 1991). Sri Lanka is not a member of the IWC, but marine mammals within its 200-mile Exclusive Economic Zone (EEZ) are in theory protected under national legislation – the Fauna and Flora Protection Ordinance of 1993, as well as the Fisheries and Aquatic Resources Act of 1996. However, little is known about the composition, abundance and zoogeography of cetaceans off Sri Lanka, providing a poor basis for informed conservation efforts.

The physical characteristics of the coast of Sri Lanka, which include the presence of numerous deep canyons adjacent to the coast, help create a heterogeneous environment, which provides habitats for a variety of cetacean species. While references to the whales in Sri Lankan waters date as far back as the 2nd Century, records of stranded whales were first reported in the scientific literature in 1859 (Blyth, 1859; Fernando, 1912). The *Tulip* expedition, which spent three field seasons in the waters of Sri Lanka between the spring of 1982 and the spring of 1985 has thus far been the only comprehensive cetacean research programme in the waters of Sri Lanka (Alling, 1986). Although the study was focused on the tracking and documenting of sperm whale (*Physeter macrocephalus*)

populations (Gordon, 1991), other species such as blue whales (*Balaenoptera musculus*) (Alling *et al.*, 1991) and odontocetes such as spinner dolphins (*Stenella longirostris*), spotted dolphins (*S. attenuata*), striped dolphins (*S. coeruleoalba*), Risso's dolphins (*Grampus griseus*), bottlenose dolphins (*Tursiops truncatus*), pygmy killer whales (*Feresa attenuata*), dwarf sperm whales (*Kogia sima*), rough toothed dolphins (*Steno bredanensis*), false killer whales (*Pseudorca crassidens*) and Cuvier's beaked whales (*Ziphius cavirostris*) were documented either as live or bycaught specimens (Alling, 1986). The research conducted in Sri Lanka throughout the last thirty years concludes that a total of 27 species of cetacean occur in Sri Lankan waters (Bröker and Ilangakoon, 2008; Ilangakoon, 1989; 1997; 2002; 2006a; 2006c; Ilangakoon *et al.*, 2000a; Ilangakoon and Perera, 2009; Ilangakoon *et al.*, 2000b; Leatherwood and Reeves, 1989).

As a part of a five-year global programme the 'Voyage of the *Odyssey*', collected baseline data on the distribution and concentrations of chemical contaminants in the world's oceans. Ocean Alliance's research vessel *Odyssey* entered Sri Lankan waters in the spring of 2003. While the above goals were achieved by collecting tissue samples from sperm whales, the research was designed to obtain broader information on the species composition and distribution of all other cetaceans sighted. This paper presents sighting and acoustic data of cetaceans in Sri Lankan waters made from

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on board the *Odyssey* during the months of March–June 2003 with the aim of contributing additional data on cetaceans in this little surveyed area with increasing human encroachment.

MATERIALS AND METHODS

The sighting surveys were conducted from March–June 2003 onboard the *R/V Odyssey*, a 28m ketch equipped for open ocean cetacean research. As the main aim of the cruise was to locate sperm whales, the vessel primarily followed depth contours greater than 500m and thus sightings of other cetaceans are biased to this preferred sperm whale habitat. In addition, the whole coastline was not surveyed due to security restrictions.

Visual effort

Observation watches were performed during daylight hours (0600–1845hrs) from an observation platform situated 4.6m above water level. Using their naked eye and a pair of 7 × 40 binoculars two observers would make observations 180° forward of the boat out to the horizon at 7.5km. Vessel speeds were maintained at 4–6 knots. All sightings and other relevant data collected on the cetaceans were recorded in *logger 2000 v. 2.05* (developed by the International Fund for Animal Welfare – IFAW). In addition GPS position, local time and GMT, vessel course and speed, information on sea surface temperature and weather relating to sightings ability (sea state, swell and meteorological data) and navigational data were collected half hourly. Visual observations made within 2km of the *Odyssey's* track line were approached to make positive species identifications, collect photo-identification data and estimate group size.

Acoustic effort

Acoustic detections were made using a two-hydrophone array towed at 100m from the stern via Kevlar-shielded cables. The hydrophone elements were separated by 3m and held together by a stabilising plastic mesh. Effective listening range was 2–20km depending on weather, sea conditions, vocalising species and whether the vessel was motoring or sailing. The output signal was connected to a pair of headphones and stereo speakers located in the pilothouse and monitored by the helmsperson 24 hours a day.

Two kinds of acoustic stations were conducted during the research. Every half hour and on the odd hour a 'slow to listen' was carried out, which involved slowing the boat to idle speed with the autopilot on standby and listening for 5–10 minutes on the headphones connected to the hydrophone. On the even hour an 'acoustic stop' was conducted that involved switching off the boat's engine, putting the boat in neutral gear, and listening in a similar manner with the hydrophone sunk to an average depth of 30m from the surface. Any acoustic contacts were then recorded.

Sperm whale acoustic detections

Once sperm whales were acoustically detected the boat was manoeuvred in an effort to track the clicks using the 'bearing/time' display in the software *Rainbow Click* (RBC) v. 1.03.00 (IFAW). The output signal was also interfaced with a PC desktop computer with a stereo 16-bit sound card

and RS232 data input. Input data was automatically processed in real-time using RBC, which is specifically written for the analysis of sperm whale clicks. RBC uses the time of arrival of clicks at the hydrophone to generate a bearing to the sound source.

RESULTS

During the three research legs conducted between 29 March and 17 June 2003, representative of the inter-monsoon and southwest monsoon periods, the *R/V Odyssey* covered a total track line of 4,480 km around Sri Lanka (Fig. 1). The first leg, lasting 6 days from 29 March through 3 April, followed the south coast of Sri Lanka along the 1,000m contour line to 6°36'N 82°03'E and returned to Colombo via the 2,000m depth contour (Fig. 1).

The second leg lasted from April 15 to April 30. After heading northwest into the Gulf of Mannar to 8°25'N 79°30'E, the *Odyssey* zigzagged southwards to 6°05'N 78°32'E, prior to travelling east along the 4,000m contour line. Next the *Odyssey* headed north along the east coast to 7°20'N 82°06'E before turning south and returning to Colombo via the 4,000m contour line (Fig. 1).

The final research leg of 7 days was conducted in three phases due to bad weather conditions resulting from the onset of the southwest monsoon. During this leg the *Odyssey* surveyed the Gulf of Mannar on the west coast (Fig. 1).

Visual effort

A total of 76 marine mammal group sightings of an estimated 1,943 individuals were made during the study period (Table 1, Fig. 2), 68% of which were identified to the species level. Among the 11 species identified, three were whales and eight were small cetaceans (Table 1). The most commonly sighted was the sperm whale, which accounted for 13% of all sightings (Fig. 2). However, as the track lines were primarily designed to locate this species this dominance of sperm whales is likely biased. Blue whales and Bryde's whales were the other large whale species recorded in the area (Table 1). Of the small cetaceans, Risso's dolphins were recorded most often (6 sightings) while the spinner dolphin was the most abundant in terms of number of individuals ($n = 605$). 32% of all sightings were of unidentified species, which included whales, dolphins and one beaked whale (Table 1).

Acoustic effort

1,106 acoustic stations were conducted during the 624 hours of acoustic effort (Fig. 3). Cetaceans were detected 58% ($n = 640$) of the time. The majority belonged to unidentified delphinids ($n = 514$; 46%) with the rest belonging to sperm whales ($n = 126$; 11%). The similarity in tonal and click sounds of the delphinid species rendered it difficult to acoustically identify the various species detected. As expected, blue whales were not detected using towed hydrophones since flow noise masks their low frequency signals and thus acoustic detections were biased towards odontocetes that vocalise at higher frequencies.

DISCUSSION

A total of 11 species were positively identified during this study. This represents 41% of all cetacean species ever

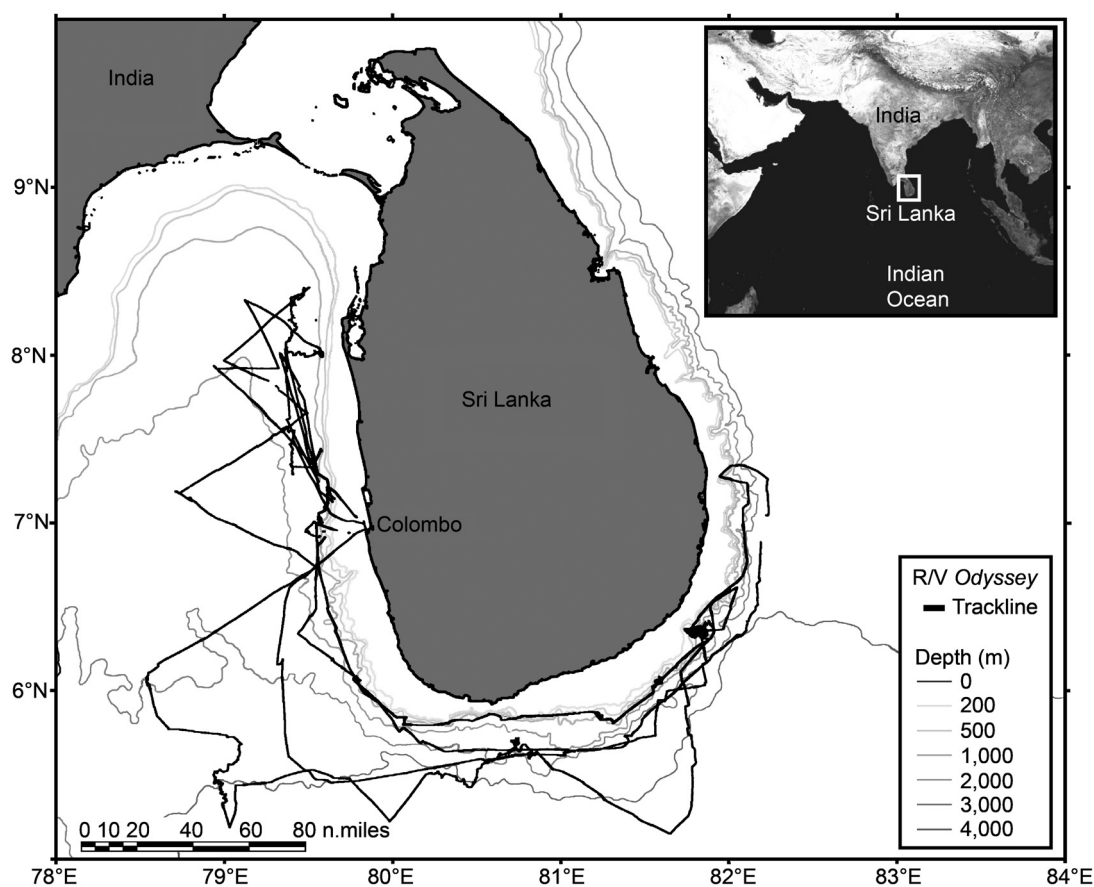


Fig. 1. Cruise track of the R/V *Odyssey* between 29 March and 17 June 2003 (black line).

recorded around the island (Ilankoon, 2002). Of those not recorded many, such as the Ginkgo toothed beaked whale (*Mesoplodon ginkgodens*), common dolphin (*Delphinus delphis*) and finless porpoise (*Neophocaena phocaenoides*) are considered rare (Ilankoon, 2002) while the records of fin whales (*Balaenoptera physalus*) within the Northern Indian Ocean (NIO) are currently being challenged (Dr R.L. Brownell Jr., pers. comm.).

Table 1

Visual sightings recorded during the three legs from 29 March to 17 June 2003.

Species (common name)	No. of sightings	Approx. no. of individuals
Family Balaenopteridae		
Blue whale	9	12
Bryde's whale	3	4
Unidentified balaenopterid	8	6
Family Physeteridae		
Sperm whale	10	128
Family Delphinidae		
Bottlenose dolphin	2	33
False killer whale	2	5
Fraser's dolphin	5	205
Melon-headed whale	3	180
Pantropical spotted dolphin	5	253
Risso's dolphin	6	153
Spinner dolphin	4	605
Striped dolphin	3	90
Unidentified delphinid	15	268
Family Ziphiidae		
Unidentified ziphiid	1	1

Family Balaenopteridae

Blue whale (Balaenoptera musculus)

This species is currently classified into three subspecies; *B. m. musculus* (northern hemisphere blue whale), *B. m. intermedia* (Antarctic or 'true' blue whale) and *B. m. brevicauda* (pygmy blue whale). The blue whale recorded around Sri Lanka is reportedly the pygmy blue whale (Alling *et al.*, 1991) albeit Brownell and Donahue (1994) proposed that the Northern Indian Ocean (NIO) populations be recognised as a separate subspecies, *B. m. indica*. These populations, like those of the NIO humpback whales reportedly have a restricted range and breed six months out of phase with the pygmy blue whales in the Southern Indian Ocean (Mikhalev, 2000), highlighting the conservation implications and significance of these subdivisions.

A juvenile blue whale was recorded off the west coast with other observations off the south east coast in close proximity to the Basses Submarine Canyon (Swan, 1983) (Fig. 2). Worldwide, aggregations of blue whales appear to be associated with areas of high productivity, particularly submarine canyons (Croll *et al.*, 2005; Rennie *et al.*, 2009). Observations of faecal matter during the present surveys also indicate that Sri Lanka represents a feeding ground for this species (Alling *et al.*, 1991; Branch *et al.*, 2007). Records show that blue whales are commonly documented around the island (Afsal *et al.*, 2008; Alling *et al.*, 1991; Ballance and Pitman, 1998; Branch *et al.*, 2007; Bröker and Ilankoon, 2008; de Silva, 1987; Ilankoon, 2002; 2006a), despite the limited sightings made during the

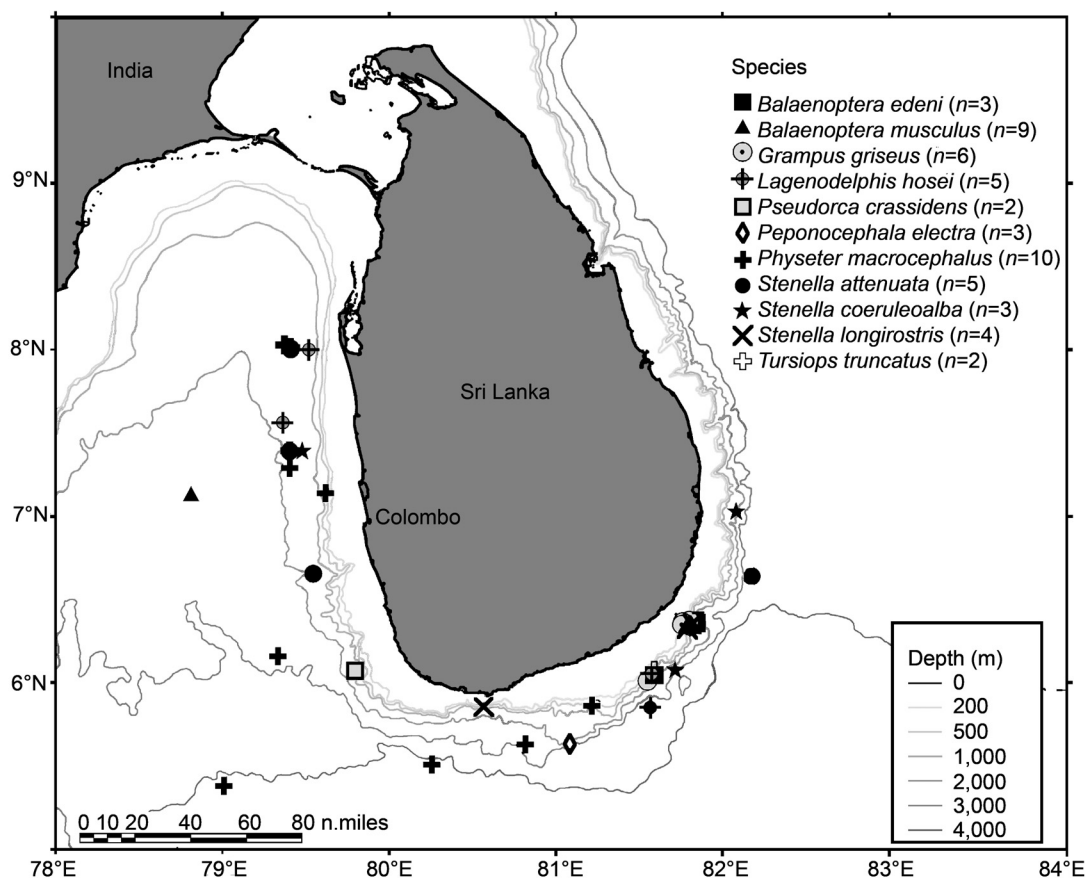


Fig. 2. Visual sightings recorded during the study period.

present study. In the past, sightings and stranding records of this species have been consistently made throughout the year (Deraniyagala, 1932; 1948; 1965; Fernando, 1912; Ilangakoon, 2002; 2006b) suggesting that the blue whales inhabiting these waters either do not undertake regular seasonal migrations, or maintain a population in this area throughout the year lending support to the theory of a NIO stock (Mikhalev, 1996; Yochem and Leatherwood, 1985).

Bryde's whale (Balaenoptera edeni)

Bryde's whales were the only other balaenopterid species observed during the surveys. All three sightings were made off the southeast coast close to the Basses Submarine Canyon (Swan, 1983) (Fig. 2). This species has been documented by all surveys undertaken around the island since the 1980s (Ballance and Pitman, 1998; Ilangakoon, 2002; 2009; Ilangakoon and Perera, 2009; Leatherwood *et al.*, 1984; Leatherwood and Reeves, 1989). However, strandings of this species have been low relative to other balaenopterids recorded in these waters (de Silva, 1987; Ilangakoon, 2006b). Evidence of Bryde's whales feeding – in the form of faecal matter – was observed several times.

Family Physeteridae

Sperm whale (Physeter macrocephalus)

During the Sri Lankan research leg, a total of ten sperm whale groups were sighted, comprising 128 individuals (Table 1; Fig. 2). The groups mostly consisted of sub-adults with few calves and adults being recorded. As the primary

objective of this cruise was to locate this species for tissue sampling, this high sighting rate highlights the bias in the data set. However, in general, they are commonly recorded and widely distributed in Sri Lankan waters (Afsal *et al.*, 2008; Ballance and Pitman, 1998; Bröker and Ilangakoon, 2008; de Silva, 1987; Gordon, 1987; 1991; Ilangakoon, 2002; 2006a).

The largest single group, numbering 23 individuals, was observed off the southern coast, almost directly south of Dondra head, the southern most point of the country. This sighting coincides with the Dondra Submarine Canyon (Swan, 1983) that may play a role in enhancing the productivity of this region. About 40 sperm whales were also recorded in close proximity to one another off the northwest coast, an area popular with whalers during the months of August to December in the 1840s (Wray and Martin, 1983). A dedicated survey by Bröker and Ilangakoon (2008) within the Bar Reef Marine Sanctuary also indicated the presence of this species during the inter-monsoonal period of August–September. The frequent sightings of large groups including calves in the waters off the northeast coast by Gordon (1987) may indicate that Sri Lankan waters are an important calving ground for this species.

Sperm whales were the only species acoustically identifiable to species level (Fig. 3). While the majority of acoustic detections were of 'unidentified delphinids' acoustic identification to the species level was difficult because of the similarity in the sounds produced. Therefore it is evident that there is a bias in the acoustic data towards large, easily identifiable (acoustically and visually) species.

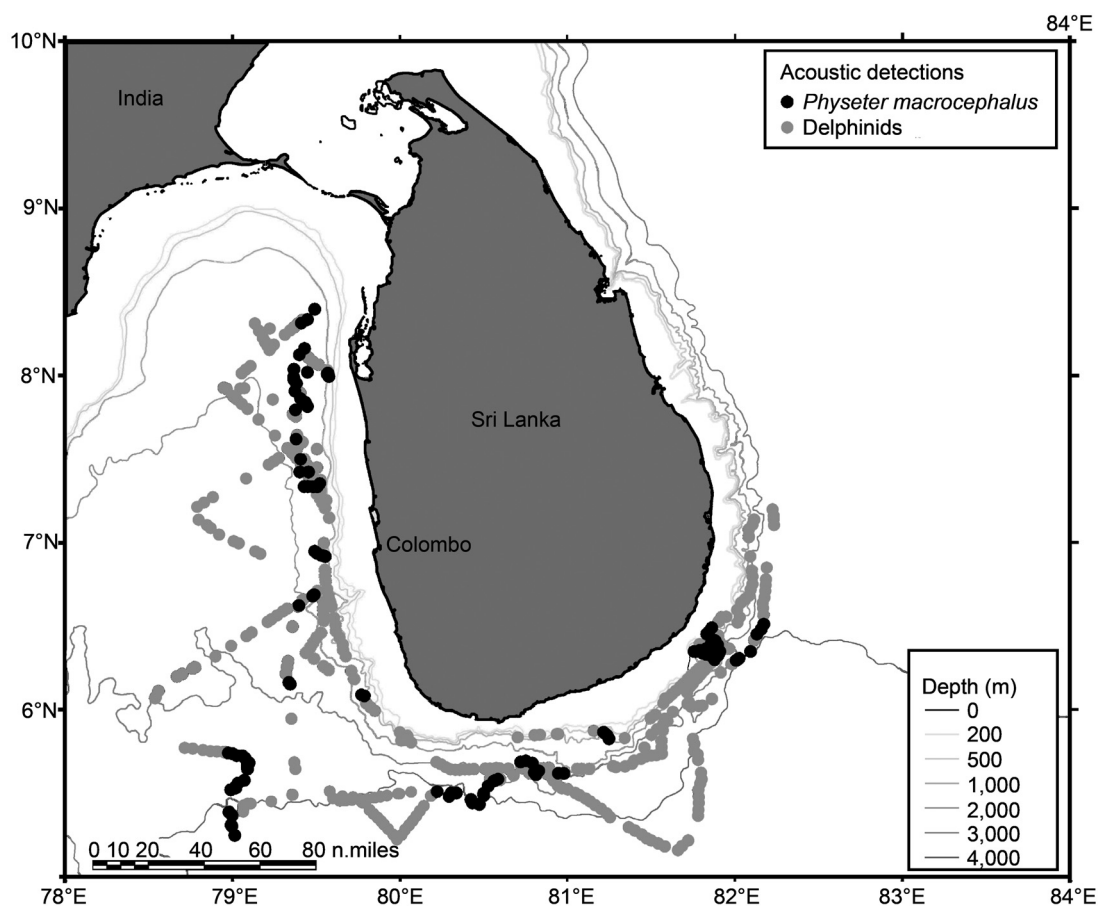


Fig. 3. Acoustic detections along *Odyssey's* track line. Sperm whales (black) and unidentified delphinids (grey).

Family Delphinidae

Bottlenose dolphin (Tursiops truncatus)

Bottlenose dolphins were sighted on two occasions, off the west coast (Table 1; Fig. 2) and in the vicinity of the Basses Submarine Canyon in waters 1,000–1,800m deep. Their large sizes coupled with the depths at which they were recorded suggest that these groups belong to the offshore form of bottlenose dolphin. The small group recorded on the west coast of the country was seen travelling with a group of approximately 100 striped dolphins. Mixed-species groups such as this have been documented in the Western Indian Ocean and other parts of the world (Ballance and Pitman, 1998; Jefferson *et al.*, 2008). A group of 30 bottlenose dolphins was sighted on the southeast coast, a somewhat uncommon sighting as most are found in groups of 20 individuals or less (Jefferson *et al.*, 2008). This species is considered common around the island as evidenced by the frequent sightings and catch data from around the coastline (Alling, 1986; 1988; Bröker and Ilangakoon, 2008; de Silva, 1987; Ilangakoon, 1997; 2002; Ilangakoon *et al.*, 2000a; Ilangakoon *et al.*, 2000b).

False killer whale (Pseudorca crassidens)

Only two of the five species of 'blackfish' recorded from Sri Lankan waters were observed during this research cruise. Although false killer whales are considered highly social and often seen in groups of more than ten individuals (Jefferson *et al.*, 2008), only two sightings of small group sizes were made during this cruise (Table 1; Fig. 2). One record was made at a depth of 1,200m off the west coast of the island which is

not unusual as they are known to spend time in relatively deep, offshore waters (Jefferson *et al.*, 2008). This species has been recorded as live observations, strandings and in bycatch from around the island in the past (de Silva, 1987; Deraniyagala, 1960; Ilangakoon, 1997; 2002; Ilangakoon *et al.*, 2000b; Leatherwood *et al.*, 1991; Leatherwood and Reeves, 1989).

Fraser's dolphin (Lagenodelphis hosei)

Five groups of Fraser's dolphins were recorded representing 205 individuals (Table 1). They were generally observed at depths exceeding 1,000m, further reinforcing the observation that they are primarily an oceanic species (Ilangakoon, 2002; Jefferson *et al.*, 2008; Leatherwood *et al.*, 1992). The majority of records from Sri Lankan waters are provided through bycatch data collected between 1985–1994 by Leatherwood and Reeves (1989), Ilangakoon (1989; 1997), Ilangakoon *et al.* (1992) and Dayaratne and Joseph (1993). Ballance and Pitman (1998) also observed this species on the west coast of Sri Lanka while one unconfirmed sighting of this species was made in the Trincomalee area, on the east coast (Alling, 1986). On two occasions, schools of Fraser's dolphins were associated with other species, specifically Risso's and Pantropical spotted dolphins. Such associations have previously been documented by Leatherwood *et al.* (1992) and Perrin *et al.*, (1994). In the Maldives and elsewhere they have also been documented associating with short-finned pilot whales (*Globicephala macrorhynchus*) and melon-headed whales (Anderson, 2005; Leatherwood *et al.*, 1992; Perrin *et al.*, 1994).

Melon-headed whale (Peponocephala electra)

One group was sighted on the west coast of the country while the other was observed off the southern coast (Fig. 2). The latter group had an estimated 165 individuals, within which ten were classified as calves. This species is known to be highly social and generally found in very deep waters (Jefferson *et al.*, 2008), as confirmed by the data collected through this survey in waters 1,800 and 4,500m deep. Historical catch records indicate that melon-headed whales were present within the Palk Strait area (Blanford, 1891). Other areas where catch data indicate their presence include the west, southwest, south and northeast coasts (Dayaratne and Joseph, 1993; Ilangakoon, 2002; Ilangakoon *et al.*, 1992; Leatherwood *et al.*, 1991). Only one other confirmed sighting record is available from within the Bar Reef Marine Sanctuary on the northwest coast (Bröker and Ilangakoon, 2008) and one unconfirmed sighting from the east coast (Alling, 1986). During these surveys one group of melon-headed whale was seen associating with sperm whales – to our knowledge, a previously unrecorded sighting.

Pantropical spotted dolphin (Stenella attenuata)

Pantropical spotted dolphins are found extensively in all oceans and are primarily oceanic animals that prefer offshore waters. During these surveys they were observed in depths between 1,500–3,200m on the west, northwest and southeast of the country (Fig. 2). In the past, this species has been observed off the northwest coast off Puttalam, the southwest and the east coasts by Leatherwood *et al.* (1984) and Alling (1986). Past catch records indicate that they also appear around the northeast, southwest and southern coasts (Dayaratne and Joseph, 1993; de Silva, 1987; Ilangakoon, 1997). In terms of numbers of individuals sighted, this species ranked second ($n = 253$).

Risso's dolphin (Grampus griseus)

Six groups of Risso's dolphins were sighted with group sizes ranging from 8–50 individuals. Past catch and sightings data indicate that this species is common and widespread around Sri Lanka (Afsal *et al.*, 2008; Alling, 1986; 1988; de Silva, 1987; Ilangakoon, 1997), however it was only documented off the southeast coast during these surveys. Risso's dolphins were generally recorded at depths between 800–2,000m confirming their preference for waters seaward of the continental shelf, steep bottom topography (Baumgartner, 1997; Kruse *et al.*, 1999) and deep oceanic waters (Alling, 1986; Ilangakoon, 2002). While most records were of traveling or bow-riding Risso's dolphins, one unusual record was also made of a large group of mating individuals. Additionally, in one instance, this species was seen closely associating with a large group of Fraser's dolphins as previously reported (Leatherwood *et al.*, 1992; Perrin *et al.*, 1994).

Spinner dolphin (Stenella longirostris)

The largest group of dolphins sighted during these surveys comprised of an estimated 500 spinner dolphins. According to Ballance and Pitman (1998) spinner dolphins were the most abundant species, in terms of numbers sighted, in the western Indian Ocean. Afsal *et al.* (2008) noted that this species was the most abundant in terms of number of

individuals in their surveys within the Indian EEZ and contiguous seas. In addition, catch records (Dayaratne and Joseph, 1993; de Silva, 1987; Ilangakoon, 1989; 1997; Ilangakoon *et al.*, 2000a; Ilangakoon *et al.*, 2000b; Leatherwood and Reeves, 1989) and sightings surveys (Afsal *et al.*, 2008; de Silva, 1987; Ilangakoon, 2002; 2005; 2006a; 2006c) show that this species is the most common cetacean in Sri Lankan waters. The presence of large active groups (Afsal *et al.*, 2008) provides evidence of their highly gregarious nature, which has been documented in the past (Ilangakoon, 2002). Three of the four groups recorded were observed in the Basses area, with one group comprising of two juveniles and five calves (Fig. 2). Alling (1986) previously documented the presence of calves during this same period. The final sighting was made along the southern coast adjoining Dondra Head, in the vicinity of a deep-water submarine canyon.

Striped dolphin (Stenella coeruleoalba)

Striped dolphins were sighted on three occasions during this study. They were consistently recorded in deep oceanic waters (1,450–4,500m) confirming their preference for these offshore habitats (Alling, 1986; Jefferson *et al.*, 2008). The largest group comprising of 50 individuals was sighted off the west coast of the country where it was sighted in a mixed group with bottlenose dolphins. A further group was observed in the Basses Canyon area on the southeast coast, with a final group on the east coast adjoining Batticaloa, the northernmost extent of this research cruise (Fig. 2). The submarine canyons located in these areas may play a role in enhancing productivity, which in turn attracts cetaceans.

Alling (1986) documented the occasional presence of calves off Sri Lanka in surveys conducted in February–April, however no calves were sighted during these surveys. Other catch (Alling, 1988; Dayaratne and Joseph, 1993; de Silva, 1987; Ilangakoon, 1997; 2002) and sighting data (Alling, 1986; Ballance and Pitman, 1998; de Silva, 1987) highlight the prevalence of this offshore species around the coast of Sri Lanka.

Conservation implications

The data gathered during the Sri Lankan research leg add support to the view that Sri Lanka is an area of high cetacean diversity, within the Indian Ocean Sanctuary (Afsal *et al.*, 2008). The narrow and very steep continental shelf/slope resulting in deep waters close to the shore and the presence of submarine canyons around the coastline (Swan, 1983) probably contributes to enhancing the productivity of the waters that attract and support the feeding requirements of the numerous species distributed around the island. This has been shown to be the case in other parts of the world (Croll *et al.*, 2005; Hooker *et al.*, 1999; Rennie *et al.*, 2009). Additionally, other physical processes such as the monsoonal regime with seasonally reversing currents that lead to water exchange between the Bay of Bengal and the Arabian Sea drive the seasonal upwelling observed in these waters that may influence the marine mammal populations by enhancing productivity. Historical records have consistently alluded to the presence of a variety of cetacean species around Sri Lanka. However, they lack comprehensive records of

population sizes due to the scarcity and logistical challenges of line transect surveys off Sri Lanka. In the absence of such data, it is not possible to evaluate the conservation status of each species.

It is nevertheless relevant to briefly identify and discuss some of the threats to the cetaceans surrounding the island. Noise pollution caused by ship traffic and seismic activity within the habitat of the whales is a cause for concern particularly because the life of the whale is largely dependent on acoustic transmission underwater (Gordon and Tyack, 2001). With the end of the civil war Sri Lanka is being opened up for oil and gas exploration. The combination of a rich cetacean fauna and increased levels of anthropogenic activity in the marine habitats of Sri Lanka call for in depth studies of abundance and habitat use of cetacean species to mitigate human encroachment responsibly. Elevated background noise levels caused by manmade noise may interfere with or prevent marine mammals from detecting sounds that are otherwise important to their survival (Richardson *et al.*, 1995).

The level of consistent shipping noise recorded from the commercial shipping lanes on the south coast, is extremely high as evidenced by the difficulties faced in tracking sperm whales acoustically in this area. The southern areas particularly around the Dondra and Basses Canyons seemingly act as important habitats for three large whale species; sperm whales, Bryde's whales and blue whales. Thus these levels of noise may lead to a reduced carrying capacity of large whales in the area due to increased masking levels, and a subsequent increase in ship strikes. The high cetacean biodiversity on the south coast of Sri Lanka is unique and calls for an array of mitigation measures if the marine life in such vital areas is to be effectively protected.

While commercial whaling has not been documented around the island, a small scale dolphin fishery using handheld harpoons is known to occur (Ilangakoon, 1989; 1997; 2002; Ilangakoon *et al.*, 2000b; Leatherwood and Reeves, 1989) with concerns about its increase (Ilangakoon *et al.*, 2000b). Leatherwood (1994) estimated that during a two-year period spanning 1984–86 between 8,042 and 11,821 dolphins were caught annually. Bycatch levels are also high. In 1987 Alling (1988) reported that an estimated 38,000 odontocetes were entangled annually in gillnets deployed within 30 miles (48km) of the shoreline from 26'–60' vessels. More recently, Dayaratne and Joseph (1993) estimated that 5,000 small cetaceans are entangled in gillnets around the island every year.

The incidental entrapment and entanglement of cetaceans in tended and untended nets was, and continues to be of serious concern (Wallace, 1984). The modernisation of fishing gear, technical advances and a steady increase in the number of vessels harvesting fish are cited as the primary causes of such mortality. Specifically, the replacement of cotton or jute nets with synthetic monofilament gillnets by the United Nation's Food and Agriculture Organisation (FAO) in the 1950s marked the beginning of an increased take of target commercial fish and non-target marine animals, cetaceans, birds and turtles (Wallace, 1984).

The populations of cetaceans off the coast of Sri Lanka are also potentially threatened by marine pollution in the

form of organic and inorganic chemicals. Fertilisers and other such pollutants carried in the many waterways around the island that extend from the inland areas to the coastal waters, may result in reproductive failure and immune system breakdown in the marine life inhabiting Sri Lanka's waters. Current knowledge of the Bay of Bengal indicates that existing levels of toxic contaminants particularly that of PCBs and DDT, are high enough to cause severe health risks to animals through suppressed immune system complications (Prudente *et al.*, 1997; Simmonds *et al.*, 1999). More comprehensive research on the extent of pollution in the waters around Sri Lanka using sperm whales as indicator species was the primary focus of the 'Voyage of the *Odyssey*'. The results of these analyses are presented in Wise (2009) and forthcoming publications.

In conclusion, it appears that certain areas around Sri Lanka's vast coastline house a large number of species in considerable numbers. These habitats may provide good breeding, calving and/or feeding grounds for a number of the whale and dolphin species recorded. One such area is located on the southeast coast in the vicinity of the Basses Canyon. This area, which lies between Dondra and Sangamankande Point, is subject to both monsoons and is known for possessing the strongest coastal currents documented around the island (Swan, 1983). The physical attributes of this region may provide deep, cold nutrient rich water that can support sufficient krill to feed the cetaceans that aggregate here. However, the presence of heavy shipping (Kaluza *et al.*, 2010) in the adjoining shipping lanes is a potential cause for concern for the cetaceans in these waters with recent strandings showing evidence of whales being killed as a result of ship strikes (Ilangakoon, 2006c). Further research assessing the importance of these waters and the effects of these varying threats is needed to develop comprehensive management plans for the effective conservation of these species.

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The need for taxonomic investigations on Northern Indian Ocean blue whales (*Balaenoptera musculus*): implications of year-round occurrence off Sri Lanka and India

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ABSTRACT

The blue whale (*Balaenoptera musculus*) is one of the most common cetaceans in the waters around Sri Lanka and in a worldwide context one of the highest low-latitude sighting rates for this species has been recorded in these waters. As genetic analyses, acoustic studies and even long-term sighting surveys for blue whales in these waters are limited, the taxonomic status and population affinities of these animals are not definitively known at present. Sighting records of this species were examined from the waters around Sri Lanka and stranding records from the coasts of both Sri Lanka and India in terms of seasonality of occurrence and it was found that the species is clearly present in these waters throughout the year. This, together with secondary data on certain morphological characteristics and behavioural anomalies, indicates that these waters are ecologically important to blue whales in the Northern Indian Ocean and questions are raised regarding the subspecific identity and population affinities of the animals in the region. It is not clear if they belong to either of the two subspecies currently recognised for the Southern Ocean and Indian Ocean region: their apparently non-migratory nature is akin to the pygmy blue whale *B.m. breviceauda*, while some morphological and behavioural characteristics are indicative of Antarctic blue whales of the subspecies *B.m. intermedia*. This raises the possibility of an entirely different or intermediate subspecies and the need to re-examine *B.m. indica* as a third subspecies in the Northern Indian Ocean. As clarifying their taxonomic status is important in the context of conservation and management, multi-disciplinary studies are urgently needed.

KEYWORDS: BLUE WHALE; NORTHERN INDIAN OCEAN; TAXONOMY; SUBSPECIES; NORTHERN HEMISPHERE

INTRODUCTION

The blue whale (*Balaenoptera musculus*) is the most common large mysticete in the waters around Sri Lanka (5°55'–9°50'N; 79°42'–81°53'E), in the Northern Indian Ocean (Ilangakoon, 2002; 2006b; Leatherwood and Reeves, 1989). Sighting rates for this species are high in these waters in comparison to other low-latitude regions of the world (Branch *et al.*, 2007). These animals are unique in that their northward movement is limited by a land barrier, namely the landmass of Asia. Primary productivity in the waters around Sri Lanka and India, as in other parts of the Northern Indian Ocean, is driven mainly by monsoon-related upwelling (Vinayachandran *et al.*, 2003; Vinayachandran and Mathew, 2003). While the ecology of the blue whale in this region is not yet clearly understood, it has been suggested that there is a resident population (Ballance and Pitman, 1998; Gordon *et al.*, 1986; Ilangakoon, 2002; 2006b; Leatherwood and Reeves, 1989) with a geographical distribution that does not overlap with those of Southern Indian Ocean populations (Branch *et al.*, 2007; Mikhalev, 2000). The breeding cycle of the Northern Indian Ocean blue whale is also out of phase with those in the Southern Indian Ocean (Mikhalev, 2000), indicating that there is no interbreeding with other populations.

Although blue whales are the largest mammals on the planet and were extensively hunted until the middle of the 20th century, little is known about their distribution and migration patterns in the Northern Indian Ocean (Branch *et al.*, 2007). The two currently recognised subspecies of blue whale in the Southern Ocean and Indian Ocean region

are the Antarctic blue whale (*Balaenoptera musculus intermedia*) and the pygmy blue whale (*B.m. breviceauda*). The Antarctic blue whale is believed to remain south of 55°S in the austral summer, while pygmy blue whales generally remain north of 54°S (Ichihara, 1966; Kato *et al.*, 1995). These two subspecies are not easy to distinguish in the field though Antarctic blue whales attain a greater total length (>30m as against 24.1m) and have a proportionately longer tail region compared with pygmy blue whales (Ichihara, 1966; Mackintosh and Wheeler, 1929). Other morphological characteristics distinguishing the two subspecies include a 'torpedo' body shape in the Antarctic blue whale as opposed to a 'tadpole' shape with a proportionately larger head in the pygmy blue whale and differences in the relative position of the central groove of the blowhole, which usually ends with the anterior margin of the nostrils in the Antarctic blue whale but extends beyond the nostrils in the pygmy blue whale (Kato *et al.*, 2001). *Balaenoptera indica* was suggested in the middle of the 19th century (Blyth, 1859) as a separate species occurring in the Northern Indian Ocean but is not widely recognised because its distinguishing features are unclear (Rice, 1998). It is currently not definitively known if the blue whales in the Northern Indian Ocean, including those around Sri Lanka and India (Fig. 1), belong to either of the two accepted subspecies.

Through an examination of sighting records from around Sri Lanka over the past three decades, combined with historical and recent stranding data from India and Sri Lanka, the ecological importance of these waters to blue whales was evaluated and questions regarding their affinity to the

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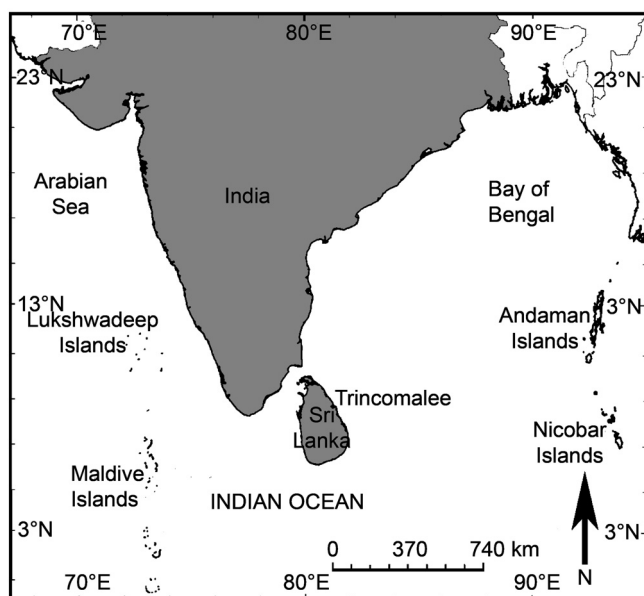


Fig. 1. Study location.

currently accepted subspecies were addressed. Limited morphological and behavioural observations were used as supporting secondary data and the possibility that the species described earlier as *B. indica* is actually a third distinct Northern Indian Ocean, subspecies of blue whale, that would merit the name *Balaenoptera musculus indica* by the rules of nomenclature was considered. Attention is drawn to research limitations in this region and the need for taxonomic evaluation of blue whales in the Northern Indian Ocean in order to close the current gaps in knowledge, which could have long-term conservation and management implications.

METHODS

All published records of blue whale strandings that occurred on the coasts of Sri Lanka and India between 1894 and 2004 were initially listed separately for the two countries by extracting them from compilations of cetacean stranding records for the two countries by Ilangakoon (2002; 2006b) and Sathasivam (2004). Subsequently these records were collated with data from more recent publications (Afsal and Rajagopalan, 2007; Baby, 1999; Jayasankar *et al.*, 2006; Krishnan *et al.*, 2004) and one comprehensive list was developed for closer examination. Strandings of this species occurring after 2004 but not yet reported in the literature were included in this analysis if the specimens had been examined personally by one of the present authors and authenticated as being blue whales.

Published blue whale sightings data are currently available in any quantifiable manner only for Sri Lanka and not for Indian waters. Therefore, all sighting records from published sources for which a clear date of sighting and area of sighting were available (Branch *et al.*, 2007; Ilangakoon, 2002; 2006a; Leatherwood and Reeves, 1989) were compiled separately from the strandings data. Unpublished but reliable sightings from cetacean survey reports (Ocean Alliance, 2003) and unpublished data from project reports of recent surveys undertaken by the first author (Ilangakoon, 2009; Ilangakoon and Perera, 2008; 2009) in Sri Lankan waters

Table 1
Blue whale sighting records from Sri Lanka.

Month/year	Area	No. of animals	Source
March 1985	Northeast	2	Leatherwood and Reeves (1989)
March 1985	Northeast	1	Leatherwood and Reeves (1989)
March 1985	Northeast	1	Leatherwood and Reeves (1989)
May 1985	Southwest	1	Leatherwood and Reeves (1989)
May 1985	Southwest	1	Leatherwood and Reeves (1989)
December 1985	Southwest	1	Leatherwood and Reeves (1989)
December 1985	South	1	Leatherwood and Reeves (1989)
December 1985	South	1	Leatherwood and Reeves (1989)
December 1985	South	1	Leatherwood and Reeves (1989)
February 1987	Northeast	1	Branch <i>et al.</i> (2007)
February 1987	Northeast	1	Branch <i>et al.</i> (2007)
February 1987	Northeast	3	Branch <i>et al.</i> (2007)
February 1987	Northeast	1	Branch <i>et al.</i> (2007)
February 1987	Northeast	1	Branch <i>et al.</i> (2007)
March 1987	Northeast	1	Branch <i>et al.</i> (2007)
March 1987	Northeast	1	Branch <i>et al.</i> (2007)
March 1987	Northeast	1	Branch <i>et al.</i> (2007)
March 1987	Northeast	1	Branch <i>et al.</i> (2007)
March 1987	Northeast	1	Branch <i>et al.</i> (2007)
May 1994	West	1	Ilangakoon (2002)
July 1994	West	2	Ilangakoon (2002)
August 1994	West	1	Ilangakoon (2002)
August 1994	West	1	Ilangakoon (2002)
April 2003	Southeast	2	Ocean Alliance (2003)
April 2003	West	1	Ocean Alliance (2003)
April 2003	Southeast	1	Ocean Alliance (2003)
April 2003	Southeast	1	Ocean Alliance (2003)
April 2003	Southeast	1	Ocean Alliance (2003)
April 2003	Southeast	1	Ocean Alliance (2003)
April 2003	Southeast	2	Ocean Alliance (2003)
June 2003	West	1	Ocean Alliance (2003)
October 2003	West	7	Branch <i>et al.</i> (2007)
August 2004	Northwest	2	Ilangakoon (2006a)
September 2008	South	4	C. Jayatilleke, pers.comm/pics
November 2008	South	1	Ilangakoon and Perera (2009)
November 2008	South	9	Ilangakoon (2009)
November 2008	South	2	Ilangakoon (2009)
November 2008	South	1	Ilangakoon (2009)
December 2008	South	1	Ilangakoon and Perera (2009)
January 2009	South	1	Ilangakoon (2009)
February 2009	South	4	Ilangakoon and Perera (2009)
February 2009	South	1	Ilangakoon (2009)
February 2009	South	2	Ilangakoon (2009)
February 2009	South	7	Ilangakoon (2009)
February 2009	South	5	Ilangakoon (2009)
March 2009	South	1	Ilangakoon and Perera (2009)
April 2009	South	2	Ilangakoon and Perera (2009)
April 2009	South	1	Ilangakoon and Perera (2009)
April 2009	South	3	Ilangakoon and Perera (2009)
April 2009	South	1	Ilangakoon and Perera (2009)

were included. All Sri Lankan sources are listed in Table 1. As these data are from several different surveys, the methodology is not standardised either in relation to observer effort or in terms of temporal and spatial coverage. Some of the published data used are from opportunistic observations made during oceanographic surveys where a single marine mammal observer was on board. While none of the surveys were undertaken purely for the purpose of observing blue whales, the majority were cetacean surveys.

Morphological data and behavioural observations on blue whales around Sri Lanka from published material (Alling *et al.*, 1991) as well as from recently concluded and yet unpublished surveys undertaken by the first author off southern Sri Lanka in the 2008/2009 field season

(Ilangakoon, 2009; Ilangakoon and Perera, 2009) were also examined as secondary or supplementary data. Given the general dearth of survey effort in the area, these recent and yet unpublished observations, though not quantifiable, were used to add important new perspectives to the analysis.

Strandings were examined in terms of stranding events and not in terms of the number of animals. Sightings were also primarily examined in terms of the number of separate sightings, but data on the number of animals in each sighting as well as observed behaviour were also investigated. Stranding data from India and Sri Lanka were examined by month of stranding. Sightings data from Sri Lanka were similarly examined in terms of time of year to determine when blue whales are present.

RESULTS

Seasonality of sightings and strandings are reported here through examination of primary data. Additionally, morphological characteristics and behavioural observations are considered as secondary data that support the primary data.

Seasonality of sightings and strandings

Data are available for 40 blue whale strandings on the coasts of Sri Lanka (17) and India (23) between 1894 and the present. Two older records from Sri Lanka were excluded as they did not include the stranding month. Sightings are detailed in Table 1 and summarised in Fig. 4. Accordingly, 38 records from the two countries were examined by month of stranding. The most significant factor to emerge is that blue whale strandings have occurred along the coasts of the two countries in all months of the year (Fig. 2). Overall numbers for the two countries peaked in May, but in general strandings are randomly distributed throughout the year. There are months for which strandings have been reported only from one country and not the other, but as the two countries are located very close to each other, the distinction was not considered to be significant. Most strandings have been of single animals, with a single record of two animals (a female and a calf) stranding at the same location on the west coast of Sri Lanka in 1984 (Ilangakoon, 2002).

A total of 51 sightings was available from Sri Lanka (Table 1). There are sightings in every month of the year (Fig. 3), with a clear peak from February–April and a smaller peak in November–December. Smaller numbers of sightings were recorded between May and October.

The majority (67%) of sightings were of single animals,

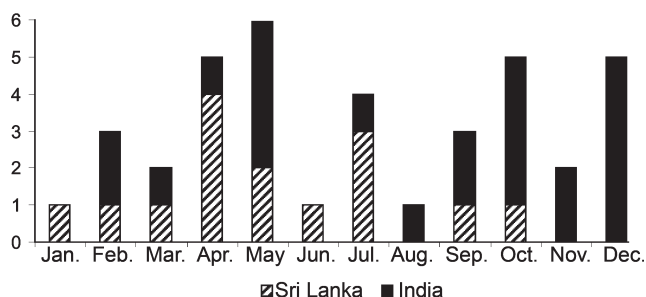


Fig. 2. Blue whale strandings in Sri Lanka and India from 1894 to the present.

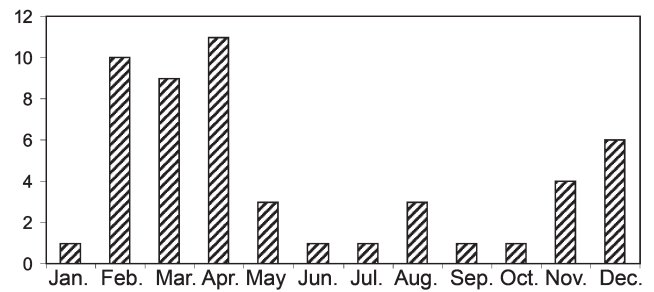


Fig. 3. Blue whale sighting events from Sri Lanka.

while 16% were of two animals together (Fig. 4). Smaller percentages of sightings were recorded for groups consisting of 3, 4, 5, 7 and 9 animals in close proximity to each other and moving in a coordinated fashion, indicating that they were part of a single unit. Most cow-calf pairs observed were among those groups.

Morphology

Kato *et al.* (2001) described three blowhole types that can be used to distinguish pygmy blue whales from Antarctic blue whales in the field: Type A, where the anterior tip of the central groove extends beyond the anterior tip of the nostril; Type B, where the anterior tip of the central groove ends at the anterior tip of the nostril and Type C, where the anterior tip of the central groove is inside the anterior tip of the nostril. During the 2008–09 field season the majority of sightings were of Type A blowholes, but at least two blue whales with a Type B blowhole were observed off southern Sri Lanka and one with a Type C blowhole was observed (Ilangakoon, unpublished data).

Several of the stranded animals from both Sri Lanka and India were close to the maximum recorded length of pygmy blue whales, 24m (Table 2), while two animals from India exceeded that length, at 26m and 28.2m respectively. The largest animal (28.2m) stranded during the austral summer (Table 2).

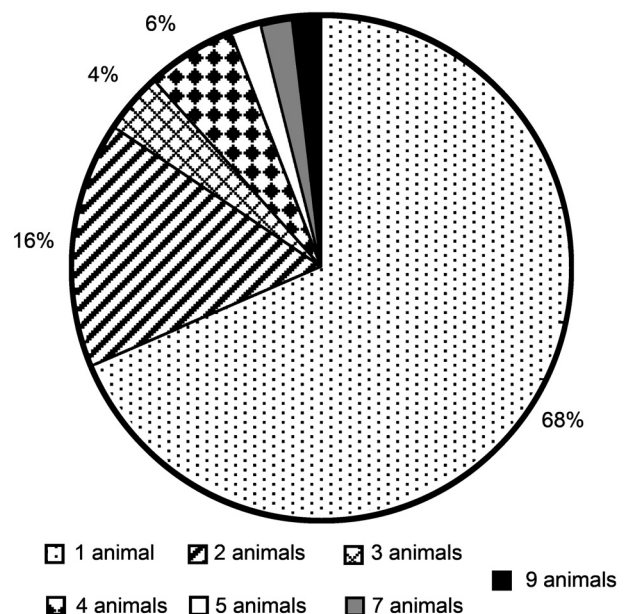


Fig. 4. Group sizes of blue whales sighted off Sri Lanka.

Table 2
Strandings of blue whales exceeding 22m in total length.

Month/year	Length (m)	Sex	Location	Source
Nov. 1927	28.2	N/A	Cochin, India.	Moses (1947)
Mar. 1939	23.7	N/A	Kathiawar, India	Moses (1947)
May 1951	22.2	N/A	Bombay, India	Chari (1951)
Dec. 1960	23.4	N/A	Gujarat, India	James and Soundararajan (1979)
May 1993	26.0	N/A	Cochin, India	James <i>et al.</i> (1993)
Jul. 1999	23.8	F	Weligama, Sri Lanka	Ilangakoon (2006)
Jun. 2009	23.3	M	Chilaw, Sri Lanka	Ilangakoon (unpublished data)

Behavioural observations

Alling *et al.* (1991) reported feeding activity in northeastern waters of Sri Lanka. Re-sighting of individually identified animals off Trincomalee in consecutive years was reported by both Leatherwood (1985) and Alling *et al.* (1991). Ilangakoon (2002) reported frequent sightings of blue whales in continental shelf waters during the south-west monsoon off the west coast of Sri Lanka in 1994. Blue whales were also observed feeding along the edge of the continental shelf between November and April during recent cetacean surveys off the south coast in the 2008–09 field season (Ilangakoon, 2009; Ilangakoon and Perera, 2009).

Feeding behavioural patterns observed in southern Sri Lanka include frequent fluke-up dives lasting 7–18 minutes, with whales resurfacing repeatedly in the same area, and subsurface skimming with occasional surface lunging. Alling *et al.* (1991) reported whales diving and resurfacing in pairs; the same synchronised diving behaviour was observed off the south coast in the 2008–09 field season (Ilangakoon, 2009; Ilangakoon and Perera, 2009), in three separate sightings. These pairs consisted of animals of similar size, as opposed to cow-calf pairs, as also observed by Alling *et al.* (1991) in the northeast.

In southern Sri Lanka the most frequently observed surfacing pattern for undisturbed adult blue whales was the appearance of the head followed by rounding of the back, showing the dorsal fin and dorsal keel with the tail stock arched and frequent lifting of the flukes 'fluking up' before submerging. The diving behaviour of mother-calf pairs off the south coast was similar in all sightings, with calves diving in synchrony with the accompanying adult, but while the adults usually raised their flukes at the onset of a dive, none of the calves raised their flukes above the surface but only displayed an arched tail stock. The dives of these cow-calf pairs were generally short in duration, lasting from 3 to 9 minutes.

Alling *et al.* (1991) noted that the blue whales seen in Sri Lanka often lifted their flukes above the water before they dived, allowing fluke photographs to be taken for identification purposes. In observations during the 2008–09 field season adult blue whales off the south coast raised their flukes out of the water on approximately 70% of dives. Only when diving hurriedly due to disturbances caused by whale watching boats did they dive without fluking up.

Acoustic recordings made in the Indian Ocean have enabled the identification of three distinct blue whale call

types (Alling *et al.*, 1991; Ljungblad *et al.*, 1998; McCauley *et al.*, 2001) attributed to pygmy blue whales because they have only been recorded north of 60°S. One of these call types was first recorded in 1984 off northeast Sri Lanka (Alling *et al.*, 1991) and subsequently the same type of call was recorded near Diego Garcia, south of the equator (McDonald *et al.*, 2006; Stafford *et al.*, 2005). However, these calls are distinct from pygmy blue whale calls recorded off Madagascar and Australia (Branch *et al.*, 2007).

Cow-calf pairs were observed off the northeastern coast of Sri Lanka in both 1983 and 1984 in February–March (Alling *et al.*, 1991). Likewise, in the 2008–09 field season cow-calf pairs were encountered off the south coast on two occasions, in November and February. A sighting on 11 November 2008 was of particular interest as two cow-calf pairs were sighted in close proximity to each other among a feeding aggregation of nine individuals (Ilangakoon, 2009). Additionally, there is a single record of a female and calf stranding together on the west coast of Sri Lanka in February 1984 (Ilangakoon, 2002).

A blue whale was observed breaching repeatedly off southern Sri Lanka and photographed from a distance by whalewatchers on 10 March 2009 (Fig. 5).

DISCUSSION

This analysis demonstrates that blue whales are present in the Northern Indian Ocean waters around Sri Lanka and India during all months of the year. While strandings in both countries are distributed throughout the year, the peaks in sightings in certain months may not reflect the actual abundance of blue whales in different months of the year, but rather the sea conditions suitable for surveys to be carried out and opportunistic observations to be made. The small numbers of sightings from May to October are certainly the result of the south-west monsoon, which prevails during this period and makes cetacean surveys off the west and south coasts of Sri Lanka nearly impossible from May to August and difficult due to unpredictable seas in September–October. Therefore, although the peaks and troughs in sightings may not be indicative of the actual abundance of animals present, they show that blue whales were present in the waters around Sri Lanka during periods when survey effort was minimal.

The general view of blue whale migration is that Antarctic blue whales remain in waters south of 55°S in the austral summer and venture northwards into temperate waters, e.g. around southern Africa, in winter, while pygmy blue whales do not migrate to Antarctic waters but generally remain north of 54°S at all times (Ichihara, 1966; Kato *et al.*, 1995). Accordingly, it has been assumed that blue whales in the Northern Indian Ocean are all pygmy blue whales (Alling *et al.*, 1991; Mikhalev, 2000; Yochem and Leatherwood, 1985) although their taxonomic status is as yet uncertain due to the extremely limited number and nature of taxonomic studies there.

Some authors have suggested that blue whales in the Northern Indian Ocean undertake a roughly east-west migration, taking advantage of monsoon upwellings around Somalia and Arabia, from May to October, dispersing eastwards and southwards towards the Maldives and Sri



Fig. 5. Breaching blue whale off southern Sri Lanka.

Lanka from November to April (Anderson, 2005; Anderson *et al.*, 1999). Previous surveys limited to the water off northeast Sri Lanka found blue whales to be rare around Sri Lanka between May and October (Alling *et al.*, 1991; Leatherwood *et al.*, 1984). Based on these reports and the seasonal presence of blue whales in the waters around the Maldives, it was suggested that the animals passing the Maldives from November to April were the same as those that appeared off the northeast coast of Sri Lanka from December to April (Anderson, 2005). Several authors have suspected that at least a part of the blue whale population in the tropical Northern Indian Ocean may remain year-round in high-productivity areas including the waters off Sri Lanka (Branch *et al.*, 2007; Ilangakoon, 2002; 2006b). Subsequent studies off the Sri Lankan west and south coasts (Branch *et al.*, 2007; Ilangakoon, 2006a; 2009; Ilangakoon and Perera, 2009; Ocean Alliance, 2003) have confirmed that blue whales are present in Sri Lankan waters at all times of the year. The east-west movement theory does not fit neatly with these findings or with the present analysis, which takes into account both live sightings and strandings. It fails to explain the high sighting rates or how and why blue whales are present around Sri Lanka and India throughout the year. Branch *et al.* (2007) suggested that the classic theory of migration patterns for blue whales may be in need of revision and we agree with this suggestion insofar as it applies to the Northern Indian Ocean population.

Based on the currently examined data an alternative hypothesis is that the blue whales in this part of the Northern Indian Ocean undertake extremely localised movements within a small but highly productive, monsoon-driven feeding area. While blue whale ecology in the Northern Indian Ocean is poorly understood, a few feeding areas have been identified in the Indian Ocean, including off Sri Lanka in the past two decades (Alling *et al.*, 1991; Gill, 2002; Ilangakoon, 2009). Sri Lanka has a relatively narrow continental shelf (Wijeyananda, 1997) and, being located just south of the Indian Subcontinent, with no landmass to its south, is affected by both the south-west and north-east monsoons (Shankar *et al.*, 2002; Vinayachandran *et al.*, 2003). The north-east monsoon affects the northeast coast of Sri Lanka and adjacent waters from November to March, the time when blue whales are abundant in the waters around Trincomalee, as reported by Alling *et al.* (1991), who suggested that these waters are an important feeding ground. The outfall of Sri Lanka's largest river, the Mahaweli, is

located in Trincomalee and deposits the largest volume of nutrient-rich waters at this time of the year, enhancing productivity in the area. Re-sightings of individually identified animals in consecutive years also indicate site fidelity to these productive feeding grounds. Vinayachandran and Yamagata (1998) suggested that a thermal dome forms east of Sri Lanka from May to July, modifying the upper ocean thermal structure and maintaining cooler water temperatures within it. As a result, cooler, nutrient-rich water is brought to the surface by open-ocean upwelling within this dome. Though no blue whale sightings have been reported from the northeastern waters during this period (Alling *et al.*, 1991), two strandings have occurred in May (Ilangakoon, 2006b) and it is possible that the whales move further offshore at this time in order to take advantage of the open-ocean upwellings created by the thermal dome. In doing so, they may have moved out of the area covered by the surveys in 1983 and 1984. Concurrently, the south-west monsoon creates upwelling and nutrient enrichment through river outfalls off the south and west coasts from May to September and localised upwelling occurs between the southern tip of India and Sri Lanka (Rao *et al.*, 2006). Both sightings and strandings have been recorded from the west, northwest, south and southeast coasts during the period of the south-west monsoon (Ilangakoon, 2002; 2006a; 2006b; 2009; Ilangakoon and Perera, 2009; Ocean Alliance, 2003). However, sightings and feeding off the south coast are not limited to this monsoon period but have also been recorded during the north-east monsoon (Ilangakoon, 2009; Ilangakoon and Perera, 2009), indicating that feeding opportunities are not limited to monsoon-related upwelling.

The implications are that blue whales around Sri Lanka and India exploit seasonal upwelling-related food sources and at least a part of the population is able to find enough sustenance there throughout the year. Ballance and Pitman (1998) have also suggested that blue whales in the Western Indian Ocean and Eastern Tropical Pacific track localised areas of high productivity to take advantage of feeding opportunities in low latitudes. Based on the data presented here it is suggested that in the Northern Indian Ocean similar feeding opportunities allow blue whales to remain in low-latitude waters around Sri Lanka throughout the year. Based on work in other low-latitude areas, it has also been suggested that certain populations of blue whales, along with other baleen whales, remain in such waters throughout the year (Bannister, 2002; Hucke-Gaete *et al.*, 2004; Mikhalev,

1997). Remaining throughout the year in areas with adequate food is also reported for Antarctic blue whales, as catch data and acoustic recordings have shown that some blue whales over-winter in Antarctic waters instead of migrating north (Harmer, 1931; Hinton, 1915; Risting, 1928; Sirovic *et al.*, 2004).

Given the above, questions arise about the taxonomic status and stock affinities of these animals. However, owing to the lack of historical data for these waters, it is not known if this year-round presence has been a constant phenomenon over the ages. If the animals have been non-migratory over long periods of time, it is even possible that they are of an entirely different subspecies from the two currently recognised for the Southern Ocean and Indian Oceans. Mikhalev (2000) concluded that the Northern Indian Ocean blue whale population is isolated and suggested further studies to determine the extent of this isolation, which is in agreement with this study. Further, a different species, *B. indica* (Blyth, 1859), described in the mid 19th century from the Northern Indian Ocean, though currently not accepted as a species, warrants re-evaluation as a possible subspecies, *B. m. indica*.

Uncertainty regarding the taxonomic status of these Northern Indian Ocean blue whales is compounded by the limited morphological observations on blue whales available from Sri Lanka and India. According to Kato *et al.* (2001), the Type B blowhole is most common in Antarctic blue whales, while Type A is peculiar to pygmy blue whales and Type C is occasionally seen in pygmy blue whales. Contrary to what may be expected, two animals sighted off southern Sri Lanka in 2008–09 had Type B blowholes. Likewise, it is accepted that the pygmy blue whale does not exceed 24.1 m in total length, while Antarctic blue whales can attain lengths of over 30 m (Branch *et al.*, 2007; Rice, 1998; Sears and Perrin, 2009). Some of the stranded animals in Sri Lanka and India were very large, with a stranding of the largest animals during early austral summer, when, according to the classic migration theory, Antarctic blue whales should be feeding in Antarctic waters. However, it has already been noted that there is uncertainty regarding the accuracy of length measurements in the earlier strandings as it is not known how the measurements were made.

Behavioural observations add weight to the possibility that the blue whales around Sri Lanka are different from blue whales found elsewhere. Surfacing patterns of undisturbed adult blue whales observed off southern Sri Lanka are different from surfacing patterns typical of pygmy blue whales, wherein the dorsal fin and keel are not always seen in the surfacing sequence (Kato *et al.*, 2001). In Sri Lanka the dorsal fin and arched tail stock were always seen and often the flukes were also seen before submergence. This is a surfacing pattern more commonly seen in the Antarctic blue whale. The frequent fluking behaviour reported from the northwest and south of Sri Lanka during different studies is not typical of blue whales described from elsewhere in the world. Similar percentages (73%) have been recorded only from the Maldives (Anderson, 2005), which is also in the Northern Indian Ocean and in close proximity to the present study area. Blue whales are generally reported to fluke up on only 18% of dives (Sears and Perrin, 2009), but in Sri Lanka this behaviour is observed on a much higher

percentage (70%) of dives. Fluking up is a behavioural characteristic that may simply represent prevailing motivation, such as feeding, and hence these observations are invoked here only as secondary data that indicate an unusual form of behaviour.

Acoustic data suggest some sort of north-south movement of animals between Sri Lanka and Diego Garcia, south of the equator and it is therefore possible that only a part of the blue whale population in the Northern Indian Ocean around Sri Lanka and India remains there throughout the year, while some animals may undertake longer migrations. This also leads to questions regarding blue whale breeding areas in the Indian Ocean because little is known about where either of the presently accepted subspecies calve or mate (Mackintosh, 1966; Stafford *et al.*, 2004). Though it has been assumed that Antarctic blue whales migrate to temperate mating and calving areas in the winter (Branch *et al.*, 2007), the actual areas where they breed in the Indian Ocean have yet to be identified (Sears and Perrin, 2009). Likewise, little is known about the breeding areas of the pygmy blue whale in the Indian Ocean. While cow-calf pairs were observed between November and February off southern Sri Lanka, similar sightings have been recorded south of Madagascar in December (Best *et al.*, 2003). Mikhalev (2000) recorded late prenatal stage fetuses and those in the early stages of development in catches from the Arabian Sea in November–December and concluded that Northern Indian Ocean blue whales have a breeding cycle six months out of phase with populations in the south. All the sightings of cow-calf pairs off Sri Lanka in different years, despite limited survey effort and the single stranding of a cow-calf pair, raise questions as to whether the waters around Sri Lanka could be a blue whale breeding area in addition to being a feeding area. Within the past decade, a blue whale feeding and nursing ground was discovered near Chile in the Pacific Ocean (Hucke-Gaete *et al.*, 2004) and the waters near Sri Lanka may be similarly important in the Indian Ocean.

It has been noted that vigorous surface activity such as raising the body high out of the water, porpoising forward and even occasionally breaching is possibly a part of blue whale mating behaviour (Sears and Perrin, 2009) and the repeated breaching behaviour of a blue whale off southern Sri Lanka in March 2009 is of interest in this respect. It has also been reported previously that lactating pygmy blue whale females with large calves are observed in the same regions where mating occurred (Mikhalev, 2000), strengthening the possibility that the waters around Sri Lanka are of importance to Northern Indian Ocean blue whales for breeding purposes. Breeding around Sri Lanka or somewhere near it could also explain blue whales' year-round presence there. It is possible that calving females remain throughout the year while other animals of the same population migrate southwards seasonally towards Diego Garcia, but not far enough to mingle with other reproductive groups.

All the foregoing indicates that the waters around Sri Lanka and India are ecologically important to blue whales and leads to the question as to whether these blue whales in the Northern Indian Ocean belong to either of the presently recognised subspecies or are of an entirely different subspecies. It is indeed curious that they display movement patterns similar to those of pygmy blue whales, certain morphological

characteristics similar to those of Antarctic blue whales and some anomalous behavioural characteristics. Another possibility, however, is that animals from two different subspecies use these waters without intermingling, as has been reported from areas in the Eastern Tropical Pacific near Chile and Peru (Berzin, 1978; Donovan, 1984; Ichihara, 1981), where blue whales are also found year-round (Palacios, 1999; Reilly and Thayer, 1990), as in the vicinity of Sri Lanka.

The present data clearly raise more questions than provide answers in relation to the taxonomic affinities of the Northern Indian Ocean blue whales. Taxonomic investigations on the blue whales around Sri Lanka and India are urgently needed. This is particularly important as populations of both the Antarctic blue whale and, to a lesser extent, the pygmy blue whale are considerably depleted due to whaling in the past (Branch *et al.*, 2004) and are recovering only slowly. The IUCN Red List of threatened species (IUCN, 1996) lists the Antarctic blue whale as 'Endangered', while the pygmy blue whale is currently listed as 'Data Deficient' due to its uncertain status. Accordingly genetic studies on Northern Indian Ocean animals should be considered a matter of priority in order to compare their genetic affinities with animals from other regions and to resolve their taxonomic status. Photo-identification could also add valuable information in relation to movement patterns and habitat use in the long-term. Likewise, little is known about what blue whales actually feed on in this area. Examination of faeces and plankton hauls in the vicinity of feeding animals should provide valuable information on feeding habits. Multi-disciplinary studies are therefore needed. Such knowledge could have implications for the conservation, long-term management and maintenance of genetic diversity of blue whales in the Northern Indian Ocean.

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Seasonal distribution, movements and taxonomic status of blue whales (*Balaenoptera musculus*) in the northern Indian Ocean

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ABSTRACT

There is a distinct population of blue whales, *Balaenoptera musculus*, in the northern Indian Ocean. The taxonomic status of these animals has long been uncertain, with debate over whether this population represents a distinct subspecies, and if so which name should apply. They have most frequently been assigned to *B. musculus brevicauda*, but are currently considered to be *B. m. indica*. The movements of these blue whales within the northern Indian Ocean are poorly understood. This paper reviews catches ($n = 1,288$), sightings ($n = 448$, with a minimum of 783 animals), strandings ($n = 64$) and acoustic detections ($n = 6$ locations); uses ocean colour data to estimate seasonality of primary productivity in different areas of the northern Indian Ocean; and develops a migration hypothesis. It is suggested that most of these whales feed in the Arabian Sea off the coasts of Somalia and the Arabian peninsula during the period of intense upwelling associated with the southwest monsoon (from about May to October). At the same time some blue whales also feed in the area of upwelling off the southwest coast of India and west coast of Sri Lanka. When the southwest monsoon dies down in about October–November these upwellings cease. The blue whales then disperse more widely to eke out the leaner months of the northeast monsoon (during about December to March) in other localised areas with seasonally high productivity. These include the east coast of Sri Lanka, the waters west of the Maldives, the vicinity of the Indus Canyon (at least historically), and some parts of the southern Indian Ocean. The data are consistent with the hypothesis that at least some of the blue whales that feed off the east coast of Sri Lanka in the northeast monsoon also feed in the Arabian Sea during the southwest monsoon. These whales appear to migrate eastwards past the north of Maldives and south of Sri Lanka in about December–January, returning westwards in about April–May.

KEYWORDS: BLUE WHALE; INDIAN OCEAN; STRANDINGS; SANCTUARIES; INCIDENTAL SIGHTINGS; MIGRATION

INTRODUCTION

'[Blue] whales are great travellers; a study of their distribution is largely a study of their migrations ...'
Mackintosh (1966)

There appears to be a distinct population of blue whales, *Balaenoptera musculus*, in the northern Indian Ocean (NIO) (Blyth, 1859; Branch *et al.*, 2007b; Yochem and Leatherwood, 1985). These whales hold a particular fascination for marine biologists for at least three reasons.

First, the taxonomy of these animals has long been unresolved. General understanding has been that they were probably pygmy blue whales, *Balaenoptera musculus brevicauda* (Ichihara, 1966) or of unknown taxonomic status (Alling *et al.*, 1991; Gordon *et al.*, 1986; Jefferson *et al.*, 2008; Rice, 1998; Yochem and Leatherwood, 1985). However, it is likely that they are a distinct subspecies, *B. m. indica* (Blyth, 1859). Certainly Blyth (1859) intended the name *indica* to apply to the common 'Great Rorqual' of the northern Indian Ocean. While there has been recent progress, uncertainty remains (Branch *et al.*, 2007b; LeDuc *et al.*, 2007; Perrin *et al.*, 2010; Rice, 1998), and we return to this issue in the Discussion.

Secondly, the NIO population of blue whales was subject to a short but intense period of illegal whaling by the former Soviet Union during 1963–1966. Catches were made during October–December (mostly November) as Soviet whaling fleets sailed south from Odessa for the Antarctic whaling

season. At least 1,294 blue whales were taken from the Arabian Sea (Mikhalev, 1996; Mikhalev, 2000). While catch data were reported in Russian in 1982 (Zemsky and Sazhinov, 1994) they were not reported to the International Whaling Commission (IWC) at the time, nor were they made more widely available until much later (Berzin, 2008; Brownell, 1995; Clapham and Ivashchenko, 2009; Mikhalev, 1996; Mikhalev, 2000; Yablokov, 1994). The extent of population depletion and subsequent recovery are unknown. Although Zemsky and Sazhinov (1994) suggested that 90% of the initial stock may have been removed in the 1960s, their data do not agree with that of Mikhalev (1996; 2000), and recent sightings rates are relatively high in comparison with other regions (Branch *et al.*, 2007b). Reeves *et al.* (2004) highlighted the understanding of NIO blue whale population status and trends as priorities for research.

The third reason why NIO blue whales are of particular interest is that they appear to be concentrated in tropical waters year-round. This is in contrast to most other populations of blue whales which have been thought to typically (though not invariably) migrate between higher latitude summer feeding grounds, and lower latitude winter breeding areas (Branch *et al.*, 2007b; Burtenshaw *et al.*, 2004; Mackintosh, 1966; Mackintosh and Wheeler, 1929). The NIO does not extend north to the Arctic. But so entrenched was the idea that blue whales follow this typical migration strategy, that for decades it was assumed that NIO

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blue whales must migrate seasonally either to the Southern Ocean (de Silva, 1987; Deraniyagala, 1960) or to the north Pacific (Mörzer-Bruyns, 1971; Slijper *et al.*, 1964).

It now appears that most of these whales are resident within the NIO. This understanding is based on year-round sightings (Branch *et al.*, 2007b; Yochem and Leatherwood, 1985) and strandings (Anderson *et al.*, 1999; Branch *et al.*, 2007b; Ilangakoon and Sathasivam, 2012). There also appear to be gaps in the distribution of blue whales to both the south and east (Branch *et al.*, 2007b; Kasuya and Wada, 1991; Miyashita *et al.*, 1995; Zemsky and Sazhinov, 1994). For example, Zemsky and Sazhinov (1994) noted an absence of reports by Soviet whalers of blue whales from the central latitudes of the Indian Ocean and Bay of Bengal 'even though these regions were frequently visited by our boats' and concluded 'that pygmy blue whales of the Arabian Sea ... form a local-subpopulation and their migration to the south is insignificant'. Although there is still some uncertainty (see Discussion), NIO blue whales also show distinctive biological characteristics, including: somewhat shorter length at sexual maturity (Branch and Mikhalev, 2008); breeding seasonality consistent with that of a northern hemisphere population (Mikhalev, 1996; 2000); low frequency of shark bite scars compared with southern Indian Ocean pygmy blue whales (Mikhalev, 2000); and unique 'Sri Lanka' call type (Alling and Payne, 1987; Alling *et al.*, 1991; McDonald *et al.*, 2006; Stafford *et al.*, 2011; Tolstoy and Bohnenstiehl, 2002).

Despite being largely restricted to the NIO, these blue whales do appear to undertake intra-regional migrations

(Anderson, 2005; Anderson *et al.*, 1999). These migrations are the main subject of this paper.

METHODS

Study area

This study concentrates on the Maldives, southern India and Sri Lanka, but encompasses all of the northern Indian Ocean, west of 100°E and north of 10°S (Fig. 1). This southern boundary marks the approximate position of the thermal equator and a major oceanographic front (Longhurst, 1998; Wyrtki, 1973). These boundaries also enclose all of the discrete grouping of blue whale records in the Arabian Sea and adjacent waters (Branch *et al.*, 2007a; Mikhalev, 1996). Although this area extends to 10°S, for convenience we refer to it here as the northern Indian Ocean (NIO).

The meteorology of this region is dominated by the monsoons. During the southwest (SW or boreal summer) monsoon, winds over the Arabian Sea are predominantly southwesterly or westerly, blowing from the Horn of Africa towards India. During the northeast (NE or boreal winter) monsoon winds over the Arabian Sea are predominantly northeasterly. Winds in the NE monsoon are generally much lighter than in the SW monsoon. The approximate durations of the two monsoons are:

SW: May to October; and

NE: December to March.

The early months of both monsoons are generally windier and wetter than the later months. As a result, those later months are sometimes referred to as the post-monsoons,

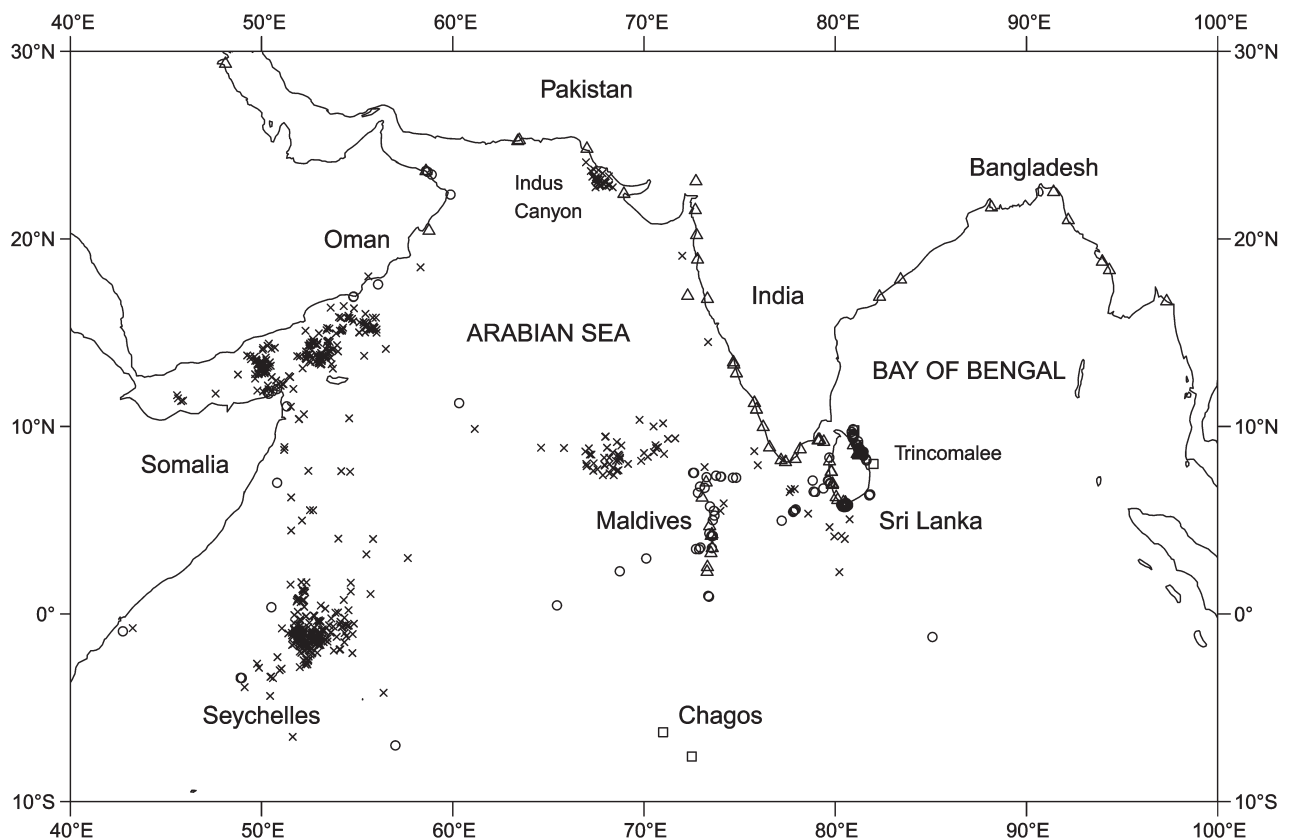


Fig. 1. Northern Indian Ocean location map, showing all known positions of blue whales catches (crosses, $n = 1,288$), sightings (circles, $n = 396$), strandings (triangles, $n = 64$) and acoustic detections (squares, $n = 6$ locations). Data from prior to 1973 are in grey; data after 1973 are in black. This figure is updated from Branch *et al.* (2007b).

although wind direction remains more-or-less constant throughout each season. April and November are inter-monsoon months, when winds are generally variable. Monsoon timings vary slightly according to latitude. Due to the Coriolis force, the NE monsoon becomes the NW monsoon south of the equator while the SW monsoon derives from the austral SE monsoon.

The oceanography of this region is strongly affected by these seasonally reversing monsoon winds (Hydrographic Office, 2007; Molinari *et al.*, 1990; Schott, 1983; Schott and McCreary, 2001; Shankar *et al.*, 2002; Swallow, 1984; Wyrtki, 1973). During the SW monsoon, the strong winds blowing across the Arabian Sea towards India force the development of a clockwise circulation and promote upwelling off the coasts of Somalia and southwest Arabia. At the eastern boundary of the Arabian Sea (i.e. along the west coast of India) this anticyclonic circulation flows southward as the West Indian Coastal Current and then eastward around the south of Sri Lanka where it joins with the Southwest (or Summer or Indian) Monsoon Current flowing into the Bay of Bengal. Within the Bay of Bengal itself, the East Indian Coastal Current flows northwards along the east (Coromandel) coast of India.

During the NE monsoon, most currents in the region reverse. The eastward flowing Southwest Monsoon Current is replaced by the westward flowing North Equatorial Current. The West Indian Coastal Current reverses, and flows northward along the southwest Indian (Malabar) coast. The East Indian Coastal Current reverses and flows southward for only a short period during the early part of the NE monsoon, being northward flowing for the remainder of the year.

In brief, throughout much of the NIO the general direction of flow in the SW monsoon is to the east, while during the NE monsoon it is to the west (although there are counter-currents south of the Equator). During the SW monsoon these currents induce significant upwellings off the coasts of Somalia, southwest Arabia and southwest India, as a result of which there are major plankton blooms in these regions at this season (Fig. 2). The upwellings, and their associated plankton blooms, die down during the NE monsoon.

Blue whale data

This study is largely based on published records of blue whale catches, sightings and strandings, most of which were previously compiled and critically scrutinised by Branch *et al.* (2007b) (see also de Silva, 1987; Leatherwood, 1986; Sathasivam, 2000). The wide-ranging study of Branch *et al.* (2007b) only briefly discussed the northern Indian Ocean, which we consider in more detail here. The Indian Ocean datasets they used (and we analyse further here) included: (a) Soviet catch data for the period 1963–66 (Mikhalev, 1996; 2000; Yablokov, 1994), which were made available by the Secretariat of the IWC; (b) published and previously unpublished records of sightings, the sources of which were summarised by Branch *et al.* (2007b: Appendix 2); (c) published and previously unpublished records of strandings, the details of which were tabulated by Branch *et al.* (2007b: Appendix 3); and (d) acoustic records, again documented by Branch *et al.* (2007b: Appendix 5).

In this study the same datasets have been used, with some

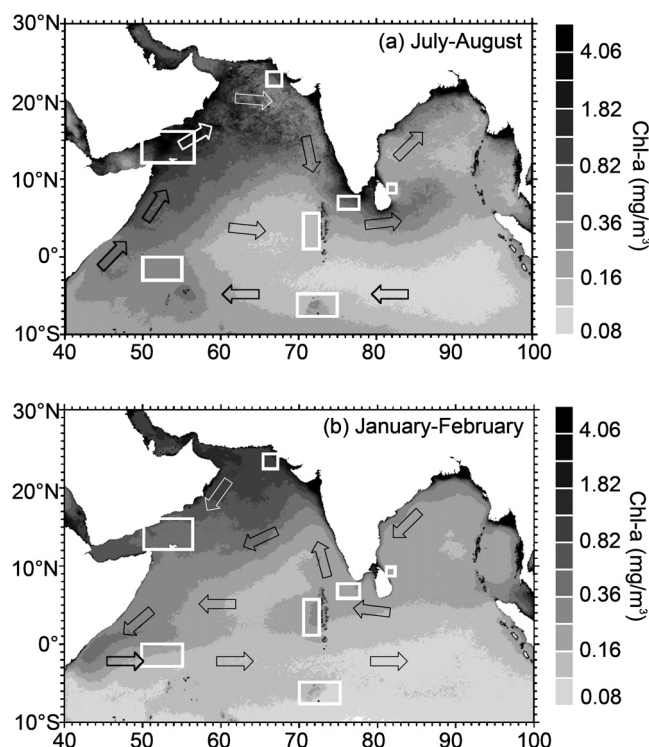


Fig. 2. Chlorophyll-a concentrations in the northern Indian Ocean (from SeaWiFS ocean colour data, see text for details). Boxes enclose areas for which seasonality of Chl-a have been estimated (see text for details). Arrows show schematic representation of major surface current directions. (a) July–August (SW monsoon). (b) January–February (NE monsoon).

additions and minor alterations (Fig. 1). Leatherwood *et al.* (1984) reported nine sightings off NE Sri Lanka in February 1983, not May as recorded by Branch *et al.* (2007b: Table A2). It should also be noted that the position of the stranding reported by Lal Mohan (1992) from ‘Paravana (12°10′N 76°30′E) near Calicut on 29-9-1988’ must be incorrect since that location is inland; here a revised position of 11°15′N 75°47′E was used, which is near Calicut. Details of ten sightings from northeastern Sri Lanka by A.D. Ilangakoon are excluded from this study; they are instead included in the review of Ilangakoon and Sathasivam (2012). Some additional information has been incorporated in this review, including the published records of sightings by Carwardine (1994) and Afsal *et al.* (2008), and of one stranding each by Jayasankar *et al.* (2006) and Gray (2009).

New and previously unreported observations have also been collected. Two sightings from NE Sri Lanka in March 2004 have been included, which were supported by photographs (Chris Paporakis, pers. comm.). One of the authors (RCA, accompanied on two days by AA) visited southern Sri Lanka in April 2007, specifically to test the hypothesis that blue whales were migrating past at that time of year. Observations were made from Dondra Head (the southernmost point of Sri Lanka) on 18 and 19 April, and from a boat at sea off Dondra on 21 and 23 April 2007. Subsequently, records of blue whale sightings off southern Sri Lanka up to April 2009 were collected. These were based on observations by two of the authors (RCA and AA, $n = 117$ encounters), together with logbook records of a commercial boat tour company (Mirissa Watersports, $n = 96$ encounters), after the crew had received training in species identification

Table 1

Sightings of blue whales on voyages between India, Sri Lanka and Maldives. SW monsoon May to October. NE monsoon December to March.

Dates	Vessel	Start	Finish	Blue whales (Sightings (individuals))		Source
				ID definite	ID uncertain	
Jan. 3–5, 2004	<i>Hebridean Spirit</i>	Colombo	Malé	0	0	RCA (unpublished data)
Jan. 11–13, 2007	<i>Hebridean Spirit</i>	Colombo	Malé	0	0	RCA (unpublished data)
Jan. 13–14, 2002	<i>Hebridean Spirit</i>	Cochin	Malé	0	0	RCA (unpublished data)
Jan. 14–16, 2007	<i>Hebridean Spirit</i>	Malé	Cochin	0	0	RCA (unpublished data)
Jan. 15–17, 2002	<i>Hebridean Spirit</i>	Maldives	Galle	0	0	RCA (unpublished data)
Jan. 16–17, 2003	<i>Hebridean Spirit</i>	Cochin	Malé	0	0	RCA (unpublished data)
Jan. 18–20, 2003	<i>Hebridean Spirit</i>	Maldives	Galle	0	0	RCA (unpublished data)
Jan. 18–21, 2007	<i>Hebridean Spirit</i>	Kannur	Galle	0	0	RCA (unpublished data)
Jan. 20–25, 1983	<i>Tulip</i>	Colombo	Colombo	0	0	Alling <i>et al.</i> (1983)
Jan. 23–24, 2003	<i>Hebridean Spirit</i>	Colombo	Vilinjani	0	0	RCA (unpublished data)
Jan. 27–28, 2002	<i>Hebridean Spirit</i>	Cochin	Malé	0	0	RCA (unpublished data)
Jan. 31, 2003	<i>Hebridean Spirit</i>	Vilinjani	Colombo	0	0	RCA (unpublished data)
Feb. 4–5, 2003	<i>Hebridean Spirit</i>	Galle	Malé	0	0	RCA (unpublished data)
Feb. 9–12, 1982	<i>Tulip</i>	Arabian Sea	Colombo	0	0	Alling <i>et al.</i> (1982)
Feb. 12–17, 1984	<i>Tulip</i>	Malé	S of Sri Lanka	0	0	Alling <i>et al.</i> (1984)
Feb. 21–23, 2007	<i>Hebridean Spirit</i>	Colombo	Malé	0	0	RCA (unpublished data)
Feb. 19–Mar. 16, 1982	<i>Tulip</i>	Colombo	Colombo	0	0	Alling <i>et al.</i> (1982)
Mar. 29–30, 2003	<i>Odyssey</i>	Colombo	S of Sri Lanka	0	0	Ocean Alliance (2003)
Apr. 2–4 2003	<i>Odyssey</i>	S of Sri Lanka	Colombo	0	0	Ocean Alliance (2003)
Apr. 19–20, 1983	<i>World Discoverer</i>	Colombo	Malé	0	0	Leatherwood <i>et al.</i> (1984)
Apr. 21, 1995	<i>Malcolm Baldrige</i>	8° Channel	Colombo	1 (1)	1 (2)	Ballance <i>et al.</i> (1996)
Apr. 26–30, 2003	<i>Odyssey</i>	S of Sri Lanka	Colombo	0	0	Ocean Alliance, (2003)
Apr. 28, 1995	<i>Malcolm Baldrige</i>	Colombo	8° Channel	0	0	Ballance <i>et al.</i> (1996)
May 14–16, 2003	<i>Odyssey</i>	Colombo	Colombo	0	0	Ocean Alliance (2003)
May 23–27, 2003	<i>Odyssey</i>	Colombo	Colombo	0	0	Ocean Alliance (2003)
Jun. 16–17, 2003	<i>Odyssey</i>	Colombo	Colombo	1	0	Ocean Alliance (2003)
Jun. 16–21, 1995	<i>Malcolm Baldrige</i>	8° Channel	Malé	8 (13)	9 (12)	Ballance <i>et al.</i> (1996)
Nov. 6–27, 1983	<i>Tulip</i>	S of Sri Lanka	Malé	0	0	Whitehead <i>et al.</i> (1983)
Dec. 4–13, 1983	<i>Tulip</i>	Malé	Malé	0	0	Whitehead <i>et al.</i> (1983)

Table 2

Sightings of blue whales during crossings from Maldives to Seychelles (Malé to Mahé). January–February is NE monsoon (NW monsoon south of the Equator); April is inter-monsoon.

Dates	Vessel	Blue whales (Sightings (individuals))		Source
		ID definite	ID uncertain	
Jan. 21–25, 2004	<i>Hebridean Spirit</i>	2 (3)	0	RCA (unpublished data)
Feb. 21–24, 2010	<i>Discovery</i>	1 (2)	1 (1)	RCA (unpublished data)
Feb. 24–28, 2007	<i>Hebridean Spirit</i>	1 (2)	0	RCA (unpublished data)
Apr. 21–24, 1983	<i>World Discoverer</i>	1 (4)	0	Leatherwood <i>et al.</i> (1984)

from the senior author. In addition, RCA has completed a number of crossings between Maldives, Sri Lanka and India, and between Maldives and Seychelles on vessels of opportunity (cruise ships) during which cetacean watches were maintained. Details are summarised in Tables 1 and 2.

In total, records of 1,288 blue whale catches, 448 sightings, 64 strandings, and acoustic detections from 6 locations in the NIO have been compiled. For 296 sightings, numbers of individuals were recorded ($n = 631$, mean = 2.1 individuals per sighting). For the remaining 152 sightings, numbers of individuals were not available. Thus for all 448 sightings a minimum of 783 (631+152) individuals were recorded (note that sightings were compiled over several decades and there are known to have been some re-sightings, so this does not imply anything about population size). Only 396 sightings were recorded with location data of sufficient accuracy to be included in Figs 1 and 4.

Acoustic studies have demonstrated a unique call type for NIO blue whales. This was first recorded off Sri Lanka

(Alling and Payne, 1987; Alling *et al.*, 1991) and subsequently around the Chagos Archipelago (Tolstoy and Bohnenstiehl, 2002). Until recently such studies were of limited value for understanding seasonality of NIO blue whales. However, while this paper was in review, an analysis of two years' monitoring of blue whale calls around Chagos became available (Stafford *et al.*, 2011) and is of great relevance for this investigation.

A number of limitations in our data can be noted. In particular, it was not possible to standardise effort. Our analyses of sightings are therefore based on raw incidental data, not sightings rates. This can clearly lead to problems of interpretation. We do, however, have an understanding of seasonal variations in sea conditions (which affect sightability), and some knowledge of relative amounts of effort between subregions and seasons. For example, in both Sri Lanka and the Maldives, more sightings effort has been conducted in the NE monsoon (which is relatively calm, particularly in its later months) than in the generally much

rougher SW monsoon. Further analysis as more detailed data become available is planned to address this shortfall. It should also be noted that blue whale strandings depend, among other things, on wind and current directions, which in this region vary dramatically with the seasons.

Chlorophyll-a concentrations

Blue whales feed almost exclusively on euphausiids. Although some information is available (e.g. Brinton and Gopalakrishnan, 1973), the seasonal distribution of euphausiids in the tropical Indian Ocean is not known in sufficient detail to be of direct use in this study. We have therefore used chlorophyll-a concentrations (hereafter Chl-a) as a proxy for blue whale food. There are limitations to this approach (e.g. that Chl-a may not adequately reflect primary productivity; that deep chlorophyll maxima may not be adequately accounted for in the data used; that there will be lags between Chl-a and euphausiid abundance peaks; and that there may be spatial and temporal variability in any relationship between Chl-a and euphausiid abundance). Nevertheless, in the absence of more appropriate data, this approach does allow a first investigation of some factors influencing the seasonal distribution of blue whales in the NIO, and highlights areas for further study.

Chl-a concentrations were quantified using monthly composites of the 9-km Level 3 SeaWiFS data, from the NASA Goddard Space Flight Center (GSFC) Distributed Active Archive Center (DAAC) (McClain *et al.*, 1998). The reflectance values of the original data files were converted into chlorophyll concentrations using the empirical algorithm of O'Reilly *et al.* (1998). The dataset used is for the period September 1997 to December 2008, which represents a sequence of 136 monthly images. For the purposes of this study we have estimated the seasonal distribution of Chl-a for seven areas (Fig. 3), which are delineated in Fig. 2 and have the following boundaries:

Gulf of Aden:	12°–16°N, 50°–57°E
North of Seychelles:	0°–3°S, 50°–55°E
Indus Canyon:	22°–24°N, 66°–68°E
West of Maldives:	1°–6°N, 70.5°–72.5°E
West of Sri Lanka:	3°–12°N, 74°–80°E
NE Sri Lanka:	8°–9°N, 81°–82°E
Chagos:	5°–8°S, 70°–75°E

The choice of box boundaries was to some extent subjective, and there is undoubtedly scope for further refinement in future studies. Areas where blue whales were suspected to be feeding seasonally were investigated, not necessarily where they might be transiting. Thus, in the case of the Maldives our box was placed west of the atoll chain (where blue whales may be feeding during the NE monsoon), not over it (where the larger number of blue whale records are suspected to be of transiting animals). In the case of the western Arabian Sea, this is a vast area, and we have used the Gulf of Aden as a representative subarea, where many blue whales were caught by Soviet whalers (Fig. 1).

RESULTS

Seasonal distributions of Chl-a for seven areas within the NIO are given in Fig. 3. Both the Gulf of Aden and the

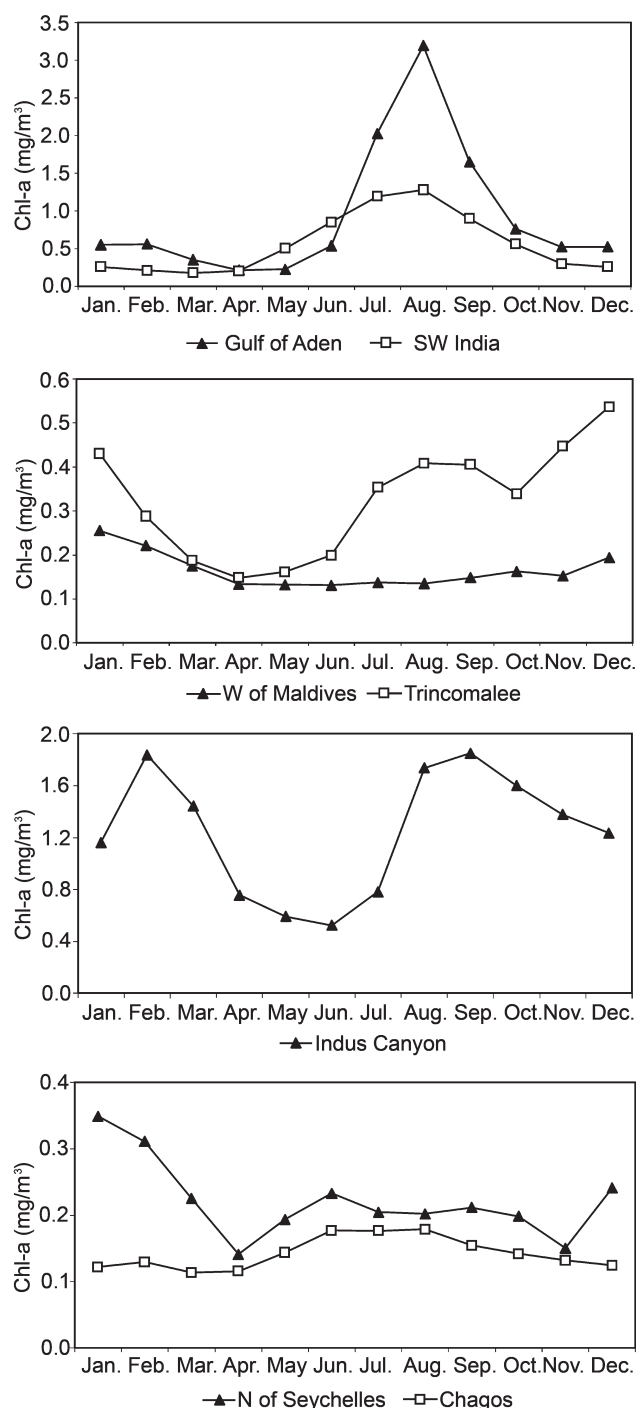


Fig. 3. Seasonal distribution of Chl-a in seven areas of the northern Indian Ocean, corresponding to boxes in Fig. 2 (from SeaWiFS data, see text for details; note different scales). SW monsoon May to October, NE monsoon December to March.

waters off SW India showed marked seasonality in Chl-a, with clear peaks from about June or July to September, i.e. during the southwest monsoon. In contrast, the area west of Maldives, which has much lower Chl-a overall, shows a peak in Chl-a during December to March, i.e. during the northeast monsoon season. Trincomalee on the east coast of Sri Lanka also shows a peak in Chl-a during the northeast monsoon season, notably during November to January. A second, lesser peak in August–September is likely associated with the increased run-off from the Mahaweli River during the latter part of the southwest monsoon. The Indus Canyon area shows distinctly bimodal seasonality, with Chl-a peaking in

February–March (northeast monsoon) and August–October (latter part of southwest monsoon). The former is possibly associated with local upwelling, the latter with increased run-off from the Indus River associated with the SW monsoon. The area north of Seychelles also shows bimodal seasonality in Chl-a, with peaks in both monsoon seasons. In the waters around the Chagos, Chl-a is low year-round, with a slight seasonal peak in June–August. These results are consistent with existing knowledge (e.g. Banse, 1968; Currie *et al.*, 1973; Darbyshire, 1967; Longhurst, 1998; Smith and Bottero, 1977; Smith, 1984; Vinayachandran *et al.*, 2003).

All available blue whale records from the NIO are mapped in Fig. 1. The same records are presented by month in Fig. 4. All Soviet catches were made during Oct–Dec, so by themselves they tell us relatively little about seasonal distribution. Most captures were actually made in November, which is the transition between the SW and NE monsoons.

Seasonality of blue whale sightings within different areas of the NIO is summarised in Fig. 5 (note that sightings are not available from all areas, so fewer areas are included in Fig. 5 than in Fig. 3). In addition, summaries of blue whale sightings made during crossings between Maldives, India and Sri Lanka are presented in Table 1. Blue whales were recorded in both June voyages, and during one of five April voyages, but not during other months. The relatively large number of crossings between mid-January and March suggest that blue whales are not common in this area at this time.

Summaries of blue whale sightings made on four crossings between Maldives and Seychelles are presented in Table 2. Blue whales were recorded west of Maldives on each of the four crossings, suggesting that they are relatively common in this area, at least during January–April. Numbers of sightings of blue whales on a standard transect off Trincomalee, Sri Lanka, completed by the RY *Tulip* during 1983–84 are summarised in Table 3 (Alling *et al.*, 1991; Whitehead, 1983).

Strandings within the NIO are clearly concentrated in the South Asian region (Fig. 1). Further west, around the Horn of Africa and on the southern Arabian coast, there is only one stranding reported. Numbers of strandings in different parts of South Asia (Pakistan and NW India; SW India and west Sri Lanka; Maldives; and Bay of Bengal) are summarised by month in Table 4, and by time period (before and after the period of Soviet whaling) in Table 5. The area including the coasts of Pakistan and NW India had the highest number of recorded strandings up to 1967, but has had no reported strandings since that time. In contrast, the Maldives (where there was almost no cetacean research conducted prior to the 1980s) had no recorded blue whale strandings prior to 1985. Seasonality of strandings by area is illustrated in Fig. 6.

DISCUSSION

Blue whales are the largest animals that have ever lived, and have particularly high prey demands, which they meet by seeking out areas of particularly high productivity (Croll *et*

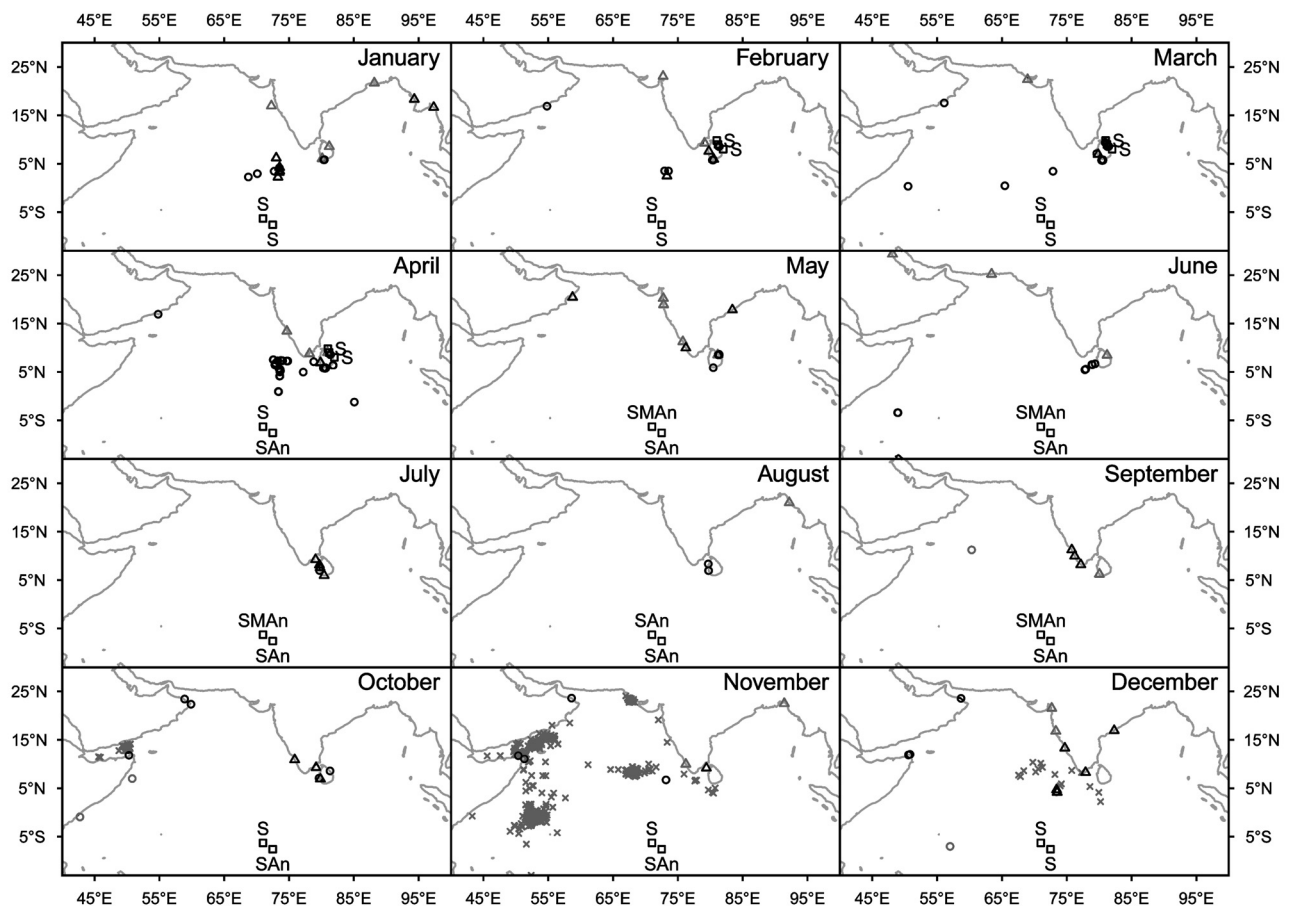


Fig. 4. Monthly distributions of blue whales in the northern Indian Ocean, showing all known positions of catches (crosses), sightings (circles), strandings (triangles) and acoustic detections (squares: S = Sri Lankan, M = Madagascan, An = Antarctic call types). Data from prior to 1973 are in grey; data after 1973 are in black. This figure is modified from Branch *et al.* (2007b). SW monsoon May to October, NE monsoon December to March.

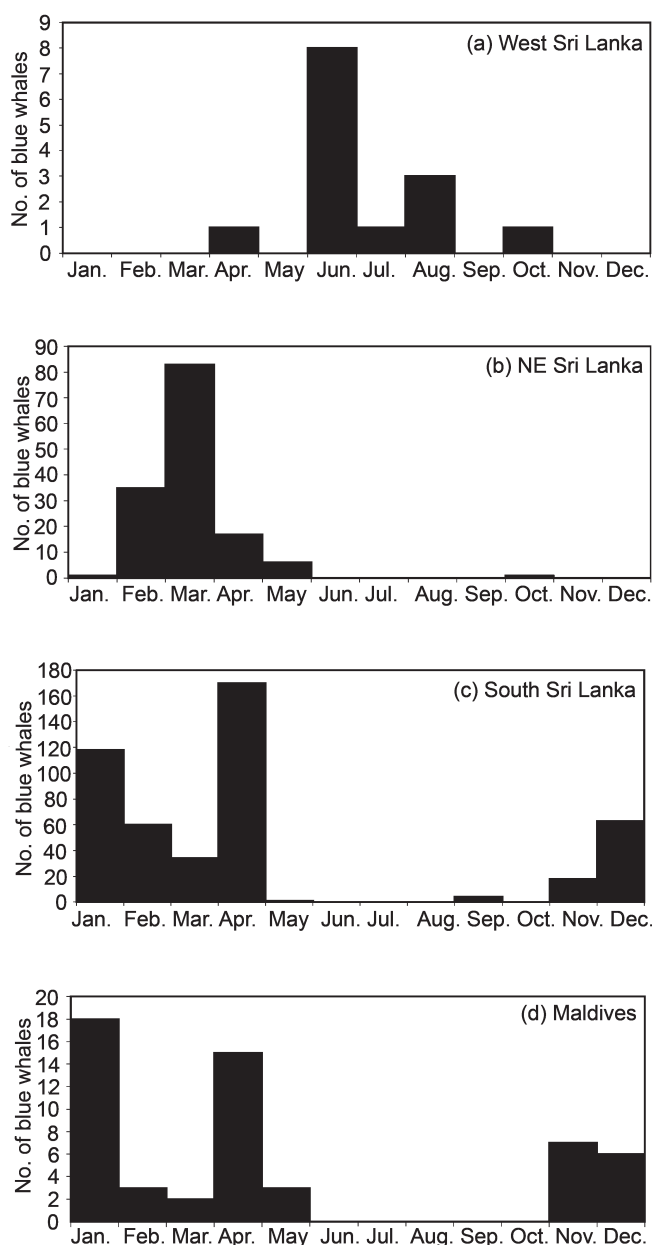


Fig. 5. Sightings of blue whales by month from four areas in the central Indian Ocean: (a) west Sri Lanka, $n = 14$ blue whales; (b) NE Sri Lanka, $n = 143$; (c) south Sri Lanka, $n = 468$; and (d) Maldives, $n = 54$. SW monsoon May to October, NE monsoon December to March.

et al., 2000). We assume that NIO blue whales are no different from other blue whales in this regard, and that they too search out areas of especially high krill (euphausiid) abundance. Since regions of high productivity within the NIO shift with the seasonally changing monsoon currents, we expect that the whales do so too. Indeed some intra-regional movements have already been proposed (Anderson, 2005; Anderson *et al.*, 1999).

Strandings of blue whales in south Asia (Maldives, India and Sri Lanka) are known to occur year-round, but peak during the NE monsoon (Anderson *et al.*, 1999). This well-defined seasonal pattern of strandings implied that there were migrations within the NIO, with many blue whales moving away from south Asia during the SW monsoon. It was suggested that the most likely destination for these whales was the western Arabian Sea (Anderson *et al.*, 1999). In that area, during the SW monsoon, intense upwelling off the

Table 3

Sightings of blue whales along standard transect off Trincomalee (NE Sri Lanka) from RV *Tulip*. SW monsoon May to October, NE monsoon December to March.

Date	No. blue whales	Source
12 Mar. 1983	7	Alling <i>et al.</i> (1991)
22 Mar. 1983	23	Alling <i>et al.</i> (1991)
24 Apr. 1983	0	Alling <i>et al.</i> (1991)
16 Oct. 1983	1	Whitehead <i>et al.</i> (1983)
2 Nov. 1983	0	Whitehead <i>et al.</i> (1983)
22 Feb. 1984	3	Alling <i>et al.</i> (1991)
11 Mar. 1984	7	Alling <i>et al.</i> (1991)

coasts of Somalia and Arabia, combined with open-ocean Ekman pumping, promote a major plankton bloom (Figs 2a and 3); in fact, this is one of the most productive seasonal upwellings in the world ocean (Longhurst, 1998).

Sightings of blue whales in the Maldives were subsequently shown to occur during November to April (Anderson, 2005). Noting that blue whales occurred off the NE coast of Sri Lanka near Trincomalee during December to April (Alling *et al.*, 1991; Leatherwood *et al.*, 1984; Leatherwood and Reeves, 1989), Anderson (2005) suggested that if at least some of these 'Sri Lankan' whales also fed in the Arabian Sea during the SW monsoon, then they must migrate via the Maldives in April. As he noted, Ballance and Pitman (1998) had previously documented the presence of numerous blue whales in the Eight Degree Channel at the northern end of the Maldives archipelago in April.

In brief, the hypothesis tested and developed here is that many blue whales in the NIO feed in the highly productive zones associated with the major SW monsoon upwellings, namely in the western Arabian Sea and off the SW coasts of India and Sri Lanka. With the change of monsoon in October–November, these upwellings stop, and within a month or so zooplankton concentrations also dissipate. The blue whales then disperse more widely in the NIO to seek out other, more localised zooplankton concentrations.

Thus it is predicted that: during the SW monsoon blue whales occur in the upwelling areas of the NW Arabian Sea and off the SW coast of India and west coast of Sri Lanka; during the NE monsoon blue whales occur in other (smaller or lesser) productive areas within the NIO; and that during intermonsoon periods, peaks in abundance of blue whales occur in intermediate areas as the whales pass between SW and NE monsoon feeding grounds. In the absence of detailed information on the seasonality of euphausiids throughout the NIO, we use satellite-derived Chl-*a* data to provide a rough proxy for blue whale forage. We note that it may take one or two months for zooplankton biomass to build up at the beginning of each upwelling season, while later in the season zooplankton grazing may keep Chl-*a* low even while production is high. Blue whale abundance may therefore lag peak Chl-*a* (Croll *et al.*, 2000).

Blue whales in the western Arabian Sea

A major prediction of this migration hypothesis is that blue whales should be found in areas of high productivity in the western Arabian Sea (including the Gulf of Aden) during the SW monsoon season. This is a wide area, and we have used

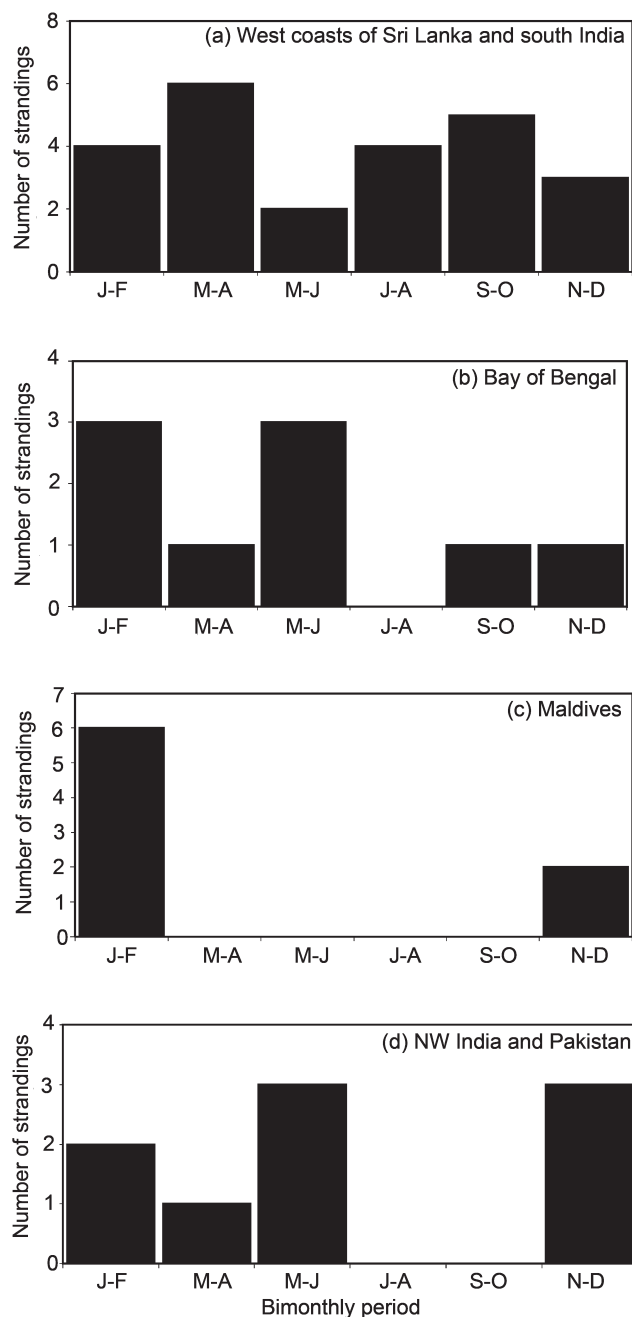


Fig. 6. Strandings of blue whales by bimonthly period from four areas in the central Indian Ocean: (a) west Sri Lanka and SW India; (b) Bay of Bengal; (c) Maldives; (d) NW India and Pakistan. SW monsoon May to October, NE monsoon December to March.

the Gulf of Aden as a representative subarea for Chl-a analysis, while recognising that finer scale analyses are desirable. Within the Gulf of Aden there is a very marked peak in Chl-a during July–September (Fig. 3). Elsewhere in the Arabian Sea, ocean colour data (which we have analysed but do not present here) show that in the Somali Basin, Chl-a increases rapidly in May as upwelling starts, and peaks during June–September. For the western Arabian Sea as a whole it is therefore likely that zooplankton (and thus potentially blue whale) abundance is high from about June–July to October or November.

Blue whales are certainly present in the western Arabian Sea from at least September to November. Nineteenth century sperm-whalers recorded blue whales on the ‘Arabian

Table 4

Strandings of blue whales by month for major regions in south Asia. (Southwest = west coasts of Sri Lanka and south India, south of 12°N. Northwest = coasts of Pakistan and west India, north of 12°N). SW monsoon May to October, NE monsoon December to March.

	Bay of Bengal	Southwest	Northwest	Maldives	Total
Jan.	3	1	1	5	10
Feb.	0	3	1	1	5
Mar.	0	1	1	0	2
Apr.	1	5	0	0	6
May	2	2	2	0	6
Jun.	1	0	2	0	3
Jul.	0	4	0	0	4
Aug.	0	0	0	0	0
Sep.	1	3	0	0	4
Oct.	0	3	0	0	3
Nov.	0	2	0	0	2
Dec.	1	1	2	2	6
Total	9	25	9	8	51

Table 5

Strandings of blue whales before and after 1967, for major regions in south Asia. (Southwest=west coasts of Sri Lanka and south India, south of 12°N. Northwest=coasts of Pakistan and west India, north of 12°N).

	Bay of Bengal	Southwest	Northwest	Maldives	Total
1967 and before	9	10	11	0	30
1968 and after	5	15	0	8	28
Total	14	25	11	8	58

grounds’ during September to November, with one vessel reporting ‘lots’ off the Somali coast at 7°N 50°49’E in October 1888 (Wray and Martin, 1983). Slijper (1962, p.337) noted ‘records made by some Dutch officers who reported, *inter alia*, that on 23rd September, 1953, 30–50 Blue Whales in groups of 3–4 were seen over an area of about ten square miles in the Indian Ocean (at 11°15’N and 60°13’E)’. The wording of this report is similar to that of Mörzer Bruyns (1971), suggesting that he may have been one of the Dutch officers concerned. Mörzer Bruyns (1971: chart 14) also recorded blue whales off the Horn of Africa and Socotra during September–November, as well as noting that he ‘encountered them [during] several southern winters well east of Socotra Island and also in the Gulf of Aden’. In the 1960s, Soviet whalers took many blue whales in the Gulf of Aden and western Arabian Sea during October–November (Figs 1 and 4; Mikhalev, 1996; 2000; Yukhov, 1969).

There is, however, little evidence for the predicted presence of blue whales in the western Arabian Sea, or indeed in most other parts of the NIO, during the period June–August. Some authors have taken this as evidence that blue whales must move out of the NIO at this time of year (e.g. de Silva, 1987; Deraniyagala, 1960; Slijper *et al.*, 1964). However, a more satisfactory explanation is that sea conditions are simply too rough during June–August for any useful cetacean surveys. Several researchers have noted the difficulties of observing cetaceans in the northwest Indian Ocean at this time of year, when the SW monsoon is at its most fierce (e.g. Ballance and Pitman, 1998; Eyre, 1995; Reeves *et al.*, 1991; Small and Small, 1991). Small and Small (1991) carried out no survey work at all off the Indian

Ocean coast of Somalia during June–September. Eyre (1995) provided data which illustrate the impact of poor observing conditions during this season. She rounded the Horn of Africa in late June 1993. During the 9-day period 26 June to 4 July inclusive, there were 8 days with an average sea state of 4 or more, and one day with an average sea state 2. During those 8 rough days, she recorded just two sightings. In contrast, on the one calmer day she recorded no less than 15 cetacean sightings. There is clearly a need for more work during the rough SW monsoon season; remote technologies such as satellite tracking and acoustic monitoring may provide the means to do so.

It is predicted that there should be relatively few blue whales in the open Arabian Sea during the NE monsoon season, when productivity is relatively low (Figs 2b and 3). There is indeed a lack of offshore sightings during January to April (Fig. 4). Sea conditions are usually relatively calm throughout much of this season, when there are reports of sperm whales for example (Ballance and Pitman, 1998; Mörzer-Bruyns, 1971; Slijper *et al.*, 1964). So one might expect at least some reported sightings of blue whales if they were present in numbers. Nevertheless, in the absence of sighting effort data, this cannot be taken as unequivocal evidence for a lack of blue whales. Furthermore, it is possible that some blue whales may loiter in coastal locations with elevated productivity during the NE monsoon season.

In contrast to some other areas within the NIO (see below), there is no evidence for blue whale seasonality in the western Arabian Sea from strandings data. Indeed, there is only a single reported stranding from the entire Arabian and NE African coasts, in Oman in May (Figs 1 and 4). The reason(s) for this dearth of strandings are unknown, but there are at least two possibilities. One is that there may be less likelihood of strandings being detected and reported on these sparsely populated coasts than on the much more densely populated coasts of the Indian subcontinent. A second possibility is that blue whale strandings along the western seaboard of the Arabian Sea may be genuinely rare. In support of this second possibility, we note that fairly comprehensive reports of strandings from Oman had until very recently failed to report a single blue whale stranding (Collins *et al.*, 2002; Gray, 2009). The hypothesis presented here predicts that blue whales are most abundant off these coasts during the SW monsoon when the prevailing winds are offshore; the likelihood of any dead whale being cast ashore must therefore be greatly reduced. In addition it seems likely that many of the blue whales in this region occur some distance offshore (Fig. 1), again reducing their chances of stranding. One reason for this may be that the inshore upwelling food chains along these coasts are dominated by copepods and myctophids rather than euphausiids (Smith *et al.*, 1998; Smith, 1984).

SW India and west of Sri Lanka

During the SW monsoon, the long-shore flow of the West Indian Coastal Current induces upwelling along the SW coast of India, promoting a major phytoplankton bloom there (Banse, 1968; Darbyshire, 1967; Longhurst, 1998). This productive water is carried southward around the west and south coasts of Sri Lanka, where it is enhanced by further upwelling (Vinayachandran *et al.*, 2003), before being

transported eastwards with the SW Monsoon Current into the Bay of Bengal (Figs 2a and 3).

It is predicted that blue whales should occur in this area of high productivity from about June to October or November and be absent or rare when productivity is low during the NE monsoon season (Fig. 3). Again, rough weather during the SW season has restricted opportunities for cetacean surveys. Nevertheless, the limited data from the west coast of Sri Lanka (Fig. 5a) do support this prediction: there are no reported sightings of blue whales during the calm NE monsoon, despite several surveys at that season (Table 1; Leatherwood and Reeves, 1989), but there have been sightings during the rough SW monsoon. Ilankoon (2002) ‘frequently encountered’ blue whales off the west coast of Sri Lanka during May to October 1994, and there have been other reports of sightings in June (De Vos *et al.*, 2011; Asha de Vos, pers. comm.) and August (Bröker and Ilankoon, 2008). Further offshore, in the area between Sri Lanka, India and Maldives, blue whales were recorded in June by Ballance and Pitman (1998), and in November by Soviet whalers (Fig. 4).

It is also predicted that blue whales travelling between the western Arabian Sea and the east coast of Sri Lanka (see below) should transit this area in about December and April–May. While there have been no offshore sightings in December (Table 1), there were several catches by Soviet whalers in November and December (Fig. 4). It is, however, not clear if these catches were of blue whales which had spent the SW monsoon feeding locally or whales which were in transit from the western Arabian Sea. And with only a single offshore sighting from April (Table 1 and Fig. 4), this is one area where additional survey work and/or satellite tracking will be required to test our predictions.

Despite this shortcoming, there is further support for this migration hypothesis from strandings records. Strandings on the west coasts of southern India and Sri Lanka occur more-or-less year-round (Fig. 6a, Table 4). But the peaks in strandings during April and July (Table 4) are consistent with our predictions of relatively large numbers of blue whales transiting this area in April, and feeding offshore in July. The relatively small numbers of strandings (just two) in December and early January, at a time when relatively large numbers of blue whales are predicted to be transiting the area is also to be expected, since winds and currents are offshore at this season. This is reflected in the peak of strandings downstream, in the Maldives, during December and early January (see below).

NE Sri Lanka

It has been known for many decades that blue whales occur off the east coast of Sri Lanka. Deraniyagala (1948) noted that blue whales ‘commonly occur off Ceylon’ [Sri Lanka] and that ‘the abundance of whales and their proximity to land off Trincomalee is particularly noteworthy’. Even earlier, Blyth (1859) considered the ‘great rorqual’ to be relatively common throughout the northern Indian Ocean, including Sri Lanka, and specifically noted the stranding of a whale which he apparently considered to be *B. indica* ‘in Ceylon ... near Trincomali’. However, the presence of blue whales there was largely forgotten by marine biologists, and their rediscovery in February 1983 came as something of a surprise (Whitehead, 1983; 1989).

The seasonality of these blue whales has not been well established, since most fieldwork has been conducted during the NE monsoon season (e.g. Alling *et al.*, 1991; Carwardine, 1994; Leatherwood *et al.*, 1984). However, Gunaratna *et al.* (1985) stated that blue whales were seen off Trincomalee from November to mid-May, while Alling *et al.* (1991) noted that few were recorded after April. The sightings data that we have compiled support the contention that most blue whales occur in this region during the NE monsoon season, with recorded sightings peaking during February–April (Fig. 5b). We note that this area can be quite rough at the beginning of the NE monsoon, with strong onshore winds during December–January, so the dearth of sightings in those months may not reflect genuine absence. Indeed, there is a peak in strandings in January (Table 4), which suggests that at least some blue whales are present off NE Sri Lanka at this time, despite so few sightings.

The absence of blue whales from this area during the SW monsoon is not well established from sightings, since relatively little time has been spent at sea in this area at this season. But during one 16-day survey off NE Sri Lanka during October–November 1983 (by the RY *Tulip*), only one blue whale was recorded (Whitehead, 1983). Other data collected from the RY *Tulip* included sightings from a standard 20 n.miles (36km) transect running due E–W off Trincomalee; despite limited coverage during the SW monsoon, these data could suggest that blue whales are scarce in this area between late April and November (Table 3). Records of strandings in the Bay of Bengal are consistent with this pattern of seasonality, with 75% of strandings occurring during the period November to May. In addition, this pattern of blue whale seasonality is consistent with the seasonality of Chl-a (Fig. 3b), which peaks in November–January, suggesting peak zooplankton abundance during approximately December–March. The observed pattern of Chl-a seasonality may be heavily influenced by seasonally variable run-off from the Mahaweli Ganga (Sri Lanka's largest river), which enters the sea at Trincomalee (Alling *et al.*, 1991). In addition, physical processes may concentrate blue whale prey in the vicinity of the submarine Trincomalee Canyon, where blue whales congregate (Alling *et al.*, 1991).

While most blue whale strandings in the Bay of Bengal occur during the NE monsoon season, a few do occur during the SW monsoon. Whether these represent a few stragglers, or a regular year-round occurrence, remains unclear. Also, the distribution of strandings around the Bay of Bengal occurs over a much wider area than the distribution of known sightings, which are largely confined to the east coast of Sri Lanka. The disparity between the distributions of sightings and strandings no doubt in part reflects the distribution of observer effort. But it might also be partly explained by the fact that the East India Coastal Current flows northwards for most of the year, and therefore may disperse carcasses originating from near Sri Lanka more widely around the coasts of the Bay of Bengal. Soviet scientists certainly believed that the lack of blue whales in much of the Bay of Bengal was genuine, and that this was the result of relatively low plankton productivity (Zemsky and Sazhinov, 1994). Recent studies in Bangladeshi waters have not yet reported any blue whales (Smith *et al.*, 2008). Nevertheless, further surveys within the Bay of Bengal would be valuable.

Southern Sri Lanka

If blue whales are indeed largely absent from the NE coast of Sri Lanka after about April, the question arises, where do they go? The migration hypothesis presented here suggests that blue whales from Trincomalee are migrating to the Arabian Sea. They are unlikely to do so around the north of Sri Lanka, since the Palk Straight is so shallow, being just 10m deep in the dredged shipping channel (Hydrographic Office, 2007). Therefore it is predicted that blue whales must pass around the south of Sri Lanka in about April–May.

To test this prediction, the southernmost tip of Sri Lanka, Dondra Head, was visited in April 2007. Several blue whales were seen on every one of four days of observation. All of these sightings were in the vicinity of what appears, from the rather inadequate charts of this area, to be a canyon off Dondra Head. As a result of this finding, commercial whale watching has developed rapidly in the south of Sri Lanka, centred on the fishing port of Mirissa (just a few km west of Dondra). Most blue whales sighted by that operation appear to be associated with the continental slope.

Gunaratna *et al.* (1985) previously reported a sighting of two blue whales off Dondra Head on 7 May 1984. They further noted that since blue whales were seen off Trincomalee from November to mid-May, but apparently not at other times, these whales might migrate south to the south coast of Sri Lanka in the northern spring. Alling *et al.* (1991) did not speculate on migratory destinations of the blue whales they observed off Trincomalee, but they did present a diagram summarising blue whale swimming directions during February to April 1984 (Alling *et al.*, 1991; Fig. 5) which suggests a net southward trend.

Sightings data collected off the southern tip of Sri Lanka since 2007 (Fig. 5c) are bimodally distributed, with peaks in December–January and April. A very similar pattern is seen in the Maldives (Fig. 5d). Such patterns are consistent with an eastward movement of blue whales at the beginning of the NE monsoon (after zooplankton production associated with SW monsoon upwellings in the Arabian Sea has died down) and a westward return at the end of the NE monsoon. Off southern Sri Lanka blue whales have been seen travelling eastward during November–January (AA, pers. obs.). This is a rather extended period; perhaps if blue whales from both the western Arabian Sea and SE Arabian Sea (i.e. the SW coast of India and west coast of Sri Lanka) migrate to the Bay of Bengal after the end of the SW monsoon, they may pass eastwards at slightly different times, although this is no more than speculation at present. It was noted, however, that in both southern Sri Lanka and Maldives, although some blue whales seen at these times are travelling in the expected directions, others are not. Rather, they appear to be loitering, or even moving in the 'wrong' direction, and some are clearly feeding (diving repeatedly in the same area, and defecating). We also note frequent sightings of mother and calf pairs in March and April (RCA and AA, pers. obs.). This is consistent with an April peak in calving estimated for Arabian Sea blue whales by Mikhalev (2000). Sightings of blue whales breaching in March and April (RCA and AA, pers. obs.) might also suggest a peak in reproductive activity at this time. However, the reproductive cycle of NIO blue whales is probably more complex than this suggests, with another calving peak possibly in October, notably

among blue whales from Seychelles waters (Mikhalev, 2000).

Leatherwood and Reeves (1989) reported on several short surveys carried out, mostly by Sri Lankan scientists, off the south coast of Sri Lanka during the 1980s. Blue whales were not seen during surveys conducted in September, October, November and March. But blue whales were seen in December, both during a vessel survey, and from shore. More recently, Afsal *et al.* (2008) noted the presence of blue whales off the south coast of Sri Lanka in February and August.

In summary, we believe that many of the blue whales seen off the south coast of Sri Lanka are migrating between the Arabian Sea (including the west coast of Sri Lanka) and the Bay of Bengal (particularly the east coast of Sri Lanka). However, when food is present they may linger.

The Maldives

The seasonality of blue whale sightings in the Maldives is distinctly bimodal (Fig. 5d). This is similar to the pattern recorded from southern Sri Lanka (Fig. 5c), and can be explained in a similar way. During November to early January, blue whales pass eastward via the Maldives en route to the east coast of Sri Lanka. In April they return en route to the major upwelling areas of the western Arabian Sea. The relative scarcity of blue whales in February and March is genuine, not an artefact of survey effort, since a relatively large amount of time has been spent at sea in those months (RCA, unpublished data; Anderson, 2005). However, the lack of sightings in May likely reflects decreased survey effort in that month as the SW monsoon starts to take effect.

Blue whale strandings in the Maldives are highly seasonal, with all strandings recorded so far occurring during the short period December to February (Fig. 6d). This is consistent with the known pattern of sightings. During December–January, any blue whale that dies while passing through the Maldives or on towards Sri Lanka will be carried back by the westward-flowing North Equatorial Current, and may strand in the Maldives. In contrast, any blue whale that dies while travelling westward in April–May from Sri Lanka will be carried away from the Maldives and back towards Sri Lanka by the eastward-flowing Southwest Monsoon Current. This also suggests that most blue whales pass by the north of the Maldives (cf. Ballance and Pitman, 1998): if more passed through the Maldives Archipelago itself in April, then some strandings at that time might be expected.

All of the blue whale strandings observed in the Maldives in this study were of carcasses that appeared to have been dead and drifting for some days. During December–February, the prevailing North Equatorial Current flows to the west at about 1–2 knots (*ca.* 2–3 km/h) (Hydrographic Office, 2007). A blue whale that died off the coast of Sri Lanka would therefore drift westward, and might strand in the Maldives after about 10–12 days. There is evidence to support this scenario from a tragic source: after the tsunami of 26 December 2004, human corpses originating from Sri Lanka washed up in the Maldives from 12 days later.

While some blue whales must die of natural causes while passing between the Maldives and Sri Lanka, blue whales transiting southern Sri Lanka do pass through one of the busiest shipping lanes in the world. Ship strikes are an increasing cause of whale mortality worldwide (e.g. Berman-

Kowalewski *et al.*, 2010; Laist *et al.*, 2001; Van Waerebeek *et al.*, 2007), and it is likely that some blue whales are killed by ship strikes in this region.

Although most blue whales appear to pass by the Maldives biannually, some blue whales may loiter. In particular, during the NE monsoon there is a regular increase in plankton productivity on the downstream (western) side of the atolls (Figs 2a and 3; Anderson *et al.*, 2011). It is therefore predicted that some blue whales should be found west of the Maldives during the NE monsoon season. This does in fact appear to be the case, with blue whales being sighted west of Maldives on each of four crossings to Seychelles (Table 2). They may therefore be relatively common in this area, at least during January–April. We also have unconfirmed reports from Maldivian fishermen and foreign big-game fishermen of blue whales west of Maldives at this season.

NE Arabian Sea

In the NE Arabian Sea, Soviet catches included at least 31 blue whales taken in November 1966, from the coastal waters of India and Pakistan (the Indo-Pakistani aggregation of Mikhalev, 2000). This area is known to have a particularly high abundance of zooplankton (Paulinose and Aravindakshan, 1977; Qasim, 1982) including euphausiids (Brinton and Gopalakrishnan, 1973). In this general area high catches of yellowfin tuna (*Thunnus albacores*), whale shark (*Rhincodon typus*) and humpback whale (*Megaptera novaeangliae*) have also been recorded (Mikhalev, 1997; Pravin, 2000; Vivekanandan and Zala, 1994).

More specifically, the Soviet blue whale catches were centred on the Indus Canyon (around 23°N 67°E). Elsewhere in the world, blue whales are known to associate with submarine canyons, for example the Monterey Canyon off California (Croll *et al.*, 2000) and the Perth Canyon off Western Australia (Rennie *et al.*, 2009). In those cases, physical oceanographic processes associated with the canyons promote the formation and maintenance of dense krill swarms on which the blue whales feed. Within this region, blue whales have been reported to be associated with the Trincomalee Canyon off NE Sri Lanka (Alling *et al.*, 1991), the Basses Canyon off SE Sri Lanka (De Vos *et al.*, 2012), and the Dondra Canyon off southern Sri Lanka (see above). On the other hand, there are as yet no reports from the Swatch-of-no-ground Canyon off Bangladesh (Smith *et al.*, 2008). Nevertheless, it seems possible that searches in the vicinity of other canyons within South Asian waters during appropriate seasons might reveal other concentrations of blue whales.

Regarding the seasonality of blue whales near the Indus Canyon, all Soviet catches were taken in November, at the beginning of the NE monsoon. Strandings from this general area all occurred during December–June, i.e. during or immediately after the NE monsoon (Fig. 6d, Table 4). There are no strandings reported from July–November. Since winds are onshore for most of that time, it seems likely that blue whales are absent from the area for much of the SW monsoon season. The pattern of Chl-a seasonality in the vicinity of the Indus Canyon is complex (Fig. 3), but Chl-a is elevated between August and March. Zooplankton abundance may be highest from about October. This supports the suggestion that blue whales are commonest in this area during the NE monsoon.

All of the strandings from Pakistan and NW India in our compilation occurred before the period of Soviet whaling in the 1960s (Table 5). Prior to that period, blue whale strandings appear to have been relatively frequent. Kinnear (1915), for example, noted 'quite a number' of strandings of what were presumably this species in the vicinity of Bombay (Mumbai). Since 1967 there have been no confirmed, published reports of blue whale strandings within this area (Branch *et al.*, 2007b: Appendix 3), although there was one unconfirmed report by Ali *et al.* (2002). This lack of recent strandings, and of recent sightings (Gore *et al.*, 2012), suggests that Soviet whaling may have seriously depleted, perhaps even extirpated, this small component of the NIO blue whale population. A survey of the Indus Canyon area would be desirable.

Seychelles

In November 1964, Soviet whalers took exactly 500 blue whales in the vicinity of the Seychelles (Mikhalev, 1996; 2000), within the area bounded by 0°–3°S and 50°–54°E. These catches may have substantially impacted blue whales in this area; when one Soviet whaling fleet returned from the Antarctic in April 1965, no blue whales were seen here (Mikhalev, 2000), although that might also reflect seasonality of occurrence. Subsequently there have been very few post-whaling reports of blue whale sightings from the vicinity of Seychelles (Eyre, 1995; Kasuya and Wada, 1991; Robineau, 1991); those few reported with dates occurred in March and June. There are no strandings from this area, and the Chl-a data also provide few clues, since there are peaks in both the SW and NE monsoons (Fig. 3). The seasonality of blue whales in this area therefore remains unclear.

Chagos

The Chagos Archipelago (officially known as the British Indian Ocean Territory) lies south of the Maldives, in 6–7°S.

It is home to a US military base, on the island of Diego Garcia. No blue whale catches, sightings or strandings have been recorded. However, the International Monitoring System has maintained two underwater listening stations nearby for many years, in support of the Comprehensive Test-Ban Treaty, and these have detected blue whales in the vicinity. Using these acoustic monitoring data, Stafford *et al.* (2011) demonstrated that blue whales with a Sri Lanka call type (i.e. NIO blue whales) were present year-round in Chagos waters, but with a major peak in calls detected during April–May and a lesser peak in December–January (Fig. 7). The extent to which blue whales might be present but not calling at non-peak times is unknown. Nevertheless, this bimodal distribution corresponds rather closely with the bimodal distributions of blue whale sightings recorded here for both southern Sri Lanka and Maldives. Thus at least some NIO blue whales may be migrating through these waters biannually, travelling from the Arabian Sea during December–January. Where they are travelling to is unknown, but Stafford *et al.* (2011) raised the possibility that they are migrating to the southern Indian Ocean, since Sri Lanka calls have also been recently recorded near Crozet (in 46°S) in relatively low numbers but with a peak in December–February (Samaran *et al.*, 2010).

Chl-a is relatively low year-round in Chagos, with just a minor peak in June–August (Fig. 3), implying a peak in zooplankton abundance from about July or August onwards. Sri Lanka call detections are at a minimum during July–September (Fig. 7; Stafford *et al.*, 2011). If NIO blue whales are absent when food is possibly at its most plentiful, it seems unlikely that Chagos is a significant feeding area for these animals.

SE Arabian Sea

In the southern Arabian Sea, to the NW of Maldives, Soviet whalers caught over 300 blue whales (Fig. 1). All were taken

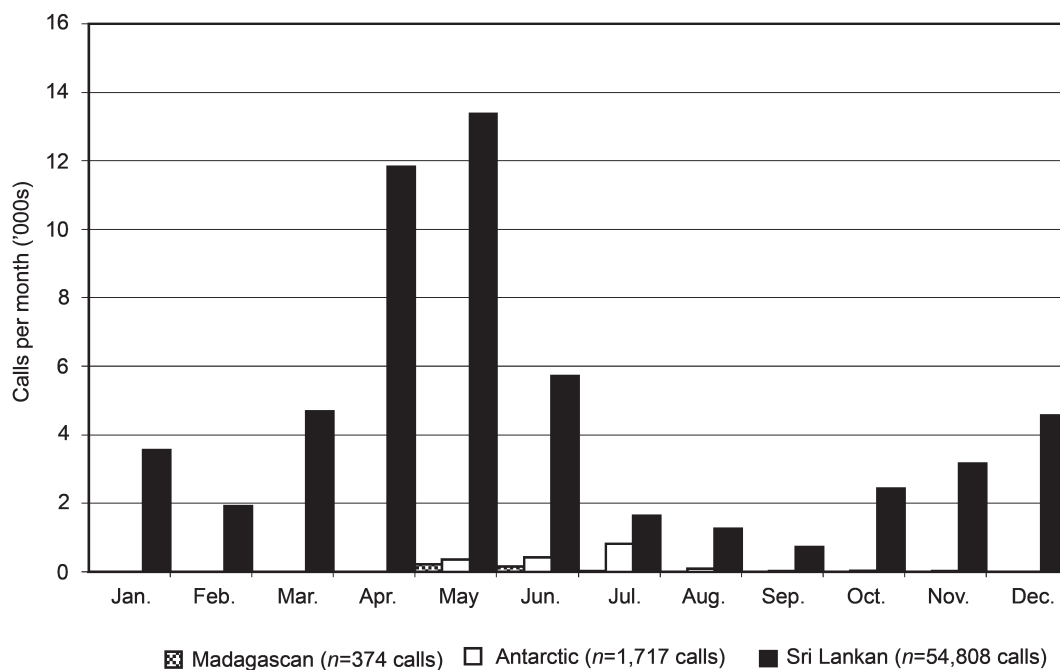


Fig. 7. Acoustic detections of three blue whale call types (Sri Lankan, Antarctic and Madagascan) near Diego Garcia (Chagos Archipelago) by month. Redrawn from Stafford *et al.* (2011) combining data from two listening stations supplied by K. Stafford. Diego Garcia is south of the Equator, so seasons differ from areas further north: SE monsoon May to October, NW monsoon December to March.

in November and December, mostly in 1964. Some were undoubtedly feeding, since they were caught with full stomachs (Mikhalev, 1996; 2000). However, relatively more blue whales from this area were taken with empty or near-empty stomachs (47%) compared with animals taken from the two other main areas exploited by the Soviets, namely the Gulf of Aden (32%) and north of Seychelles (23%) (Mikhalev, 1996; 2000). Ocean colour data (analysed by us but not presented here) show that mean Chl-a is relatively low (of the same order as that off the west of Maldives and Chagos). We think it possible that at least some of the blue whales caught to the northwest of Maldives may have been transiting the area; the timing of captures (in November and December) is certainly compatible with an eastward movement from the western Arabian Sea to the Maldives and Sri Lanka as predicted here. But this is another area where further studies would be welcome.

On *Balaenoptera indica* Blyth, 1859

Perrin *et al.* (2010) have recently inspected Blyth's holotype in Kolkata/Calcutta, India, confirmed that it is a blue whale, reviewed available information, and suggested that the name *B. musculus indica* (Blyth, 1859) should apply to the blue whales in the northern Indian Ocean. While that conclusion appears reasonable, it is not clear if this name should apply to these blue whales alone, since it has precedence over *B. m. brevicauda* (Ichihara, 1966). Furthermore, the degree of differentiation between northern and south Indian Ocean pygmy blue whale populations (or Sri Lanka, Madagascar and Australia call types) is still not well understood. There remains debate about the level of evidence needed to elevate blue whale populations to the status of subspecies (Branch *et al.*, 2007a; 2008; 2009). A standard definition of a subspecies includes two components: geographic isolation and distinguishing biological features (Branch *et al.*, 2007a). Regarding geographic isolation, this did seem fairly well established for NIO blue whales, but the recent recording of Sri Lanka type blue whale calls in the southern Indian Ocean suggest that things are not so clear cut (Samaran *et al.*, 2010). Regarding distinguishing biological features, although Perrin *et al.* (2010) cited the difference in length of female maturity between NIO blue whales and southern Indian Ocean pygmy blue whales as evidence of distinctiveness, this difference is small (just 0.5–0.6m) and there is overlap between putative populations (Branch and Mikhalev, 2008). The usefulness of this trait as a subspecific characteristic is therefore debatable. Another potentially distinctive trait of NIO blue whales is breeding seasonality consistent with that of a northern hemisphere population (Mikhalev, 1996; Mikhalev, 2000), although that understanding is based on sampling in predominantly just one month (November), and there was some suggestion of two breeding seasons (Mikhalev, 1996; 2000). In addition, the one genetic study conducted so far failed to separate northern from southern Indian Ocean 'pygmy' blue whales, although it included just two samples from the NIO (LeDuc *et al.*, 2007). In contrast, Chilean blue whales differ in length by 2m from both Antarctic and southern Indian Ocean blue whales (Branch *et al.*, 2007a), and are also genetically distinct (LeDuc *et al.*, 2007); but these whales are not currently considered to be a separate subspecies. Further studies, including additional acoustic and genetic analyses, are needed to clarify population

separation within the Indian Ocean. In addition, satellite tracking could not only test the migration hypothesis presented here, but also help delineate stock boundaries. It is already known that at least some NIO blue whales wander beyond the boundaries considered in this study. It is likely that their stock status, as well as their seasonal distributions and migrations, will prove to be more complex than the relatively simple scenario presented here.

Another source of uncertainty, raised by Rice (1998), was that Blyth's 'type specimen ... was 84ft (25.6m) long, and another individual 90ft (27.4m) long was reported, whereas the largest *brevicauda* ever taken was only 79ft (24.1m) long'. The longest Arabian Sea blue whale caught and measured by Soviet whalers was recorded as 24.0m (see also Gordon *et al.*, 1986; Mikhalev, 1996). But Blyth (1859) himself noted that the 90ft length he reported was 'as alleged' and the other stranding was 'stated to have been 84ft. in length', suggesting that any measurements may not have been especially accurate. Furthermore, it was common practice in the 19th and early 20th centuries to measure whales to the tip (rather than the central notch) of the flukes; no NIO stranding since 1927 has exceeded 24.1m reported length (Branch *et al.*, 2007b). Chari (1951) presented both measurements from one specimen of '*Balaenoptera indica*', the difference between them being about 8%. Applying this figure to the 84ft type specimen gives an estimated length of 23.6m. Blyth (1859) noted that the mandibles of this specimen were 'within less than 2 [inches] of 21 ft' i.e. 6.35m. From four strandings in the Maldives (lengths 16.8–22.9m, mandible lengths 4.82–5.50m, RCA unpublished data) mean mandible length was 26.6% (range 24.1–28.8%) of total length. Applying this figure to the 6.35m mandibles of the type specimen gives an estimated total length of 23.9m. The close agreement between these two total length estimates gives some confidence that the 'true' (i.e. central notch) length of this specimen may have been < 24m. We recognise that the conversion factors and estimates used here may not be highly accurate. But they nevertheless demonstrate that the reservation of Rice (1998) is, by itself, insufficient to dismiss Blyth's taxon.

The possibility that individuals of other subspecies of blue whale, for example Antarctic blue whale *B. m. intermedia*, occur in the NIO at least occasionally should be mentioned. Some strandings of very large blue whales have been recorded from the Indian region, including for example a 94ft (28.7m) individual stranded near Cochin in November 1927 (Moses, 1947). It is likely that most such cases are the result of incorrect measuring or reporting. However, the possibility of Antarctic blue whales straying north of the Equator, particularly in earlier days before commercial whaling reduced that subspecies to less than 1% of its original abundance (Branch, 2007; Branch *et al.*, 2004), cannot be entirely dismissed. Certainly, there is acoustic evidence of Antarctic-type blue whale calls in the vicinity of the Chagos Archipelago, where both Sri Lanka and Madagascar type calls have also been recorded (Stafford *et al.*, 2004; 2011). And LeDuc *et al.* (2007) presented genetic evidence (albeit from other regions) of blue whale vagrancy.

CONCLUSIONS

The available data suggest that there is a distinct population of blue whale, which should probably be known as *B.*

musculus indica, in the NIO. This population shows parallels with the Arabian Sea population of humpback whale, *Megaptera novaeangliae*, which also appears to be resident year-round in these tropical waters, to have a Northern Hemisphere breeding cycle, to be reliant on the SW monsoon upwellings and to have been heavily impacted by Soviet whaling in the 1960s (Mikhalev, 1997; 2000; Minton *et al.*, 2008; Reeves *et al.*, 1991).

It is proposed here that most of the NIO blue whales feed in the Arabian Sea off the coasts of Somalia and southern Arabia during the period of intense upwelling associated with the SW monsoon. At the same time some of these blue whales feed in the area of enhanced productivity off the southwest coast of India and west coast of Sri Lanka. When the SW monsoon dies down in October these upwellings cease. The blue whales subsequently disperse more widely, searching out other areas of enhanced productivity to last them through the leaner months of the NE monsoon.

One such NE monsoon feeding area is off the east coast of Sri Lanka. It is suggested that at least some of the blue whales feeding there originate in the western Arabian Sea. They must pass by the north of Maldives and south of Sri Lanka in November–January, while heading eastwards, returning westwards in April–May. Other blue whale feeding areas during the NE monsoon include the waters west of the Maldives and in the vicinity of the Indus Canyon. However, there have been no recent records from the NE Arabian Sea, which suggests the possibility that the Indus Canyon component of the NIO blue whale population may have been extirpated by Soviet whaling in the 1960s. Soviet whalers also caught large numbers of blue whales north of Seychelles; again, there have been few observations from that area since.

As more data become available, the use of abundance indices, such as sightings per day (rather than just sightings with no measure of effort, as used here) should provide more refined insights into blue whale seasonality in the region. However, even our crude data reveal patterns of seasonality that are consistent with our predictions, and with recent acoustic analyses, and do not simply reflect sightings conditions. Thus, blue whales have been sighted off the west coast of Sri Lanka (Fig. 5a) during the rough SW monsoon season (as predicted) despite the poor sea conditions and limited effort at that season. However, they have not been recorded there during the calmer NE monsoon (again as predicted) despite good sea conditions and greater effort during that season. Furthermore, the bimodal distribution of sightings off both southern Sri Lanka and the Maldives (Figs 5c and 5d) is consistent with our prediction of a biannual passage of blue whales through those waters. This cannot be explained by variations in sighting effort alone: there is for example a peak in sightings in Maldives in January, even though there has been much less sighting effort in that month than in either February or March (RCA, pers. obs.); it seems unlikely that the two peaks occur in the same months in both Maldives and southern Sri Lanka purely by chance; and this pattern of bimodal seasonality is supported by acoustic data from Chagos (Stafford *et al.*, 2011). With regard to strandings, we recognise the shortcoming of such data. Nevertheless, the broad pattern of seasonality of strandings in each area is consistent with our migration hypothesis, and

cannot be explained by seasonal changes in sea conditions alone. We note in particular the Maldivian strandings (Fig. 6c), which have been recorded only during the remarkably short time period of December to February. This is the only period during which we predict that blue whales should be transiting waters upstream of the archipelago, and therefore prone to stranding. In short, the available data do support most of our predictions.

But there are exceptions: expected sightings from the western Arabian Sea during June–August and perhaps from off NE Sri Lanka during December–January are lacking, possibly due to rough weather in these locations at these times. Satellite tracking, acoustic monitoring and photo-identification (e.g. Calambokidis *et al.*, 2009), should provide means of addressing such shortfalls and further testing the migration hypothesis presented here. Furthermore, although the use of satellite derived Chl-a data as a proxy for food availability has given some useful insights into blue whale seasonality, it is a crude measure. More detailed studies of both physical and biological oceanographic processes will be needed to provide improved understanding of blue whale feeding ecology, and its impact on their seasonal distributions in the northern Indian Ocean.

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Cetaceans in the Maldives: a review

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ABSTRACT

The cetaceans of the Maldives were poorly known until relatively recently, but have received increased attention over the past decade. Twenty-three species of cetacean have now been recorded. A number of sightings surveys, and one acoustic survey, have been completed. The species most frequently seen is the spinner dolphin (*Stenella longirostris*). A national system for reporting cetacean strandings has been in place since 2000, although some earlier strandings were also reported; approximately 160 strandings of 16 species have been recorded to date. The species most commonly reported stranding is the sperm whale (*Physeter macrocephalus*). Ambergris has been exported from the Maldives since ancient times; recent export statistics are reviewed. All cetaceans are protected by law within Maldivian waters. More significantly, most forms of net-fishing, including gill-netting and purse-seining are banned in the Maldives to protect the traditional pole and line tuna fishery. Cetacean-watching is becoming increasingly popular, with spinner dolphins being the main attraction, although other species are also sought after on specialist trips.

KEYWORDS: INDIAN OCEAN; SANCTUARIES; WHALING – HISTORICAL; INCIDENTAL SIGHTINGS; SURVEY – VESSEL; STRANDINGS; WHALEWATCHING

INTRODUCTION

The Republic of Maldives is a small island nation in the central Indian Ocean, to the southwest of India and Sri Lanka. It lies at the heart of the International Whaling Commission's (IWC) Indian Ocean Sanctuary and has an abundant and diverse cetacean fauna. Until recently, however, it had received relatively little attention from cetologists.

The Maldives consists of a chain of atolls running north-south from about 7°N to 0.5°S. The atoll chain is single in the north and south but double in the central part of the archipelago. Maximum depths within the atolls are typically 50–60m but vary from about 10–100m. Outside the atolls the reef slopes drop steeply away to the ocean floor, at about 2,000–3,000m. An exception is found in the area between the double chain of atolls in the central Maldives, where bottom depths are of the order of 200–500m.

The waters of the northern Indian Ocean surrounding the Maldives are strongly influenced by the monsoons. The southwest monsoon (SW or boreal summer monsoon) extends from about May to October, while the northeast monsoon (NE or boreal winter monsoon) lasts from about December to March. Under the influence of the SW monsoon, ocean currents flow predominantly to the east, while during the NE monsoon they flow predominantly to the west (Hydrographic Office, 2007; Molinari *et al.*, 1990; Shankar *et al.*, 2002; Wyrski, 1973). The southern Maldives (south of about 2–3°N) is less affected by the monsoons, and more influenced by equatorial currents.

There has been one previous review of information on cetaceans in the Maldives (De Boer *et al.*, 2002), but that was brief and much new information has been become available since then. The aim of this paper is to provide an updated overview of information on cetaceans in the Maldives.

HISTORICAL WHALING

There were two periods of commercial whaling in the region of the Maldives. During the mid-19th century, sperm whales (*Physeter macrocephalus*) were hunted throughout much of the tropical Indian Ocean, mostly by 'Yankee' whalers from New England (Bannister *et al.*, 2007; Clark, 1887; Townsend, 1935; Wray and Martin, 1983). Blyth (1859) reported the following from one Rev. H. Baker who wrote to him from Kerala, India: 'Whales are very common on the coast. American ships, and occasionally a Swedish one, call at Cochin for stores during their cruises for them ... The Maldives and Seychelles are said to be the headquarters of the whalers who seek for these Whales.' Clark (1887, map of whaling grounds) charted a sperm whaling ground in the north of Maldives. Wray and Martin (1983) considered the area between Sri Lanka and Maldives to be an important sperm whaling ground in the 1840s and 1850s, and noted one particular case of sperm whales being taken east of the Maldives (in February 1847).

During the 1960s there was a brief but intense period of commercial whaling in the Arabian Sea by Soviet whaling fleets (Berzin, 2008; Clapham and Ivashchenko, 2009; Yablokov, 1994). Large numbers of blue, Bryde's, humpback and sperm whales were taken in the region, including waters that are now within the Maldivian EEZ (Mikhalev, 1996; 1997; 2000). Some older inhabitants of islands in the north and centre of Maldives report that whale blows were a common sight on fishing trips in the 1950s and early 1960s, but were rare thereafter (Anderson, 2005; unpublished data). In Sri Lanka there were similar reports from fishermen of many whales, possibly humpback whales, off the NE coast in the 1950s and 1960s, but apparently not in the 1970s (Reeves *et al.*, 1991: Table 1).

Maldivians themselves have never undertaken commercial whaling (Anderson *et al.*, 1999). There is no evidence that large whales were ever hunted in Maldives as suggested by

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Table 1
Cetaceans recorded from the Maldives.

Species	English name	Strandings	Encounters	Numbers
Mysticeta				
1 <i>Balaenoptera musculus</i>	Blue whale	8	0.7%	0.0%
2 <i>Balaenoptera edeni</i>	Bryde's whale	1	2.8%	0.1%
3 <i>Megaptera novaeangliae</i>	Humpback whale	0	0.1%	0.0%
Odontoceta				
4 <i>Physeter macrocephalus</i>	Sperm whale	57	0.5%	0.1%
5 <i>Kogia sima</i>	Dwarf sperm whale	0	4.2%	0.2%
6 <i>Steno bredanensis</i>	Rough-toothed dolphin	0	0.3%	0.2%
7 <i>Grampus griseus</i>	Risso's dolphin	2	11.4%	7.0%
8 <i>Tursiops truncatus</i>	Bottlenose dolphin	0	6.6%	2.4%
9 <i>Tursiops aduncus</i>	Indo-pacific bottlenose dolphin	0	6.6%	2.4%
10 <i>Stenella attenuata</i>	Pantropical spotted dolphin	1	3.5%	14.5%
11 <i>Stenella longirostris</i>	Spinner dolphin	2	34.8%	53.2%
12 <i>Stenella coeruleoalba</i>	Striped dolphin	0	2.4%	2.9%
13 <i>Lagenodelphis hosei</i>	Fraser's dolphin	1	0.9%	5.0%
14 <i>Peponocephala electra</i>	Melon-headed whale	12+	0.6%	4.7%
15 <i>Feresa attenuata</i>	Pygmy killer whale	2	0.2%	0.1%
16 <i>Pseudorca crassidens</i>	False killer whale	0	0.5%	0.6%
17 <i>Orcinus orca</i>	Killer whale	1	0.5%	0.1%
18 <i>Globicephala macrorhynchus</i>	Short-finned pilot whale	1	4.2%	1.9%
19 <i>Indopacetus pacificus</i>	Longman's beaked whale	1	0.2%	0.0%
20 <i>Mesoplodon densirostris</i>	Blainville's beaked whale	1	0.5%	0.0%
21 <i>Mesoplodon ginkgodens</i>	Ginkgo-toothed beaked whale	1	—	—
22 <i>Mesoplodon hotaula</i>	Atoll beaked whale	1	—	—
23 <i>Ziphius cavirostris</i>	Cuvier's beaked whale	2	1.2%	0.1%

Notes

Strandings: number of strandings from Anderson *et al.* (1999) plus additional unpublished records held at MRC; excludes specimens deliberately captured.

Encounters: is the percentage of *records* of each species among 1921 on-effort encounters reported by Anderson (2005: Table 4). Numbers: is the percentage of *individuals* of each species seen among 71,276 cetaceans by Anderson (2005: Table 7), and gives a very crude measure of relative abundance. Percentages do not add up to 100 since unidentified cetaceans are excluded here.

Tursiops species were not distinguished by Anderson (2005); together they accounted for 13.2% of encounters and 4.9% of numbers sighted in that study; we have split those figures equally between these two species for the purposes of this table.

Phillips (*in Hill*, 1958, p.9). A harpoon gun was apparently imported to Malé by the first President, Amin Didi, in about 1952 with the object of catching cetaceans for export, but it was never used (N.T. Hasen Didi, formerly of the President's Office, pers. comm., 1990 and 1998).

There was a traditional fishery for tiger sharks (*Galeocerdo cuvieri*) in the Maldives. Large tiger sharks have enormous livers, from which oil was obtained for treating wooden fishing boats. Dolphins were used as bait in this fishery, and they were caught by harpoon while bow-riding (Anderson and Ahmed, 1993; Didi, 1983; Ibrahim, 1991). The scale of the tiger shark fishery, known locally as *maa keyolhu kan*, is unknown. However, given that there are some 200 inhabited islands in the archipelago, it might perhaps have involved an annual take of many tens to a few hundred dolphins per year (species unknown, but likely including spinner dolphins). The tiger shark fishery and associated catching of dolphins died out in the early 1960s, when the more efficient method of longlining for sharks was introduced (Anderson and Ahmed, 1993) and other sources of oil became available. Although this fishery was undoubtedly an ancient one, before its demise fishermen were using toggle-head harpoons. This style of harpoon was invented in New England in 1848, and soon became widely used in the Yankee sperm whale fishery. It seems possible that New England whalers introduced it to the Maldives.

SIGHTINGS

Until relatively recently, reports of cetacean sightings from the Maldives were of limited scope. They included sightings by the Dutch sea captain Willem Mörzer Bruyns, who passed through or by the Maldives on several occasions in the 1950s and 1960s (Mörzer-Bruyns, 1971); Captain Jacques-Yves Cousteau, who visited the Maldives on board his famous ship *Calypso* in 1967 (Cousteau and Diolé, 1971; 1972); Stephen Leatherwood and fisheries worker Charles Peters who visited the Maldives separately during 1980–83 (Leatherwood *et al.* 1984) with additional information on some sightings in Gilpatrick *et al.* (1987), Leatherwood, (1986), Leatherwood *et al.* (1991) and Wilson *et al.* (1987); Japanese whaling researchers who passed through the Maldives on two scouting vessels in March 1982 (Kasuya and Wada, 1991); cetologists on the research yacht *Tulip* who visited Maldives in late 1983 and early 1984 (Alling *et al.*, 1984; Whitehead *et al.*, 1983) during the course of their research elsewhere in the Indian Ocean Sanctuary (Alling, 1986; Gordon, 1991; Whitehead, 1989); and some miscellaneous sightings by the senior author and colleagues (Anderson, 1990; 1996; Anderson *et al.*, 2006; Anderson and Shaan, 1998; 1999; Shaan, 2001). Sightings of whales from global surveys by British and Dutch merchant seamen, including some records from the vicinity of Maldives, were reported by Brown (1957) and Slijper *et al.* (1964) respectively. Popular accounts of the seasonality of

baleen whales around the Maldives were given by Buttress (2001) and Anderson (2002a).

There are several reports of dolphins from travellers, but without specific detail. For example, conchologist Alan Kohn visited the Maldives as part of the Yale Seychelles Expedition in 1957 (Kohn, 1964). He noted ‘In the lagoon of Mulaku Atoll, where we anchored [probably on 9 October 1957] in 14m in a *velu* [shallow lagoon], a large number of small porpoises, which made very short, high jumps, were observed.’ These were probably spinner dolphins, which still regularly occur in large numbers in this atoll. Travel writer Gavin Young sailed to Maldives (Young, 1981) and recorded bowriding dolphins accompanying his vessel in to Malé.

More systematic sightings surveys started with marine biologists Lisa Ballance and Robert Pitman who passed through Maldivian waters in April and June 1995 during the course of a cetacean survey of the western Indian Ocean (Ballance and Pitman, 1998; Ballance *et al.*, 1996). They recorded relatively large numbers of blue whales (*Balaenoptera musculus*) in the vicinity of Maldives. A 20-day cetacean survey in the north-eastern part of the Maldives was carried out during April 1998, with one aim being to obtain tissue samples from blue whales (Ballance *et al.*, 2001). That survey recorded 267 sightings of 16 cetacean species, with the spinner dolphin (*Stenella longirostris*) being the most commonly observed.

Subsequently, Anderson (2005) published a review of some 1,979 sightings of 20 cetacean species (plus 129 strandings), mostly recorded during 535 days at sea between August 1990 and June 2002. Again, spinner dolphins were the most abundant species recorded. They showed a clear diurnal pattern of behaviour, with many schools entering the atolls in the early morning, and leaving in the late afternoon. Spinner dolphins regularly occurred with pantropical spotted dolphins (*Stenella attenuata*) and both species associated with yellowfin tuna. Bryde’s whales (*Balaenoptera edeni*) also associated with yellowfin tuna and appeared to be most common in Maldivian waters during El Niño Southern Oscillation events. Blue whales were only recorded during November to April. Dwarf sperm whales (*Kogia sima*) were especially difficult to locate in rough weather but relatively common, making up one sixth of all sightings in flat-calm conditions. Melon-headed whales (*Peponocephala electra*) were particularly common in the south of the Maldives, but rare in the centre and north. It was noted that several species of cetacean were especially abundant along the steep atoll slopes. A summary of sightings is presented in Table 1.

Anderson (2005) recorded bottlenose dolphins as *Tursiops* sp. He noted that most appeared to be common bottlenose dolphins (*T. truncatus*), but that the possibility that some were Indo-Pacific bottlenose dolphins (*T. aduncus*) could not be discounted. In particular he noted differences between bottlenose dolphins seen inside atolls, and those seen out in the ocean. Subsequently, one of us (RCA) has confirmed from close observations and photographs, that both species occur in the Maldives. As suspected by Anderson (2005), *T. truncatus* is commoner outside of the atolls, tends to occur in larger groups, and often associates with other species. In contrast, *T. aduncus* occurs inside the atolls, or only just outside, tends to occur in small groups or singly, and rarely associates with other species.

Clark *et al.* (2012) report on two visits to the Maldives, in 2003 and 2004, by the research yacht *Odyssey* (Ocean Alliance, 2009). 157 cetacean sightings were recorded.

STRANDINGS

Some 16 species have been recorded from strandings so far, with the sperm whale being the most frequently recorded (Table 1) (Anderson *et al.*, 1999; Dalebout *et al.*, 2003; MRC, unpublished data). The relatively large number of sperm whale strandings, in comparison to the relatively few sightings recorded (Table 1) largely reflects the relatively little amount of survey effort conducted offshore. Many ‘stranded’ cetaceans are actually found floating dead at sea by fishermen (who may tow them to their islands in order to recover oil for treating wooden boats, and to search for valuable teeth and ambergris). Most of those carcasses that do wash up on islands or reefs appear to be dead at the time of stranding. Dead whales drift with the monsoon currents, so are found most frequently on the eastern sides of atolls and islands during the NE monsoon, and on the western sides of atolls and islands during the SW monsoon (Anderson *et al.*, 1999).

Two species, both beaked whales, have been so far been positively recorded in Maldives only from strandings: ginkgo-toothed beaked whale, *Mesoplodon ginkgodens* (cf Anderson *et al.*, 1999) and atoll beaked whale, *Mesoplodon hotaula* (Deraniyagala, 1963). The latter name is based on a single stranded female from Sri Lanka, and was relegated to the synonymy of *M. ginkgodens* by Moore and Gilmore (1965). However, genetic studies have shown that *M. hotaula* is a valid species, close to but distinct from *M. ginkgodens* (Dalebout *et al.*, 2007). More details of the single mature male stranded in the Maldives will be published separately (Dalebout *et al.*, in prep.). Another ziphiid, the previously little-known Longman’s beaked whale, *Indopacetus pacificus*, was redescribed in part on the basis of a Maldivian stranding (Dalebout *et al.*, 2003). Popular accounts of this ‘re-discovery’ were given by Anderson (2004), Dalebout (2002) and Pitman (2002), both of the latter two accounts being illustrated with photos of live animals from the Maldives (that in Pitman (2002) being mislabelled as from the Pacific).

Until early 2000 there was no standard scheme for reporting cetacean strandings in the Maldives. Reports of cetacean strandings were occasionally sent to the Government’s Marine Research Centre (MRC), in the capital Malé, and MRC staff collected information on other strandings during field trips. In late 2000, a more formal stranding reporting scheme was initiated. Each inhabited island has a government office and government-appointed island Chief (elected island Councillor since 2009). MRC sent recording forms to each island office, with instructions on how to report every marine mammal stranding. The main aim of the scheme is to obtain basic biological information about cetaceans in the Maldives. The recent spread of telecommunications to all islands is contributing to the more frequent reporting of strandings, while the increasingly widespread use of digital cameras is improving the frequency of reliable identifications.

There are few known instances of live strandings to date. This, combined with the geography of the country (numerous

small islands and reefs spread over a vast area of ocean, with consequent transport and communication difficulties), means that a network focusing on the welfare of live stranded cetaceans (as occurs elsewhere) is unlikely to develop in the foreseeable future.

Some other strandings were documented by Deraniyagala (1956), Leatherwood *et al.* (1984), Anderson (1990; 1996) and Branch *et al.* (2007). Gulland *et al.* (2001) provided a brief summary of the strandings reporting scheme. Anderson (2002b) provided a popular account of Maldivian whale strandings. Anderson *et al.* (1999) summarised all available strandings data up to 1998 ($n = 82$, of which 56 had not been previously reported). More than 80 additional strandings have been recorded since; these should be published in due course.

AMBERGRIS

Ambergris is occasionally recovered from some sperm whale strandings, and is also found floating at sea by Maldivian fishermen (Anderson, 1990; Godfrey, 1996; Klinowska, 1991; Whitehead, 1989).

Ambergris is known in Maldives as *maavaharu*. Maldivians recognise two types of ambergris: white (*hudhu maavaharu* or *hudanvaru*) and black (*kalhu maavaharu*). On Minicoy island, which was historically part of the Maldives but is now part of the Indian Lakshadweep islands, the same distinction has been reported.

Small quantities of ambergris are used in local medicines, but most is exported. This trade has been conducted since ancient times, as was noted by several early travellers, including: Arab traders from the 9th century onwards (Gray, 1890); the Chinese who accompanied the great admiral Cheng Ho (Zheng He) on his seven voyages into the Indian Ocean in the early 15th century (Ma Huan, 1970); and Portuguese adventurers from the early 16th century onwards (Gray, 1890). In 1753 Malé was attacked by an invading force from Malabar sent by the Ali Raja of Cannanore (present day Kannur in Kerala). Assistance was sought from the French in Pondicherry (now Puducherry, India), who sent a fleet of four ships, and saw off the Malabaris. The French remained until the following year, when they were apparently paid for their mercenary services with a piece of ambergris weighing 337½ lb (153kg) (Bell, 1940). Hockley (1935) noted that a small quantity of ambergris was included in the (by then largely ceremonial) annual tribute paid by the Maldives to the colonial Governor of Ceylon. He also noted three grades of ambergris; that trade in ambergris was a monopoly of the government; and that most was exported to Bombay (now Mumbai), since at that time foreign trade was dominated by Borah merchants from Bombay. Other relevant reports include Heyd (1879), Gode (1949) and Yamada (1955).

Fishermen who find ambergris normally sell it to middlemen in Malé (in practice there is one Maldivian company that dominates this minor trade). Most now goes to the Middle East where its reputed properties as an aphrodisiac are highly valued. Ambergris is unique among Maldivian marine products in that it is the only one subject to an export tax (amounting to 50% of the export price). Perhaps for this reason there may be some temptation to avoid declaring exports. Certainly the quantity and frequency

of ambergris exports has declined as unit price has increased (Tables 2 and 3).

Most pieces of ambergris found are of relatively modest size. But occasional large pieces are recovered, the largest in recent years being:

- (1) 214kg, 1983, location unknown;
- (2) 231kg, January 1989, K. Gaafaru;
- (3) 187kg, March 1995, H.A. Kelaa.

Table 2

Declared exports of ambergris from the Maldives (MRf=Maldivian rufiyaa).

	Quantity (kg)	Value (MRf)	Unit value (MRf/kg)	Value (US\$)
1974	190	21,000	100	—
1975	40	9,000	200	—
1976	150	66,000	400	—
1977	40	110,000	2,800	—
1978	130	534,000	4,100	—
1979	137.330	462,335	3,400	—
1980	121	1,610,043	13,300	—
1981	13	154,270	11,900	\$44,077
1982	90.602	627,278	6,900	\$104,546
1983	226.030	2,643,129	11,700	\$377,590
1984	43.742	483,956	11,100	\$68,646
1985	23.690	322,900	14,200	\$45,479
1986	26.058	535,370	20,500	\$74,877
1987	2.24	22,330	10,000	\$2,422
1988	0	0	—	—
1989	231	5,111,064	22,100	\$565,383
1990	0	0	—	—
1991	0.145	2,465	17,000	\$240
1992	0	0	—	—
1993	16.48	223,980	13,600	\$20,436
1994	21	222,000	10,600	\$19,154
1995	180	2,688,726	14,900	\$228,439
1996	10.50	189,000	18,900	\$16,058
1997	0	0	—	—
1998	0	0	—	—
1999	3.23	57,130	17,700	\$4,446
2000	0	0	—	—
2001	0	0	—	—
2002	3.10	93,000	30,000	\$7,237
2003	0	0	—	—
2004	1.21	36,300	30,000	\$2,825
2005	0	0	—	—
2006	0	0	—	—
2007	0	0	—	—
2008	0	0	—	—

Sources

Maldives Customs data 1974–78 from Anon (1979); 1979–2008 compiled annually by Ministry of Fisheries and Agriculture. Exchange rates from Anon (1992; 1997).

Notes

Data for 1974–78 were reported to the nearest 10kg and MRf 1,000. Unit prices given to nearest MRf 100. MOFA recorded 1991 quantity as 0.145MT, apparently in error. UNDP (1966) recorded exports of 24cwt (1,222kg) worth MRf 12,000 in 1963, and 17cwt (865kg) worth MRf17,000 in 1964; it seems likely that the quantities are incorrect.

Table 3

Average price and frequency of export of ambergris, by decade.

Period	Av. annual export	Av. unit value	% years with exports
1974–79	114.6 kg/y	1,750 MRf/kg	100%
1980–89	77.6 kg/y	14,800 MRf/kg	90%
1990–99	23.1 kg/y	14,700 MRf/kg	60%
2000–08	0.5 kg/yr	30,000 MRf/kg	22%

CETACEAN SPECIMENS

Relatively few cetacean specimens have been collected from the Maldives.

The 19th century French merchant-shipowner and naturalist Jean-Jacques Dussumier collected several cetacean specimens from the Indian Ocean (Arvy, 1972). These appear, from watercolour illustrations by Dussumier reproduced in Arvy (1972), to have included a pregnant female striped dolphin taken '1°N, 100 leagues to the east of the Maldiv Islands', and a female spinner dolphin 'caught a few leagues to the east of the Maldiv Islands, 73°E, on 31st July 1829.' Wilson *et al.* (1987) list both these records as *Stenella coeruleoalba*. (French leagues have been of different lengths at different times, but 19th century nautical leagues were usually of 4.448 km).

During his stay in Addu Atoll in 1958–59, W.W.A. Phillips collected one melon-headed whale and five spinner dolphin specimens, which he donated to the Natural History Museum in London (Anderson *et al.*, 1999). These specimens were noted in the data catalogues of Leatherwood (1986) and Gilpatrick *et al.* (1987), and referred to in the reviews of Dawbin *et al.* (1970), Perrin *et al.* (1989) and Perrin (1990).

In recent years it has become something of a trend among resort owners to have whale skulls and skeletons on display. A partial list of specimens on resort islands was given by Anderson *et al.* (1999). The National Museum in Malé holds a single ginkgo-toothed beaked whale tooth (Anderson *et al.*, 1999). The Marine Research Centre in Malé also has a small collection of cetacean specimens, including a complete skeleton of Longman's beaked whale.

Biopsy samples were collected by Robert L. Pitman during the survey carried out in April 1998 (Ballance *et al.*, 2001) and again during one leg of the Voyage of the *Odyssey* in 2004 (Clark *et al.*, 2012). Other Maldivian biopsy samples were taken by the crew of the *Odyssey* in both 2003 and 2004, mainly for a global assessment of pollutants in sperm whales (Ocean Alliance, 2009). Wise *et al.* (2009) reported on chromium levels in these sperm whales. In addition, some tissue samples have been collected from strandings by the senior author. Galver (2002) included six Maldivian biopsy samples in her unpublished study of the molecular ecology of spinner dolphins. Dalebout *et al.* (2003) incorporated genetic analysis of tissue samples from one Maldivian stranding in their reappraisal of Longman's beaked whale. LeDuc *et al.* (2007) included two Maldivian biopsy samples in their investigation of (mostly) Southern Hemisphere blue whale population structure. Chivers *et al.* (2007) included one biopsy sample from the Maldives (Susan Chivers, pers. comm., 28 August 2007) in their study of genetic population structure of false killer whales (*Pseudorca crassidens*), mainly in the north Pacific. Six pilot whale biopsy samples were confirmed as shortfinned pilots (*Globicephala macrorhynchus*) (Susan Chivers, US NMFS, pers Comm, October 2002).

ACOUSTICS

Little acoustic surveying has been carried out in the Maldives. Attempts were made to record blue whale vocalisations in 1998 (Ballance *et al.*, 2001), but without success. During the Voyage of the *Odyssey* in 2003–04 (Clark *et al.*, 2012) a total of 2,341 acoustic stations were

conducted, during 72 days at sea, with cetaceans recorded during 1612 (69%). This acoustic detection rate in Maldivian waters was 2.5 times higher than in areas of the eastern Indian and tropical Pacific also surveyed by the *Odyssey*. Cetacean detections consisted of delphinid species ($n = 1,260$), sperm whale ($n = 196$), killer whale ($n = 7$) and humpback whale (*Megaptera novaeangliae*) ($n = 1$).

WHALE AND DOLPHIN WATCHING

Spinner dolphins are particularly common in the Maldives (Anderson, 2005; Ballance *et al.*, 2001) and have become the focus of small-scale dolphin-watching ventures from tourist resorts. There are currently 95 resort islands in the Maldives. At least 20 offer excursions to see spinner dolphins. These excursions take advantage of the fact that many spinner dolphin schools (which feed out in the ocean at night) rest inside the atolls by day. They therefore enter through reef channels in the morning, and exit in the afternoon, on a fairly predictable schedule, which greatly increases the chances of successful encounters. Some excursions are run in the mornings, but most are offered in the afternoon, sometimes being marketed as a sunset cruise with the chance to see dolphins. One operator also offers multiday whale-watching cruises. These typically see several thousand individuals of anything up to 12 or more cetacean species during 7–10 days at sea (RCA, pers. obs.).

A recent global review of whale-watching (IFAW, 2009) estimated that over 14,000 tourists took part in dolphin and whale watching excursions in Maldives during 2008, spending over US\$580,000. This was up from an estimated revenue of US\$149,000 in 1998 (Hoyt, 2001).

FISHERIES INTERACTIONS AND PROTECTIVE MEASURES

There is no fishery for cetaceans in the Maldives today. Indeed, the capture of all cetaceans is specifically banned under Maldivian law (Fisheries Law, no. 5/87, iulaan no. FA-A1/29/93/14, 15 May 1993) as is the export of cetacean products (under the Import-Export Law, no. 31/79). The main fishing methods now used in the Maldives (pole and line for tuna and handline for reef fish and tuna) do not catch cetaceans. The lack of cetacean bycatch in the Maldivian tuna fishery was briefly noted by Lal Mohan (1994). There is also some pelagic longlining, although this is currently at a very low ebb following not only a recent ban on shark fishing and shark product exports, but also the current phasing out of licenses for foreign longliners. It is possible that there may have some cetacean entanglement by the longline fisheries, but there was no monitoring by observers and no data are available.

Pelagic gillnets, purse seines and trawls have never been used commercially in the Maldives, and have been banned for many years (Fisheries Law no. 5/87), mainly to protect the livelihoods of traditional pole and line tuna fishermen. Occasionally cetaceans entangled in bits of netting are stranded, but these are believed to have drifted into Maldivian waters from outside (Anderson *et al.*, 1999). There has also been some illegal pelagic gillnet fishing within the Maldivian EEZ by Sri Lankan vessels, but the extent of any cetacean bycatch is unknown.

A handline fishery for large yellowfin tuna (*Thunnus albacares*), aimed at the export market, started in Maldives in the mid-1990s. Fishermen use the presence of dolphins to locate the schools of yellowfin (Adam and Jauharee, 2009; Anderson, 2005; Anderson and Shaan, 1998; 1999). The species most commonly associated with yellowfin tuna is the spotted dolphin, although spinner dolphins do also associate. Yellowfin tuna and dolphins also regularly associate in Sri Lankan (De Silva and Boniface, 1991) and Omani waters (Ballance and Pitman, 1998).

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Cetacean sightings and acoustic detections in the offshore waters of the Maldives during the northeast monsoon seasons of 2003 and 2004

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ABSTRACT

Despite its central position in the Indian Ocean Sanctuary, little is known about the offshore cetacean fauna of the Maldives. Here we report survey results gathered by the R/V *Odyssey* in the Maldives during the 2003 and 2004 northeast monsoon seasons, and provide data on cetaceans from visual and acoustic observations. The survey was conducted over a period of 72 days and covered 10,915 track line kilometres. The main aim of the survey was to collect biopsy samples from sperm whales (*Physeter macrocephalus*) as part of a global survey of ocean pollutants. Totals of 157 sightings and 1,461 acoustic detections of 16 identified cetacean species were recorded. Risso's dolphin (*Grampus griseus*), pantropical spotted dolphin (*Stenella attenuata*), spinner dolphin (*Stenella longirostris*) and sperm whale were the most commonly sighted species. Sperm whales and pantropical spotted dolphins were particularly abundant in the southern Maldives. The cetacean acoustic detection rate was 2.5 times higher than in the eastern Indian Ocean and Western tropical Pacific, while the non-physeterid sighting rate was 1.7 times higher than the Eastern tropical Pacific and 6.7 times higher than the eastern Indian Ocean based on other research conducted by the R/V *Odyssey* using the same methodology. It is concluded that the Maldives has a diverse and seemingly abundant cetacean community.

KEYWORDS: INDIAN OCEAN; SANCTUARIES; SURVEY-ACOUSTIC; SIGHTING; SPERM WHALE; MALDIVES

INTRODUCTION

The Indian Ocean Sanctuary (IOS) was declared by the International Whaling Commission (IWC) in 1979, and prohibits commercial whaling in the region. It has also had the effect of allowing recovery of exploited populations of great whales within the Indian Ocean and facilitating benign research on populations of cetaceans not subjected to commercial whaling. Relatively few studies have been undertaken to shed light on cetacean communities within the IOS (Ballance and Pitman, 1998; De Boer *et al.*, 2003). Consequently there remains a need for expanding the knowledge of species composition, distribution, abundance and population sizes of cetaceans in the Indian Ocean, to establish baselines for management, conservation measures and mitigation of potential threats.

The Republic of the Maldives lies within the IOS, at the centre of the northern Indian Ocean, but relatively few cetacean studies have been undertaken (reviewed by Anderson *et al.* 2012). Among recent studies, Anderson *et al.* (1999) reviewed information on cetacean strandings. Ballance *et al.* (2001) reported on a cetacean survey around the northeast of the archipelago. Anderson (2005) summarised approximately 2,000 cetacean sightings from the period 1990–2002. These studies demonstrated that Maldivian waters have a rich cetacean fauna, comprising at least 23 different species of the families Balaenopteridae, Delphinidae, Physeteridae and Ziphiidae (Anderson *et al.*,

2012b). Other areas within the Indian Ocean hold equal or greater cetacean diversity, but Maldivian waters are particularly interesting from a cetacean monitoring and conservation perspective because there is no local whaling and the fishing methods employed (mostly pole and line for tunas and handline for reef fishes) result in apparently zero bycatch of cetaceans and negligible catch of their prey (Anderson *et al.*, 2012b; 1999; 1998). Thus, the Maldivian cetacean fauna may, in contrast to many other areas in the Indian Ocean, have suffered little from either deliberate or accidental takes. Nevertheless, in the offshore waters of the Maldives in particular very little is known about the cetacean fauna. Here we report data from the 2003 and 2004 surveys by the R/V *Odyssey*, which spent 72 days in the Exclusive Economic Zone (EEZ) of the Maldives seaward of the atoll slope in search of sperm whales.

The R/V *Odyssey*, research vessel of the Ocean Alliance, launched the Voyage of the *Odyssey* in the spring of 2000. The *Voyage* was a five-year global effort designed to gather the first ever baseline data on levels of contaminants throughout the world's oceans by collecting biopsies from sperm whales (*Physeter macrocephalus*) (Ocean Alliance, 2009). An important area in that study was the tropical Indian Ocean, including Maldivian waters. Since *Odyssey's* primary research objective involved the collection of biopsies from sperm whales, track lines were biased towards passing underwater features (such as seamounts) that

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increased the chance of finding this species. Thus, the sighting and acoustic data collected do not allow for estimation of absolute densities nor population sizes for species encountered. Nevertheless, the visual and acoustic observations collected in Maldivian waters offer relevant and much needed information on the cetacean community structure and zoogeography in the northern tropical Indian Ocean. Furthermore, the results of this survey provide a contrast to previous surveys in Maldives, which have concentrated on nearshore waters. Here we present sighting and acoustic data from at least 17 different cetacean species and discuss implications for the understanding of cetacean community structure and conservation within the Maldivian region of the IOS.

MATERIALS AND METHODS

Research area and platform

The Republic of the Maldives lies within the IOS, at the centre of the northern Indian Ocean. Comprising more than 1,200 low coral islands, the archipelago stretches north-south from about 7°N to 1°S, and is surrounded by deep oceanic water. The weather is dominated by the monsoons. The northeast monsoon lasts from about December to March (when ocean currents flow mainly to the west) while the stronger southwest monsoon blows from about May to October (when currents flow eastward) (Anderson *et al.*, 2011; Anderson *et al.*, 1999; Longhurst, 1998; Tomczak and Godfrey, 1994). November and April are inter-monsoon months.

Research was conducted aboard the R/V *Odyssey*, a 28m steel ketch, fitted for extended periods of off-shore research on marine mammals. The research in Maldivian waters was conducted in two study periods: the first from 12 January to 17 March 2003, the second from 9 February to 26 March 2004. Research was thus conducted during the annual northeast monsoon season, when winds are generally light and from the NE, and currents generally run from east to west. During each research season, three cruise legs were completed (Table 1). These cruises between them covered the area between about 7°N to 1°S and 71°E to 75°E (Fig. 1). A total of 10,915 track line km were covered (Fig. 1), 1,470 h were spent on acoustic and visual searches, and 70 sperm whale biopsies obtained. Mean sea state was 2.5 ± 0.9 (mean $\pm$ SD) (range 0–6) yielding excellent (Beaufort 0–2) sighting and listening conditions 52% of the time, and fair (Beaufort 3–4) observation conditions 47% of the time.

There were some differences in areas surveyed between years. During all three legs in 2003, the R/V *Odyssey* operated offshore, beyond the 2000m isobath, searching for sperm whales. In contrast, in 2004, much time was spent more inshore, searching for beaked whales along the outer atoll slopes. In addition, the only cruise leg to visit the north of Maldives was conducted in 2003. For the purposes of this report, northern Maldives is defined as the area north of 5°N; southern Maldives the area south of 3°N, and central Maldives as the area in between.

Visual survey methodology

A watch was maintained during daylight hours (~0600 to 1900h) from an observation platform located 4.6m above water level, with a maximum sighting distance to the horizon of 7.5km. One or two observers surveyed the area 180° forward of the vessel to the horizon by naked eye and 7x40 binoculars. All marine mammal sightings were recorded in the computerised database *Logger 2000* v. 2.05 (developed by the International Fund for Animal Welfare, IFAW). Sighting data included species identification, position (from GPS), number of animals, behaviour, water depth, bearing and distance to the vessel. In addition, the following data were automatically recorded in the database for each entry: time, vessel course and speed, sea surface temperature (SST) and sea state (SS). Sea surface temperature and weather conditions relating to sighting ability (sea state, swell and meteorological conditions) and navigation data were also entered in the *Logger* database every half hour. Visual effort was suspended during times of heavy rain. Sightings within 2km of the vessel's track were approached to obtain species identification, photographs and to estimate school size.

For all species, animals that were observed to be less than half the length of an accompanying animal were classified as calves. Animals more than half the length of an accompanying adult, but less than full size were classified as immature animals. For sperm whales, mature males were determined by their large size (estimated at greater than 12m). Sexually mature female sperm whales were classified by the presence of callosities on their dorsal fin (Kasuya and Ohsumi, 1966; Whitehead and Gordon, 1986), although this method is not fool-proof.

Acoustic survey methodology

Acoustic detections of marine mammals were made using a 100m long hydrophone array, consisting of two *Benthos* AQ4

Table 1
Summary of survey effort, by cruise leg.
Note: Regions N,C,S = north, centre, south (see text for definitions).

Leg	Dates	Survey effort		Acoustic stations	Region	Inshore/ Offshore	No. sperm whale biopsies
		km	h				
1	12–24/01/2003	1,938	241	325	C, S	Off	7
2	06–28/02/2003	3,567	448	562	N,C,S	Off	16
3	04–13/03/2003	1,636	199	309	C,S	Off	18
4	09–18/02/2004	1,517	200	261	C,S	In and Off	17
5	02–06/03/2004	443	95	217	C	In	0
6	13–26/03/2004	1,814	287	480	C,S	In and Off	12
	Total	10,915	1,470	2,154			70

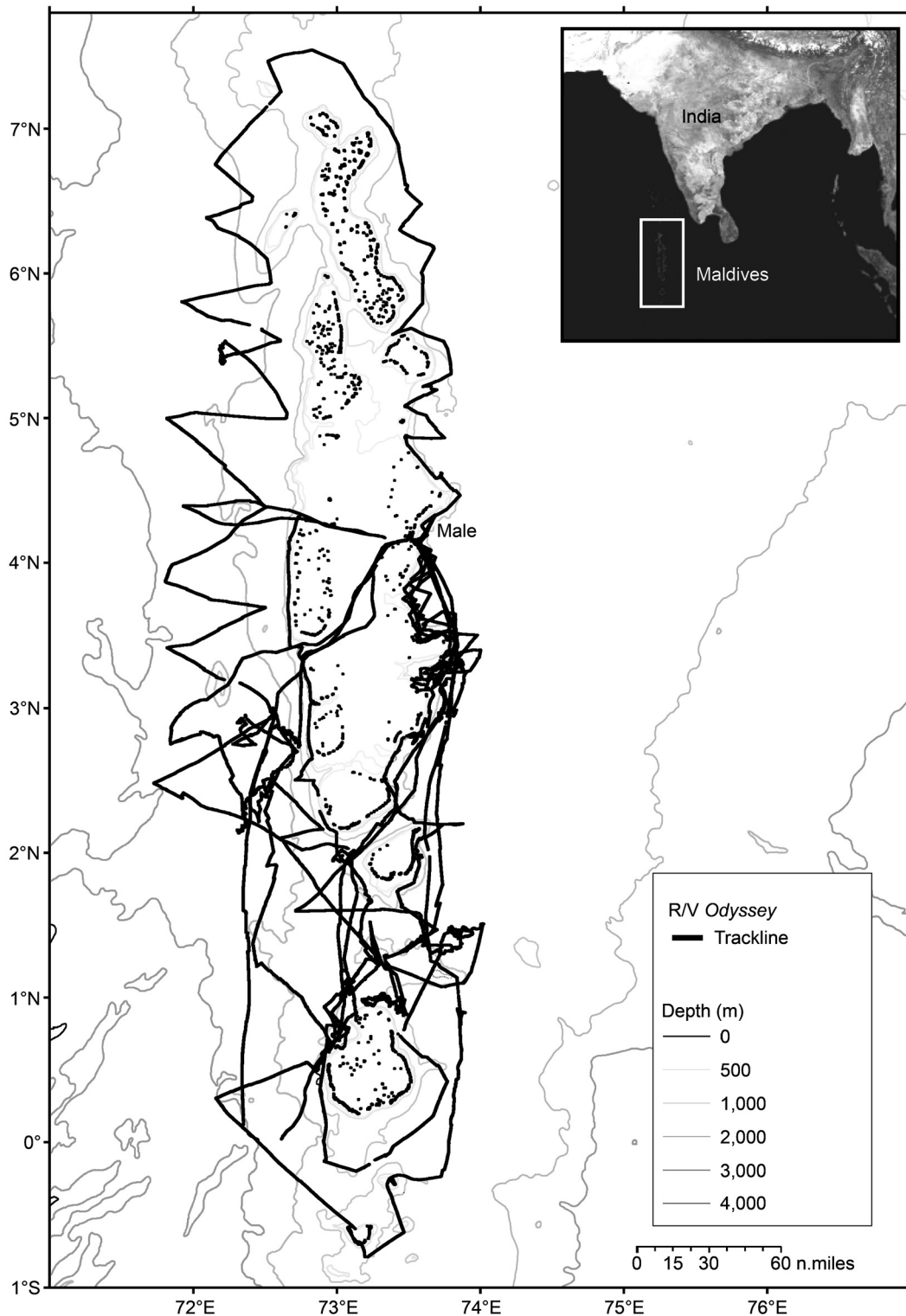


Fig 1. Trackline of R/V *Odyssey*.

hydrophone units with *Benthos* AQ201 pre-amplifiers separated by 2m. Effective listening range was 1–25km depending on weather conditions, vocalising species, and whether the vessel was motoring or sailing. The output signal was connected to headphones, as well as to a pair of stereo speakers located in the pilothouse. Sounds from the array were monitored continuously by the helmsman listening to the speaker set while the vessel was underway. When not actively working with sperm whales, listening stations with headphones were occupied every half hour. An acoustic stop

was made on even hours with the engine turned off and the vessel brought to a speed of less than one knot for a minimum of five minutes. During the half hour and odd hour stations, the engine was reduced to idle speed, the autopilot put on standby for a minimum listening period of five minutes. Acoustic contacts with marine mammals were entered in *Logger 2000*. Acoustic detection rates are reported as detections per listening station.

Incoming data from the acoustic array were automatically scanned for sperm whale clicks with different algorithms

depending on background noise levels. Once sperm whales were detected the vessel was manoeuvred to derive the bearing of clicking animals relative to the vessel. Incoming acoustic data from the array were automatically processed in real time by the software *Rainbow Click* v. 1.03 (IFAW). *Rainbow Click* analysed the stereo signal using time of arrival differences between the same clicks on the two channels to estimate a bearing to each click source.

RESULTS

Sightings

A total of 157 cetacean group sightings were made, of at least 17 different species (Table 2). 107 sightings (68%) were identified to species. Locations of all cetacean sightings are shown in Figs 2–3. Numbers of individuals observed, and mean group sizes are listed in Table 3.

For some species there were large differences in the numbers of sightings and of group sizes between years (Tables 2 and 3). For example, for sperm whales there were more sightings in 2003 ($n = 14$) than in 2004 ($n = 5$). Nine of the sighting in 2003 consisted of single animals, while no single animals were sighted in 2004. The mean size of the other sperm whale groups was 10.9 animals.

There was a marked increase in the number of spinner and pantropical dolphins sighted between 2003 and 2004. For pantropical spotted dolphins, there were more sightings ($n = 13$) in 2003 ($n = 13$) than 2004 ($n = 5$), but the mean group size was significantly larger ($t = 4.7$, $p \leq 0.0006$) in 2004 (191 ± 131) than in 2003 (24 ± 14). For spinner dolphins, the recorded number of groups was similar in both years (8 in 2003 and 7 in 2004) but the mean group size was significantly larger ($t = 2.3$, $p \leq 0.04$) in 2004 (108 ± 105) than 2003 (15 ± 9).

Table 2

Numbers of cetacean sightings by species during the 2003 and 2004 northeast monsoons.

		Number of sightings		
		2003	2004	Total
Bryde's whale	<i>Balaenoptera edeni</i>	4	2	6
Sperm whale	<i>Physeter macrocephalus</i>	14	5	19
Dwarf sperm whale	<i>Kogia sima</i>	–	1	1
Killer whale	<i>Orcinus orca</i>	–	1	1
False killer whale	<i>Pseudorca crassidens</i>	2	1	3
Pygmy killer whale	<i>Feresa attenuata</i>	–	1	1
Melon-headed whale	<i>Peponocephala electra</i>	1	1	2
Short-finned pilot whale	<i>Globicephala macrorhynchus</i>	–	1	1
Spinner dolphin	<i>Stenella longirostris</i>	8	7	15
Pantropical spotted dolphin	<i>Stenella attenuata</i>	13	5	18
Striped dolphin	<i>Stenella coeruleoalba</i>	5	3	8
Common bottlenose dolphin	<i>Tursiops truncatus</i>	1	4	5
Fraser's dolphin	<i>Lagenodelphis hosei</i>	1	1	2
Risso's dolphin	<i>Grampus griseus</i>	3	20	23
Cuvier's beaked whale	<i>Ziphius cavirostris</i>	–	1	1
Longman's beaked whale	<i>Indopacetus pacificus</i>	1	–	1
Beaked whale	<i>Mesoplodon</i> sp.	2	1	3
Unidentified whale		1	6	7
Unidentified dolphin		21	19	40
Total		77	80	157

Acoustics

A total of 2154 acoustic stations were conducted, with cetacean detections recorded during 1461 (68%). Cetacean detections included delphinid species ($n = 1175$), sperm whale ($n = 231$), pilot whales ($n = 19$), killer whale ($n = 1$) and unassigned (114). Thus, 55% of all listening stations detected the sounds of delphinids. The similarity in tonal and click sounds from a wide range of smaller delphinids did not allow for acoustic species identification, with the exception of dolphin detections which were augmented by visual identification (including Risso's dolphins, $n = 18$). However, short-finned pilot whales and killer whales could be identified by their distinctive whistles.

All sperm whale groups were first detected acoustically, followed by visual location. No sperm whale groups were detected by only one method. The mean time spent with a group was 14h (± 5 h) and acoustic and/or visual contact was maintained until effort was terminated upon data set completion; no groups were lost prior to termination of effort.

DISCUSSION

This study recorded 17 species from the Maldives. At the time of these surveys only four other cetacean species had been reported in Maldivian waters (Anderson, 2005; Anderson *et al.*, 1999; Ballance *et al.*, 2001).

Six species were sighted only once each (Table 1): dwarf sperm whale, Cuvier's beaked whale, Longman's beaked whale, killer whale, pygmy killer whale and short-finned pilot whale. The sighting of Longman's beaked whales was previously reported by Anderson *et al.* (2006). The one group of killer whales was seen attacking common bottlenose dolphins off the west side of the Maldives (at 3°03'N 72°49'E) on 24 March 2004. Killer whales and pygmy killer whales are both considered to be uncommon in the Maldives (Anderson, 2005; Ballance *et al.*, 2001). The other four species are not especially rare in the Maldives, indeed short-finned pilot whales and dwarf sperm whales are relatively abundant (Anderson, 2005; Ballance *et al.*, 2001), but they are encountered most commonly over the outer atoll slopes. This survey spent more time in offshore waters than slope waters compared to previous surveys.

More time was spent in near-atoll slope waters in 2004 than in 2003. This may explain inter-annual differences in sightings for some species. Thus, slope-associated species, notably Risso's dolphin, dwarf sperm whale and short-finned pilot whale, but also Cuvier's beaked whale (Anderson, 2005), were sighted only in 2004, but given the low sightability of this species no inferences can be drawn on year to year changes. In contrast, 'offshore' species such as sperm whale, striped dolphin and spotted dolphin, were sighted more frequently in 2003 than 2004 (Tables 2 and 4). However, there were more individuals of both striped and spotted dolphins recorded in 2004 than 2003, and we note that this division between inshore and offshore does not explain all interannual differences.

The pantropical spotted dolphin was the most common species recorded by number (Table 3). It was also the third most frequently sighted species over both seasons (Table 2). Pantropical spotted dolphins were most frequently

Table 3
Numbers of individuals seen and mean group sizes by species and survey season.

	Number of animals			Mean group size		
	2003	2004	Total	2003	2004	Total
Bryde's whale	4	4	8	1.0	2.0	1.3
Sperm whale	64	54	118	4.6	10.8	6.2
Dwarf sperm whale	0	2	2	—	2	2
Killer whale	0	8	8	—	8	8
False killer whale	40	70	110	20	70	37
Pygmy killer whale	0	10	10	—	10	10
Melon-headed whale	1	33	34	1	33	17
Short-finned pilot whale	0	15	15	—	15	15
Spinner dolphin	122	756	878	15	108	59
Pantropical spotted dolphin	288	955	1,243	22	191	69
Striped dolphin	71	127	198	14	42	25
Common bottlenose dolphin	10	107	117	10	27	23
Fraser's dolphin	100	175	275	100	175	138
Risso's dolphin	60	237	297	20	12	13
Cuvier's beaked whale	0	4	4	—	4	4
Longman's beaked	5	0	5	5	—	5
Beaked whale	3	4	7	1.5	4	2.3
Unidentified whale	2	13	15	2	2.2	2.1
Unidentified dolphin	283	226	509	13	12	13
Total	1,053	2,800	3,853			

encountered in the southern Maldives (Figs 2 and 3), and were not recorded at all from the north of Maldives. Ballance *et al.* (2001) considered pantropical spotted dolphins to be uncommon during their survey of northern waters. However, Anderson (2005) reported this species to be common throughout the Maldives, albeit especially so around the southern atolls.

Spinner dolphins have previously been recorded as the most frequently sighted species in the Maldives (Anderson, 2005; Ballance *et al.*, 2001), as well as the most abundant species in the western Indian Ocean (Ballance and Pitman, 1998). During this study, however, spinner dolphins were only the second most numerous and fourth most frequently sighted species (Tables 2 and 3). This might again be explained in part at least by the fact this survey spent much time offshore, since spinner dolphins are frequently atoll-associated (Anderson, 2005).

Sperm whales were the most commonly recorded species in 2003, and the second most commonly recorded species overall. This is consistent with the findings of both Ballance and Pitman (1998), who found sperm whales to be the most frequently sighted cetacean in the western Indian Ocean, and of Anderson *et al.* (1999), who reported the sperm whale to be the most commonly stranded cetacean in the Maldives. Furthermore, our survey was designed to maximise the likelihood of finding sperm whales, spending much time offshore and using previous experience of those bathymetric features which provide appropriate habitat for this species. In contrast, surveys of Maldivian inshore waters have recorded relatively low numbers of sperm whales (Anderson, 2005; Ballance *et al.*, 2001).

Nearly all of our sperm whale sightings and acoustic detections occurred in the southern Maldives, between about 0° and 3°N (Figs 2 and 3). This suggests that the mesopelagic prey of sperm whales may be most abundant in this area, at least during the northeast monsoon. The south of the Maldives is under the influence of the equatorial current

systems, rather than the seasonal monsoon currents that affect the northern and central atolls. As a result the south of Maldives is known to have a rather different pelagic fauna from the north and centre (Anderson, 2005; Anderson and Saleem, 1994; Anderson *et al.*, 1998).

A similar number of sperm whales were sighted during both years although there were differences in the number of groups sighted. Fourteen groups consisting of 64 sperm whales were sighted in 2003 while five groups consisting of 54 animals were sighted in 2004. However, nine of the 14 groups sighted in 2003 consisted of single animals, while no single animal sightings were recorded in 2004. Although groups of adult males and females, as well as the immature of both sexes were sighted during both years, calves were only sighted in one group in 2004. This group, which was the largest encountered during the study, included two calves and two adult females with callosities on their dorsal fin. Acoustic 'clangs/slow clicks', which are presumed to be made only by mature males (Whitehead, 2003), were recorded while with this group, suggesting that an adult male was within acoustic range of the array even though none was sighted. The two calves recorded represented less than 2% of the sperm whales sighted during this study. The ratio of calves to animals with callosities, which are presumed to be adult females (Kasuya and Ohsumi, 1966; Whitehead and Gordon, 1986), was 1 to 5.5; this is much lower than the 1:2 ratio reported for Sri Lanka (Gordon, 1987). On this basis, only 10% ($n = 11$) of sperm whales sighted were presumed adult females, which was lower than the average of 33% previously reported for tropical waters (Best, 1979). However, it is likely that there were some adult females without callosities. It is also possible that our working definition of 'calves' as being less than half the length of accompanying animals may have caused us to underestimate their true number. Nevertheless, the data we recorded suggest relatively low numbers of adult females and calves in the Maldives, and may indicate that this area is not a major

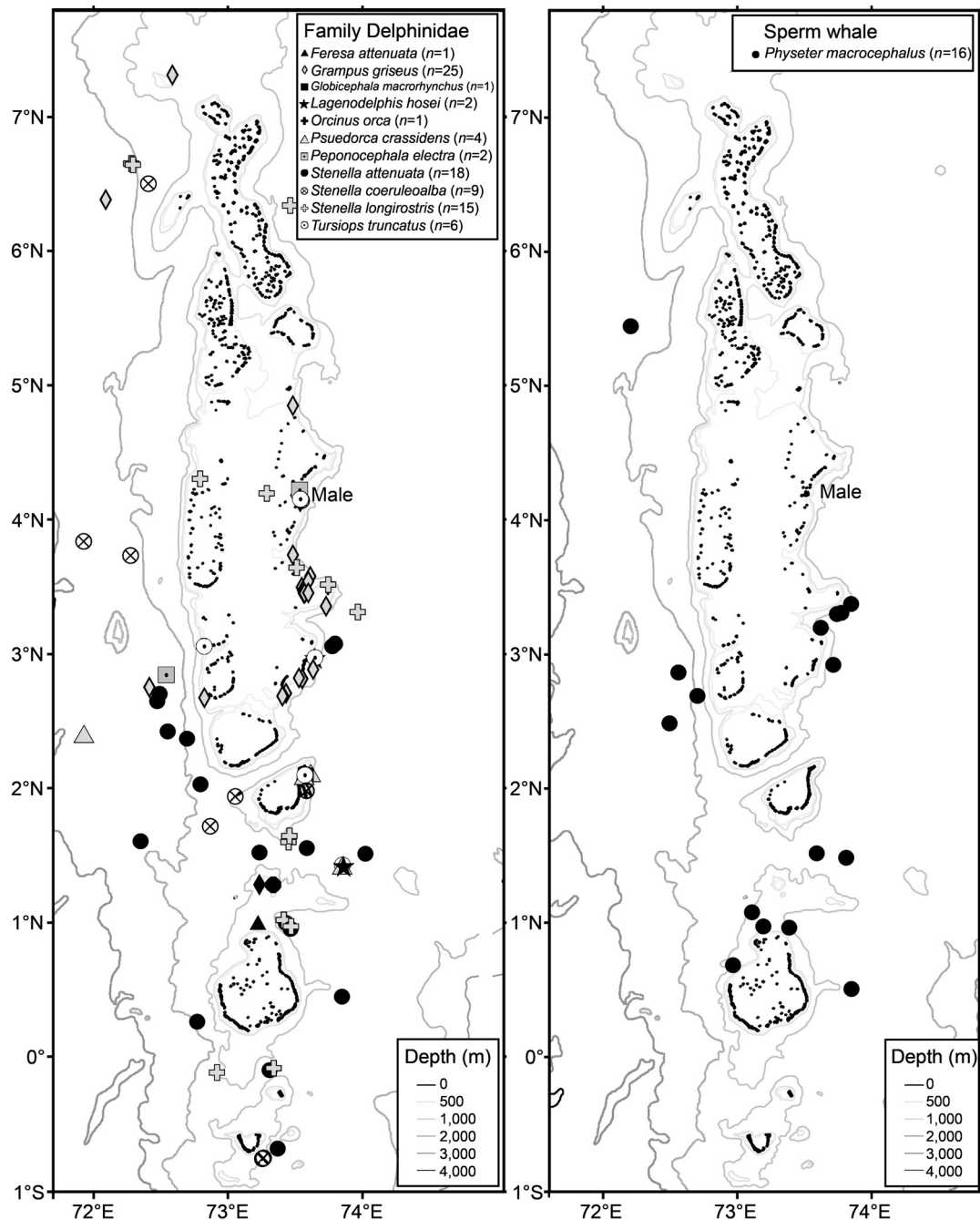


Fig 2. Delphinid and sperm whale sightings.

nursery ground for sperm whales. However, further studies, including surveys at different seasons, and of movements of sperm whale groups within the Indian Ocean, will be needed to understand the social structure of groups and how they change on temporal and geographical scales.

Subadult and adult male sperm whales ($n = 21$) accounted for nearly 19% of all sperm whales recorded. This is much higher than the 3% reported during peak breeding season in Galapagos (Whitehead, 1993) or the 4.2% reported in the West Indies (Whitehead, 1987). Furthermore Gordon (1987) rarely sighted adult males in Sri Lankan waters during the northeast monsoon; the sperm whale population there consisted almost entirely of adult females and immature animals of both sexes, with no animals exceeding 12 m in length (Gordon, 1991). In contrast, Maldivian stranding data show that about 22% of stranded sperm whales were greater

than 12m (Anderson *et al.*, 1999) suggesting that they were adult males.

We did not record any blue whales (*Balaenoptera musculus*) although this species had been previously recorded from Maldivian waters during several studies (Anderson, 2005; Anderson *et al.*, 1999; Ballance *et al.*, 2001; Ballance and Pitman, 1998). One reason may be that our hydrophone array was unable to detect blue whale calls due to flow noise, Lloyd mirror effects and a 400Hz high pass filter. In addition, most of our survey effort was in February and March, when blue whales appear to be relatively scarce in the Maldives (Anderson *et al.*, 2012a).

Both acoustic detection rates (defined as detections per listening station) and sightings rates for non-physeterid cetaceans were higher in Maldivian waters than in any other Voyage of the *Odyssey* study area (Ocean Alliance,

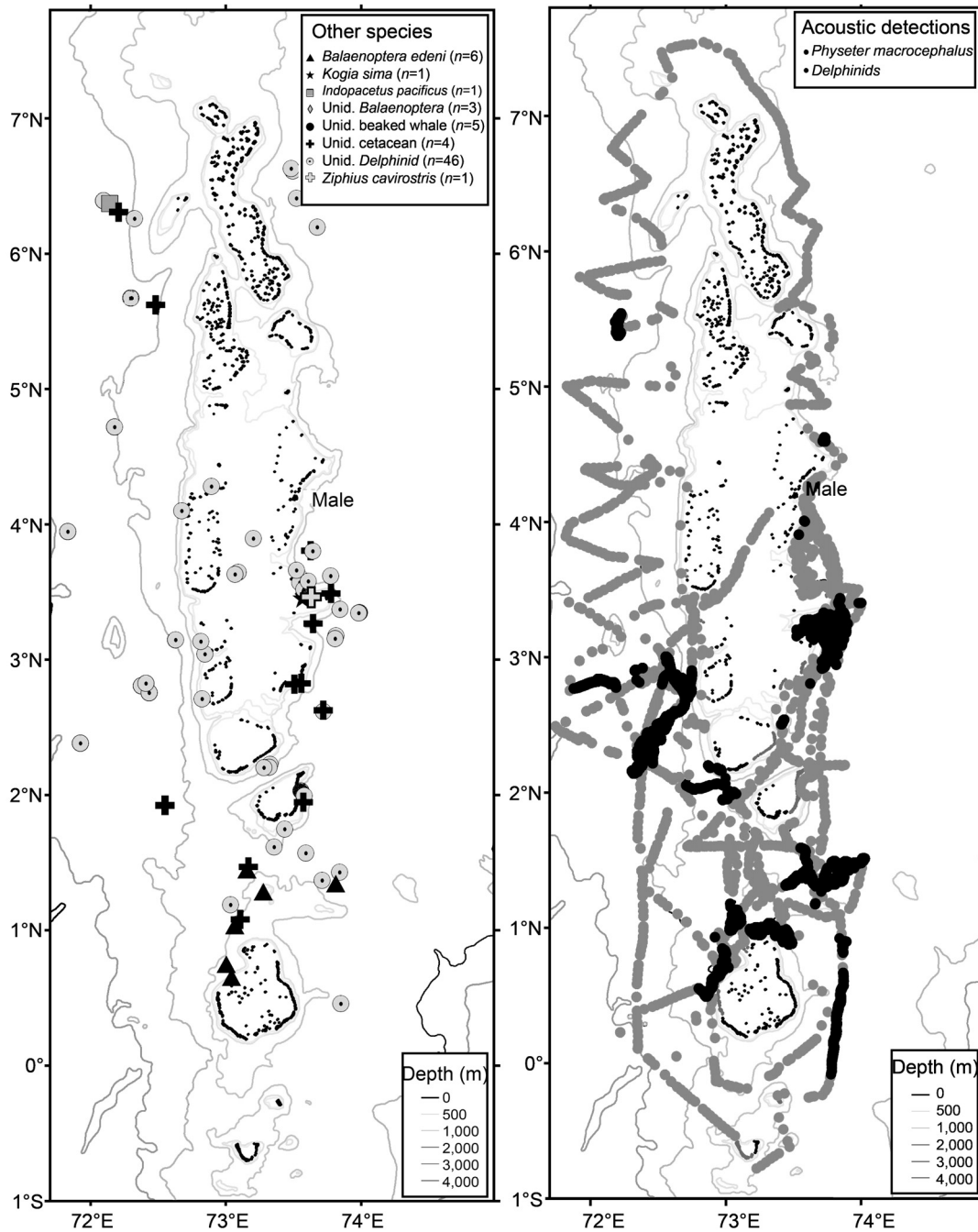


Fig 3. Sightings of other species and acoustic detections of delphinids and sperm whales.

unpublished data). Maldivian cetacean acoustic detection rates were double those for the rest of the western tropical Indian Ocean and over 2.5 times higher than both the eastern Indian Ocean and the Pacific Ocean. Maldivian sighting rates for non-physeterid cetaceans were 1.2 times higher than in the rest of the western Indian Ocean, 6.7 times higher than in the eastern Indian Ocean and 1.7 times higher than in the Western Tropical Pacific.

Differences in sea states and perhaps also seasonal effects in different survey areas will have influenced these regional differences. Nevertheless, the high acoustic and visual detection rates in the Maldives strongly suggest that these waters have a seemingly abundant cetacean fauna in comparison not only to the rest of the Indian Ocean but also to at least some parts of the Western tropical Pacific. One factor contributing to this apparently high cetacean

abundance may be the unique geographical setting of the Maldives island chain, which lies north-south across the east-west flow of the monsoon currents. Through upwelling and other processes, this juxtaposition enhances primary productivity, providing increased feeding opportunities for marine predators (Anderson *et al.*, 2011; Longhurst, 1998). In addition, fishing practice and policies within the Maldives result in apparently zero by-catch of cetaceans and very little waste of unwanted fish catch. Tuna fishing is of particular significance, and Maldivians continue to practice a traditional pole and line technique. All forms of pelagic netting (including gill-netting, purse seining and trawling) are banned. Thus, the Maldives represents a rare oceanic area in which fisheries policies are implemented with apparent benefits for cetaceans and the broader oceanic ecosystem.

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Occurrence of whales and dolphins in Pakistan with reference to fishers' knowledge and impacts

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ABSTRACT

This paper reports the findings of a project (Cetacean Conservation Pakistan) launched in 2004 with a view to: (a) undertaking quantitative surveys to determine the variety and abundance of species present; (b) working with local fisher communities to collate local knowledge and promote public awareness; and (c) promoting a marine cetacean conservation strategy and measures. Boat-based surveys for live animals and shore surveys for beachcast specimens have confirmed the presence of twelve species of whale and dolphin. Among these bottlenose dolphins (*Tursiops* sp.) occur both inshore along the coasts of Sindh and Balochistan, and offshore in parts of Balochistan; these two populations possibly representing different sub-species. Indo-Pacific humpback dolphins (*Sousa chinensis*) are common inshore around the mouth of the Indus Delta and in large sheltered bays in Balochistan, where finless porpoise (*Neophocaena phocaenoides*) also occur. Spinner dolphins (*Stenella longirostris*) were observed in very large schools (up to 2,000) around the shelf edge in eastern Balochistan, as were Risso's dolphins (*Grampus griseus*) in smaller numbers. Common dolphins (*Delphinus capensis*) were recorded even further offshore. There were two sightings of humpback whales (*Megaptera novaeangliae*), and one of a killer whale (*Orcinus orca*). Bryde's whales (*Balaenoptera edeni*), sperm whales (*Physeter macrocephalus*) and Cuvier's beaked whales (*Ziphius cavirostris*) were recorded only during beach surveys, while skeletal remains in institutions also supported the occurrence of blue whales (*Balaenoptera musculus*). Work with local fisher communities supported this picture of species distribution and provided information on threats to local cetaceans. These are principally occasional entanglement in fishing gear and opportunistic exploitation for use as food, as bait, as medicine or for other purposes. The project incorporated policy development and the preparation of a marine cetacean biodiversity action plan that included the listing of species in provincial conservation legislation, the designation of a marine protected area in Balochistan, the establishment of a national whale and dolphin conservation society, and trials of whale and dolphin watching as a means of raising public awareness and providing alternative economic value.

KEYWORDS: ABUNDANCE ESTIMATE; ARABIAN SEA; KILLER WHALE; BRYDE'S WHALE; SPERM WHALE; CUVIER'S BEAKED WHALE; BLUE WHALE; BOTTLENOSE DOLPHIN; CETACEANS; CONSERVATION; FINLESS PORPOISE; FISHERIES INTERACTION; HABITAT; RISSO'S DOLPHIN; COMMON DOLPHIN; INDO-PACIFIC HUMPBAC DOLPHIN; HUMPBAC WHALE; INCIDENTAL CATCHES; INDIAN OCEAN; SPINNER DOLPHIN; SURVEY-SHORE-BASED; SURVEY-VESSEL

INTRODUCTION

Scientific background

Until now there has been little information available on the identification, distribution and relative abundance of cetaceans occurring in the Pakistani portion of the Arabian Sea (NW Indian Ocean). Some reviews have indicated the species most likely to be present (e.g. De Boer *et al.*, 2002; de Silva, 1987; Roberts, 1997), while reports arising from illegal Soviet whaling off Pakistan during the 1960s (when 164 humpback whales were killed off Pakistan between late-October and mid-December over a three year period) indicate that significant, previously unstudied populations of humpback whales (*Megaptera novaeangliae*), blue whales (*Balaenoptera musculus*) and sperm whale (*Physeter catodon*) might be present (Mikhalev, 1997; 2000).

In addition, there have been various reports of incidental sightings or strandings. Ahmed and Rizvi (1985) reported a humpback whale caught off Port Qasim on the Sindh coast, as well as records of humpback dolphins (*Sousa plumbea*), long-beaked common dolphins (*Delphinus capensis*) and melon-headed whales (*Peponocephala electra*) off Sonmiani, Balochistan. Ahmad and Ghalib (1975) collated reports of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*), Indo-Pacific humpback dolphins, finless porpoises

(*Neophocaena phocaenoides*), blue whales, fin whales (*B. physalus*) and sperm whales from along both the Sindh and Balochistan coasts. Roberts (1997) reported a Bryde's whale (*B. edeni*) sighted off Las Belas, Balochistan, and a dwarf sperm whale (*Kogia sima*) sighted off the Indus Delta, Sindh province. A pygmy sperm whale (*K. breviceps*) was reported off Sonmiani (M. Khan and S.H.N. Rizvi, pers. comm). In addition Pilleri and Gahr (1972a; 1972b), on visiting coastal areas to search for cetacean remains, found four finless porpoises, seven humpback dolphins, five common dolphins and a bottlenose dolphin; they also found a vertebra that they suggested belonged to a Cuvier's beaked whale *Ziphius cavirostris* (see Gore *et al.*, 2007b for discussion). Similarly, until recently no systematic surveys of cetaceans had been conducted off the coasts of Pakistan's neighbours – India (Afsal *et al.*, 2008) and Iran (Braulik *et al.*, 2010a).

As noted by Kumarran (2002; 2009) a lack of data regarding threatened species invariably weakens national biodiversity policies. Thus in Pakistan, Rizvi *et al.* (1995) concluded there was inadequate information available on small cetaceans in Pakistan's Indus Delta region and called for detailed assessments to facilitate the preparation of species action plans. More recently such information has again been required in support of Pakistan's National Conservation

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Strategy and Biodiversity Action Plan. Accordingly the research reported here was undertaken between 2004 and 2009 in order to determine the identity, relative abundance, habitats, seasonality and association patterns of cetaceans occurring in the coastal waters of Pakistan.

Fishers and cetaceans

The territorial waters of Pakistan are included in the Indian Ocean Sanctuary, which was established in 1979 to protect whales from hunting. It should however be noted that this protection does not extend to dolphin species and that all cetaceans in the region remain susceptible to mortality or injury from non-targeted fishing activities. In this context, an early concern for this project was that Pakistan had greatly increased its export of fish in recent years (Marine Fisheries Department, 2006), an indicator of considerable intensification of fishing activities. As well as potentially diminishing the availability of food for cetaceans, increased fishing readily leads to increased cetacean bycatch, and perhaps also increased numbers of boat strikes (Niazi, 1990). On a global level Northridge (2002) concluded that porpoises (*Phocaenidae*) often entangle in gillnets, while dolphins are widely caught in pelagic trawls and purse seine nets, as well as on hooks. Reeves *et al.* (2003) suggested that local declines in small cetaceans are most usually due to increased vessel activity and intensification of fisheries. In Pakistan a variety of fishing vessels from 6–8m long *tony*, *katti* or *hori* to 15–25m trawlers are used nearer the coast, while offshore larger gill-netters and trawlers operate (Marine Fisheries Department, 2006). These different vessels deploy a very wide range of gear, including drift nets (2 types), bottom set gillnets (3 types), surround gillnets (4 types), encircling nets (like seine nets, 4 types) and trawl nets (3 types), as well as trap nets (5 types), pots (2 types), hand lines, long lines (3 types), and jig lines (2 types) (Hussain and Amir, 2006). Hence there is considerable scope for unintentional injury or bycatch of cetaceans, as well as a potential for deliberate targeting, which has already been reported as occurring to some degree in Pakistan (Niazi, 1990).

Thus in 2004 a project (Cetacean Conservation Pakistan) was launched with a view to: (a) undertaking quantitative surveys to determine the variety and abundance of cetaceans present in Pakistani waters; (b) working with local fisher communities to collate local knowledge of both cetacean occurrence and fishers' interactions with them; and (c) promoting public awareness of cetacean issues and developing a strategy and measures for securing cetacean conservation. As with other taxa, the extent to which effective conservation can be achieved depends on the attitude of key stakeholders, including most critically in this case local fishers; thus this work was also undertaken with a view to encouraging fishers' and wider community support for conservation measures. This paper reports the results of that project.

METHODS AND STUDY AREA

Study area

Pakistan has two coastal provinces with contrasting coastlines (Majid, 1988). The Balochistan or Makran coast bordering Iran in the west extends for about 800km, and is dominated by large rocky cliffs interspersed with long sandy shores. The continental shelf varies in width from about 3km (by Gwadar in the west) to 73km (by Hub River in the east), beyond which the shelf edge drops rapidly to 1,000m and then deeper to the Oman Abyssal Plain. By contrast the Sindh coast, which extends for 250km bordering India in the east, is dominated by sandy-muddy shores with innumerable creeks and deltaic tributaries often colonised by mangrove forest (Meynell, 1999; Quraishie, 1988). It has a broader continental shelf, ranging from about 77km wide by Karachi to 160km wide near Kori Creek mouth, except where a narrow trench 'The Swatch' that reaches 200m deep, extends shorewards in the southern part (see Fig. 1). The salinity along the Karachi coast ranges from 35.5 to 36.9ppt, but can reach 41–42ppt in tidal creeks (Ahmed and Rizvi, 1980). Oxygen levels are normally 4.0–4.5ml⁻¹ in the well mixed zones, but levels as low as 1.5ml⁻¹ can occur in shallow areas during the SW monsoon (Haq *et al.*, 1978). Tides are semi-diurnal with a range of about 3.5m.

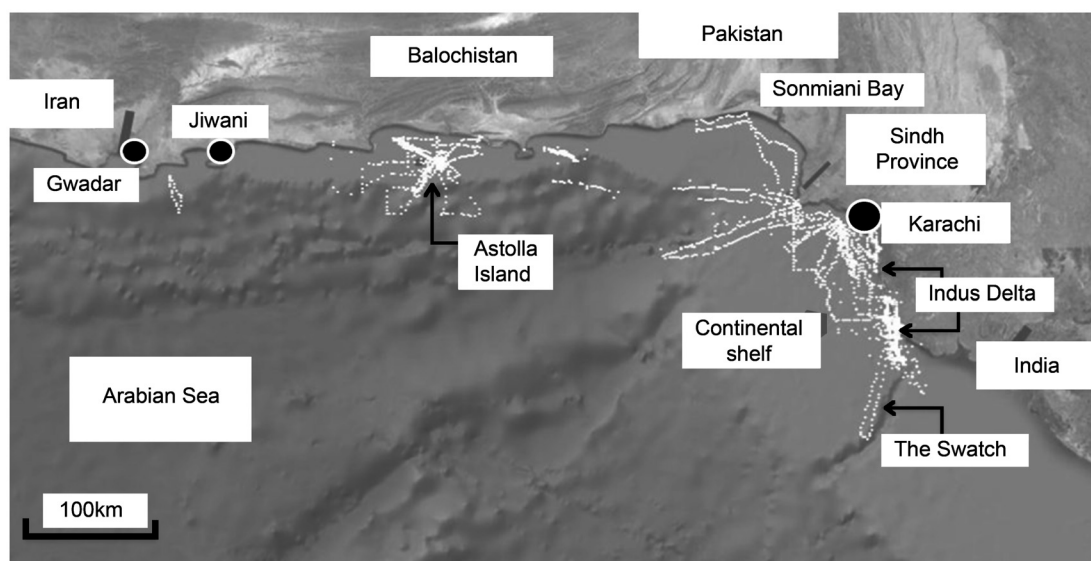


Fig. 1. Morphological and bathymetric map of the Pakistani coast and adjacent marine areas showing the regions and locations mentioned in the text together with, as a series of white dots, the majority of tracks generated during boat survey work (each dot representing a GPS location recorded during a survey).

Coastal weather contrasts sharply between NE and SW monsoon periods, which occur during November to February and June to September respectively, being separated by shorter Spring and Autumn Inter-monsoonal Periods (Kidwai and Amjad, 2000). The SW monsoon is characterised by greater wind speeds (*ca.* 25kt as opposed to <10kt) that extend water mixing below the thermocline (Wyrki, 1973) and produce extensive upwelling over a variable portion of the central Pakistan coast (Quraishie, 1988). This results in increased nutrient availability and high plankton biomass values (Qasim, 1977; Smith, 1988), although pelagic fish including mackerel, sardine and anchovy also occur along the coast during the NE monsoon (Majid, 1988).

Methods

Surveys to assess the abundance of cetaceans were conducted: (a) by boat; (b) by foot along the coastline; and (c) by interviewing fishers. Species identification guides used included Jefferson *et al.* (1993), (Perrin *et al.*, 2008) and Reeves *et al.* (2002), with a simpler identification leaflet being produced for distribution to fishers and the interested public.

Boat-based cetacean surveys

A total of 63 days of transect surveys for cetaceans were conducted by boat between 16 November 2005 and 11 December 2009. Surveys were conducted both inshore and offshore along different sections of coast, and in every month except July and October (Table 1); they were however more frequently undertaken during the NE monsoon than the SW monsoon or the inter-monsoon periods, since sea conditions are much more favourable at that time. Due to varying location and vessel availability several different platforms were employed, including a 12m fishing launch (used for longer surveys or further offshore), 5m wooden 'horas' (used largely in the Indus Delta area), and a 5m rigid inflatable boat (used both in the Indus Delta and along the coastline under more predictable conditions). Only single observation areas were available on each boat giving observer eye heights above the water of 2.5, 1.7 and 1.7m respectively.

During surveys data were collected on effort, species occurrence, relative abundance, behaviour and groupings (Ballance *et al.*, 2001; Weir *et al.*, 2001) in relation to four marine habitat zones: near shore (0–50m depth); continental shelf (50–200m depth); shelf edge (>200–1,000m depth) and pelagic (>1,000m depth). For a combination of logistical and security reasons it was not feasible to survey the whole study area either homogeneously or through a random sampling design (for discussion of this issue see Cañadas *et al.*, 2002). Instead courses were pre-selected: (a) to cover as much as

possible of the full length of the coast largely within sight of the shore; and (b) in selected sections to cover different marine zones by surveying along transects perpendicular to the depth contours (see Dawson *et al.*, 2008) (see Fig. 1). Normally surveys were initiated only when sea-state was equivalent to Beaufort wind scale force 3 or less with accompanying swells of 0.5m or less, and in weather conditions where there was little or no rain, and good or excellent visibility. Boat surveys were normally carried out over full days, with the earliest time that a survey commenced being 06:57 and the latest that one ended 19:24. Survey effort was measured as the distance (km) travelled per day with the length and route of the survey track being logged using a handheld Garmin GPS unit.

During surveys a 3-person observer team was stationed forwards on the vessel. Two scanned the water to the horizon with both the unaided eye and 7 × 50 binoculars, one observer sweeping an arc from the bow to beam on the port side, and the other likewise to starboard. The third member of the team acted both as recorder and between-times as a back-up observer. To avoid tiredness or eyestrain observers rotated their role every half hour, with each being replaced by another crew member and taking a full rest after every 1.5hrs on watch. 'Closing-mode' was adopted (Dawson *et al.*, 2008) with the search along the transect route being maintained until one or more cetaceans were sighted, at which point the vessel's course was changed to approach the animals for closer observation. At the end of the sighting, the survey track was regained at the point of departure. Data collected during sightings included: location; distance and bearing from boat at first sighting; time of day; species; group size (minimum/maximum/best estimate); group composition (adults/female and young/mixed age group); direction of travel; and observed behaviour (surface active/feeding/travelling/social interaction/interaction with vessels).

Otherwise, the following data were logged by the team recorder at ten minutes intervals throughout the duration of the survey: sea-state; apparent modal swell height in meters; speed and heading of boat; and latitude and longitude as determined by GPS. Weather conditions including wind strength (Beaufort scale) and direction, cloud cover and visibility were recorded hourly. Boat survey speed was 8–15kt [15–25km h⁻¹] dependent upon sea conditions and boat type. In addition to sightings of cetaceans, all piscivorous seabirds to a distance of 250m were recorded, as were all passing vessels to a distance of *ca.* 10km, for their potential influence on cetacean occurrence. Mean sea state was 1.8 in Sindh and 1.9 in Balochistan, with mean swell heights being 0.33 and 0.40m respectively. Mean air temperature was

Table 1

Days of boat-based survey undertaken by month, season and province (NE = northeast monsoon; IMS = spring inter-monsoonal period; SW = southwest monsoon; IMA = autumn inter-monsoonal period).

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
Season	NE	NE	IMS	IMS	IMS	SW	SW	SW	SW	IMA	NE	NE	Total
Sindh	1	0	3	4	4	1	2	2	2	0	7	12	38
Balochistan	3	18	1	0	0	0	0	0	0	0	2	1	25
Total	4	18	4	4	4	1	2	2	2	0	9	13	63

slightly higher in Balochistan than in Sindh (25.6°C vs. 23.2°C), but mean sea surface temperatures were similar (24.1°C vs. 24.0°C). During boat-based surveys numerous small fishing vessels were recorded in both provinces, but large cargo vessels and tankers were observed only in the Near Shore zone of Sindh. No military or seismic survey vessels were observed at any time.

In addition to sightings of cetaceans made while on-effort, other sightings made during transit at higher speed, during breaks, or in closing mode during surveys, were also recorded. The data on distance and bearing of first sightings have not yet been analysed to give estimates of absolute population density, but the numbers of individuals sighted per km of trackline has been used to provide a measure of relative abundance and distribution across the study area (Weir *et al.*, 2001). The data were analysed in relation to species type, abundance and grouping patterns, province, season, marine habitat type and human activity present. A general linear model was used to assess the statistical significance of trends, with the Unequal *N* Honest Significant Difference test being used as a *post hoc* test.

In addition to data from the above boat-based survey work, unpublished data from boat-based observations undertaken during an offshore seismic survey for gas and oil were provided to the authors and have been incorporated in the present study with the permission of those concerned (Pickering, 2004). This survey work took place in 320–1,300m of water approximately 190km offshore of Sindh between 11 October 2003 and 13 December 2003, in an area of 5,147 km² bounded by the points 23.70°N 66.62°E to the NW, 23.68°N 66.10°E to the NE, 23.42°N 65.62°E to the SW and 23.40°N 66.10°E to the SE. There was a single observer present throughout the daylight period who had a 180° view at 15.3m height on the bridge of a 86.9m vessel. A continuous scan was made by both unaided eye and binoculars and distance to the cetaceans was estimated. The total watching time was 746h, of which 452h 39min was during gun firing.

Shore-based surveys for beachcast specimens

A band transect method was used to survey beaches for beachcast cetaceans or their remains. Teams of surveyors walked in line abreast the full length of each beach with individual surveyors being placed approximately 4m apart, so that each observer carefully scanned 2m to either side, looking for signs of skeletal or other remains. On wider beaches the team covered the remaining width of the beach on the return journey. Observers noted their location (latitude and longitude) every ten minutes. When remains were found the date and time, the species of cetacean and condition (state of decomposition if recently dead) were also recorded and skeletal specimens and where possible tissue samples taken. Those sections of coast not surveyed were generally those that were either difficult to access, or where government permission to work the area was withheld for security reasons.

To complement field surveys and involve local communities, a community reporting scheme was established, with fishers, senior villagers and other personnel located on the coast being requested to alert the research team in the event of any stranded or beachcast cetaceans

being found. When dead specimens were encountered, body measurements and photographs were taken, and samples of tissues and teeth recovered and preserved. The authors also visited several institutions (including non-scientific ones) where cetacean skeletons were housed or on display to take measurements and check species identification.

Fisher community-based surveys

Fishing communities along the full length of the Pakistan coast were visited both to sample local knowledge through interviews with fishers, and to explain the work of the team to local people. The methods used were guided by the experience of community-surveys undertaken elsewhere (developing countries: Aragonés *et al.*, 1997; the Caribbean: Grant and Berkes, 2007; the UK: Howard and Parsons, 2006; Kenya: McClanahan *et al.*, 2005; Indonesia: Teh *et al.*, 2005). A simple questionnaire was designed and used to interview a sample of fishers in each community, along with a pictorial guide to the cetacean species likely to be present, copies of which were distributed in each community. In Sindh, 197 interviews were carried out (by BH) in 46 communities between 5 December 2005 and 12 July 2008, and in Balochistan, 105 fishers were interviewed (by UW) in 28 communities between 6 March 2007 and 30 April 2008. In addition approximately 50 fisher community leaders were invited to a workshop in each province; at each further information and feedback on project findings were provided and wider issues relating to cetacean conservation discussed.

RESULTS

Boat-based cetacean surveys

Species overview

The species recorded during boat surveys were humpback whale, Risso's dolphin (*Grampus griseus*), killer whale (*Orcinus orca*), humpback dolphin, spinner dolphin (*Stenella longirostris*), bottlenose dolphin (*Tursiops* sp.), and finless porpoise (Table 2). The most numerous species observed was spinner dolphin, which was more abundant in Balochistan than in Sindh (GLM Genus by Province: $F_{(6,518)} = 3.76$, $p = 0.001$), and also more numerous than any other species (as shown by post-hoc tests). Excluding spinner dolphins, statistical analysis showed no significant difference in relative abundance between species or between provinces (GLM Genus by Province: $F_{(5,449)} = 1.62$, $p = 0.15$).

Finless porpoise

Finless porpoises were observed only during the NE monsoon and Near Shore, but in both provinces (Table 2). They were recorded mainly between mid-morning and early evening (mean time = 15.14 hrs $\pm$ 0.3hrs), and in good sea conditions (mean sea state = 0.8 $\pm$ 0.1). In an analysis of factors including both time of day and sea state, as well as swell, depth and province, only time of day (GLM $F_{(1,20)} = 5.40$, $p = 0.031$) and sea state ($F_{(1,20)} = 11.53$, $p = 0.0028$) were significant predictors of the number of finless porpoises recorded per distance surveyed ($R^2_{\text{adj}} = 0.29$, $\text{df}_{\text{model}} = 5$, $F = 3.02$, $p = 0.034$), whereas swell ($F_{(1,20)} = 0.55$, $p = 0.5$), depth ($F_{(1,20)} = 0.24$, $p = 0.6$) and province ($F_{(1,20)} = 1.10$, $p = 0.3$) were not. Finless porpoises were observed in groups of 1–18, but were mostly encountered in small groups (mean size 2.86 $\pm$ 0.5) (Table 3); Groups could be composed of adults

Table 2

Numbers of sightings and individuals of different cetacean species recorded during different zones and seasons (abbreviations as for Table 1).

Province	Genus	Season	Habitat	Total no. sightings	Mean no. sightings per km	SE of mean	Mean no. individuals per km
Sindh	Finless porpoise	NE	Near shore	23	0.054	0.008	1.251
Sindh	Bottlenose dolphin	NE	Near shore	5	0.311	0.135	1.554
Sindh	Humpback dolphin	NE	Near shore	64	0.080	0.014	5.126
Sindh	Humpback dolphin	IMS	Near shore	17	0.051	0.006	0.868
Sindh	Humpback dolphin	SW	Near shore	5	0.089	0.028	0.444
Sindh	Unidentified dolphin	NE	Near shore	10	0.024	0.004	0.240
Balochistan	Finless porpoise	NE	Near shore	12	0.064	0.028	0.767
Balochistan	Bottlenose dolphin	NE	Near shore	3	0.410	0.053	1.231
Balochistan	Bottlenose dolphin	NE	Continental shelf	2	0.121	–	0.242
Balochistan	Bottlenose dolphin	NE	Pelagic	1	–	–	0.081
Balochistan	Spinner dolphin	NE	Near shore	1	–	–	0.121
Balochistan	Spinner dolphin	NE	Shelf edge	8	5.101	2.949	40.804
Balochistan	Spinner dolphin	NE	Pelagic	3	3.404	1.668	10.211
Balochistan	Humpback dolphin	NE	Near shore	1	–	–	0.040
Balochistan	Risso's dolphin	NE	Continental shelf	1	–	–	0.141
Balochistan	Risso's dolphin	NE	Pelagic	1	–	–	2.018
Balochistan	Killer whale	NE	Near shore	1	–	–	0.202
Balochistan	Humpback whale	NE	Near shore	2	0.020	–	0.040
Balochistan	Unid. dolphin sp.	NE	Near shore	4	0.056	0.035	0.222
Balochistan	Unid. dolphin sp.	NE	Shelf edge	1	–	–	0.020
Balochistan	Unid. dolphin sp.	NE	Continental shelf	1	–	–	0.040

or a mixture of ages (Table 4), but some compositions were more frequent than others (GLM $F_{(3,31)} = 3.92$, $p = 0.017$), with groups of adults being more likely to be observed than singletons (post-hoc test $p = 0.023$). The species was found both in locations where fishing nets or traps, and fishing boats or larger ships (cargo/tankers) were present, as well as where no human activity was absent, although most often fishing boats were in fact present ($F_{(3,31)} = 3.02$, $p = 0.044$) when the species were observed.

Bottlenose dolphin

Bottlenose dolphins were observed only during the NE monsoon, when they were recorded near shore in both provinces, and in the Continental Shelf and Pelagic zones in Balochistan (Table 2). Using Model A, sea state ($F_{(1,4)} = 33.35$, $p = 0.0044$) and swell ($F_{(1,4)} = 30.34$, $p = 0.0053$) were found to be significant predictors of the numbers of bottlenose dolphin observed per distance surveyed ($R^2_{adj} = 0.79$, $df_{model} = 5$, $F = 7.98$, $p = 0.033$), but time of day ($F_{(1,4)} = 5.24$, $p = 0.08$), depth ($F_{(1,4)} = 0.20$, $p = 0.7$) and province ($F_{(1,4)} = 0.75$, $p = 0.4$) were not. Bottlenose dolphins were observed in a wide range of depths and there was no significant effect of habitat type on abundance (GLM Habitat

type: $F_{(2,8)} = 1.27$, $p = 0.3$). The species was observed in small to medium-sized groups, (range 4–41, mean size 14.0 ± 3.4), with groups sometimes consisting of a mixture of age groups (Sindh only) and sometimes of adults only. Bottlenose dolphins occurred where fishing nets/traps, fishing boats and/or cargo vessels/tankers were present, but there was no significant effect of human activity on their occurrence (GLM human activity: $F_{(2,8)} = 3.33$, $p = 0.09$).

Spinner dolphin

Spinner dolphins were observed only in Balochistan during the NE monsoon (Table 2); they were encountered in Near Shore, Shelf Edge and Pelagic zones but always in relatively deep water ($>300\text{m}$). None of the factors included in Model A was a significant predictor of their relative abundance (GLM time observed: $F_{(1,6)} = 0.63$, $p = 0.5$; sea state: $F_{(1,6)} = 0.17$, $p = 0.7$; swell: $F_{(1,6)} = 1.86$, $p = 0.2$; depth: $F_{(1,6)} = 0.002$, $p = 0.9$). Spinner dolphins mostly occurred in very large groups of up to 1000 or more individuals (Table 3), that could be either be composed only of adults or include a mixture of age classes (Table 4), although no factors were a significant predictor of group composition (GLM $F_{(2,10)} = 0.83$, $p = 0.5$). They were sighted both in the absence of human activity and where fishing boats were present, but more were recorded when fishing boats were present than in their absence ($F_{(1,11)} = 4.33$, $p = 0.06$).

Humpback dolphins

Humpback dolphins were recorded during both NE and SW monsoons and during the spring inter-monsoon period. All sightings were in the Near Shore Zone, and all save one in Sindh (Table 2). They were observed throughout the day in waters up to 30m (mean $9.1\text{m} \pm 0.7$) deep with a notably wide range of sea surface temperatures ($12\text{--}31^\circ\text{C}$; mean $23.1^\circ\text{C} \pm 1.2$). However, none of the factors – time observed, sea state, swell, depth or weather – predicted the relative abundance of humpback dolphins (GLM time

Table 3

Total numbers of sightings and individuals, and group sizes, of each species recorded during boat surveys.

Species	Total no. sightings	Total no. individuals	Mean group size ($\pm$ S.E.)	Range of group size
Finless porpoise	35	100	2.86 ± 0.5	1–18
Bottlenose dolphin	11	154	14.0 ± 3.4	4–41
Spinner dolphin	13	2,535	195.0 ± 92.6	1–1,000+
Humpback dolphin	87	321	3.7 ± 0.5	1–35
Risso's dolphin	2	107	53.5 ± 46.5	7–100
Killer whale	1	10		10
Humpback whale	2	2	1	1
Unidentified dolphin	15	25	1.7 ± 0.5	1–8

Table 4
Frequencies of different group compositions for each species in each province (as number of sightings per 100km).

Province	Species	Single animal	Adults only	Mixed ages	Juveniles only	Mothers and young	Unknown
Sindh	Finless porpoise	0.33	0.84	0.48	0	0	0.59
Sindh	Bottlenose dolphin	0	0.84	1.50	0	0	0.48
Sindh	Humpback dolphin	1.17	3.56	3.85	1.47	0.95	0.70
Sindh	Risso's dolphin	0	0	0	0	0	0
Sindh	Killer whale	0	0	0	0	0	0
Sindh	Humpback whale	0	0	0	0	0	0
Balochistan	Finless porpoise	0.18	1.21	0	0	0	0
Balochistan	Bottlenose dolphin	2.82	0	0	0	0	0
Balochistan	Spinner dolphin	0	1.87	9.10	0	0	0
Balochistan	Humpback dolphin	0	0	0.07	0	0	0
Balochistan	Risso's dolphin	0	3.92	0	0	0	0
Balochistan	Killer whale	0	3.92	0	0	0	0
Balochistan	Humpback whale	0	0.37	0	0	0	0

observed: $F_{(1,70)} = 0.34$, $p = 0.6$; sea state: $F_{(1,70)} = 1.64$, $p = 0.2$; swell: $F_{(1,70)} = 0.02$, $p = 0.7$; depth: $F_{(1,70)} = 0.87$, $p = 0.4$; weather: $F_{(1,70)} = 0.04$, $p = 0.8$). Humpback dolphins were observed either as singletons or in groups of up to 35 individuals (mean 3.7 ± 0.5) (Table 3) composed either of adults or a mixture of different aged individuals or mothers and calves (Table 4). Mixed age groups were encountered significantly more often than singletons (GLM: $F_{(5,81)} = 5.23$, $p = 0.0003$; *post hoc* test: $p = 0.004$). The species was recorded both when nets/traps and fishing boats were present, and when these were absent, with human activity not being a significant predictor of their presence (GLM: $F_{(3,161)} = 0.36$, $p = 0.8$).

Risso's dolphin, killer whale and humpback whale

Risso's dolphins, killer whales and humpback whales were all observed only in Balochistan and only during the NE monsoon. Killer whales and humpback whales were recorded only in the Near Shore zone (in 19m and 9–11m of water respectively), while Risso's dolphins were recorded in deeper water (360–750m) in the Continental Shelf and Pelagic zones (Table 2). The humpback whale sightings were of single animals, the Risso's dolphins of medium to large size groups (mean 53.5 ± 46.5) of adults, and the killer whales were a group of about 10 adults (Table 3). The killer whales when encountered were pursuing a large group of rays under the vessel and onward, and the groups of Risso's dolphins also appeared to be hunting on both occasions. All sightings of these species were between late morning and late afternoon, but there were too few sightings of these species to draw conclusions on the influence of other environmental factors.

Seismic surveys

During cetacean observations undertaken during the offshore seismic survey both bottlenose and spinner dolphins were recorded both in shelf edge and pelagic zones, while there were single observations of Risso's dolphins on the shelf edge and of common dolphin in the pelagic zone (Table 5). Mean group size varied considerably between species, from one for Risso's dolphin (observed associated with a pod of bottlenose dolphin) to 92.3 for spinner dolphin (Table 5). Bottlenose and spinner dolphins were observed both when the seismic airgun was firing (on 7 and 6 occasions respectively) and when it was not (on 7 and 4 occasions respectively), while common dolphins were seen when the airgun was not firing (2 occasions) and the Risso's dolphin when it was (1 occasion). All cetaceans observed were adults except for one group of juvenile bottlenose dolphins and one group of juvenile spinner dolphins, both seen on the shelf edge.

Human activity

Table 6 shows the frequency with which all cetacean species combined were recorded in the presence and absence of different forms of human activity in each habitat zone. While a variety of fishing and shipping activities were common in the Near Shore Zone, in the other zones fishing vessels were the only human activity recorded. In general cetaceans were observed whether human activity was present or not, but it is noticeable that mean relative abundance tended to be slightly higher in the absence of human activity.

Shore-based surveys and strandings reports

No live strandings were found during the shore-based surveys, but the remains were encountered of 12 dolphins

Table 5

Numbers of sightings and of individuals and range and mean of group sizes of cetacean species recorded during the 2003 offshore seismic survey (abbreviations as per Table 1).

Season:	NE monsoon				Autumn IM		Range of group sizes	Mean group size
Zone:	Shelf edge		Pelagic		Shelf edge			
Species	Sightings	Individuals	Sightings	Individuals	Sightings	Individuals		
Bottlenose dolphin	3	32	6	130	5	107	4–50	24.5 ± 5.6
Spinner dolphin	9	898	1	25			1–600	92.3 ± 49.0
Common dolphin			2	13			10–15	
Risso's dolphin	1	1					1	

Table 6

Comparison of cetacean abundances per km in different marine zones (habitats) in the presence and absence of different human activities.

Marine zone (habitat)	Type of human activity	Total no. cetacean sightings	Mean abundance of all cetaceans	Mean abundance per single species
Near shore	None	90	0.069	0.001
Near shore	Nets/traps	16	0.029	0.002
Near shore	Fishing boat(s)	39	0.044	0.001
Near shore	Cargo/tanker	2	0.001	0.001
Continental shelf	None	4	0.047	0.012
Shelf edge	None	9	8.344	0.927
Shelf edge	Fishing boat(s)	1	8.125	–
Pelagic	None	3	2.123	0.708
Pelagic	Fishing boat(s)	1	0.970	–

(six in Sindh and six in Balochistan), and of a sperm whale in Balochistan (see Gore *et al.*, 2007a). None of the dolphin specimens was in a condition to be identified *in situ*, but samples of tissue and teeth are currently being analysed to determine species and gender.

Between 2005 and 2008 a total of 57 stranded animals were reported through the strandings network (Table 7). These included in both Sindh and Balochistan, finless porpoises, humpback dolphins, bottlenose dolphins, spinner dolphins, sperm whales, and Bryde's and other unidentified baleen whales, and in Sindh only, a Cuvier's beaked whale (see Gore *et al.*, 2007a; 2007b). There were more strandings reported during the NE monsoon than in other seasons. It was observed that many of the finless porpoise had their flukes cut off. The pre-existing skeletal material located in institutions in Sindh and Balochistan mostly constituted large baleen whales, including notably two blue whales.

Fisher community-based surveys

Forty six fishing communities were identified in Sindh and 28 in Balochistan. 302 fishers were interviewed; all were male. In Sindh the men were largely of a single ethnic group, while in Balochistan there were at least 6 ethnic/language groups present. The men ranged in age from 12 to 80yrs but their distribution among age categories (<20, 20–29, 30–39, 40–49, 50–59 and 60+yrs) was similar for the two provinces (Wilcoxon Matched Pairs Test: $t = 10.0$, $z = 0.104$, $p = 0.9$, $n = 6$) and there were no significant differences between age categories in their responses (Kruskal-Wallis ANOVA by ranks: $H_{(5,N=352)} = 9.88$, $p = 0.08$). When asked about the

species they encountered, the local names used and the size of groups and body sizes, most fishers identified and reported bottlenose dolphins (local name *hum*) occurring in groups of five or more, humpback dolphins (*malhar*) seen in groups of 1–10 individuals, and finless porpoises (*tabi*) seen in groups of 5–10. Whales were more frequently encountered by fishers in Balochistan than Sindh, although the four local names (*whiser*, *leare*, *leed* and *abroo*) were known in both provinces. Spinner dolphins (*goco* or *tooshunk*) were not seen often, and although common dolphins occur in both Oman (Baldwin, 2003) and Iran (Braulik *et al.*, 2010b), were not reported by fishers in either province.

However when fishers were asked whether cetaceans impacted on their fishing there was a significant difference between the provinces (Mann Whitney U test: $Z_{adj} = -2.57$, $p = 0.01$, $N_{Sindh} = 177$, $N_{Balochi} = 175$), with more Balochis responding that cetaceans did cause problems. Their complaints included that cetaceans competed for and/or were depleting fish stocks, and that dolphins and porpoises becoming entangled in and damaged fishing nets. In addition it was claimed that large dolphins and whales could capsize small fishing boats.

Fishers did not describe finding live stranded cetaceans but Balochi fishers did describe finding bones of cetaceans on the shore throughout the year. They also described their interaction with cetaceans and commented on cetacean behaviour much more frequently than did Sindhi fishers. Ten fishers (six from Balochistan and four from Sindh) spread evenly across the age groups 20 to 59 yrs, reported that they or others had killed or used cetaceans. The purposes reported included: to free fishing nets; as bait for fish or sharks; for food (apparently by 'Somalis'); for medication (for example to ease pain in the legs); and for sexual gratification (finless porpoise). In relation to the damage caused to nets it was noted that while locally a fishing net cost 4,000 Pakistani Rupees (Rs.), the wholesale price for a dolphin was only Rs 4.

DISCUSSION

This study, covering most of the 1,050km coastline of the country over a four year period, represents the first systematic survey of marine cetaceans in Pakistan. In addition to boat-based surveys, shore-based surveys were undertaken for stranded or beachcast specimens and a strandings reporting scheme established, which revealed the occurrence of several further species.

Table 7

Numbers of beachcast cetaceans recorded between 2005 and 2008 by species, province and season (abbreviations as for Table 1).

Species	Sindh					Balochistan			
	Season:	NE	IMS	SW	IMA	NE	IMS	SW	IMA
Bryde's whale	—	1	—	—	2	—	—	—	—
Unid. baleen whale	1	2	—	—	2	1	—	—	—
Sperm whale	1	1	—	—	1	—	1	1	—
Cuvier's beaked whale	—	—	1	—	—	—	—	—	—
Killer whale	1	—	—	—	—	—	—	—	—
Humpback dolphin	3	—	6	—	4	2	—	—	—
Spinner dolphin	—	2	—	—	—	—	—	—	—
Bottlenose dolphin	2	1	—	—	2	—	—	—	—
Unid. dolphin	—	—	7	—	1	2	—	—	—
Finless porpoise	1	1	—	—	6	1	—	—	—

Species occurrence

Finless porpoise

During inshore boat surveys finless porpoises were recorded relatively frequently, more often in Sindh than in Balochistan, but finless porpoise remains were also found on beaches, mainly in Balochistan. During boat survey work they were almost invariably recorded under calm sea conditions during the NE monsoon (which may partly reflect the difficulty in detecting them when waves are present), and in shallow water near shore. Finless porpoises have previously been reported from both the Indus Delta and Balochistan. Pilleri and Gühr (1972a, 1973–1974) had records of live porpoises at Gadani, Dahm and Sonmiani, all in Balochistan, and they encountered small groups in the Indus Delta creeks, although by 1979 fewer were being recorded (Pilleri and Pilleri, 1979). Roberts (1997) also noted that finless porpoises were found in mangrove creeks along the Baluchistan coast between September and April, since when a number of other records have been collated by Collins *et al.* (2005). The species has also been reported in neighbouring Oman (Braulik *et al.*, 2010a; Collins *et al.*, 2005).

Bottlenose dolphin

In the present study bottlenose dolphins were observed in both Balochistan and Sindh, and beachcast specimens were also found in both provinces. The species is known from adjacent countries: Baldwin (2003) describes them as present in Yemen, Oman and the Arabian Gulf, while Braulik *et al.* (2010a) recorded a skull of the Indo-Pacific bottlenose dolphin in the Sistan/Baluchistan area of Iran, and Afsal *et al.* (2008), using a fisheries-oceanographic ship as a vessel of opportunity, recorded Indo-Pacific bottlenose dolphins in the Arabian Sea off the coast of India at depths of up to 50m.

Two forms of bottlenose dolphin are found in the Indian Ocean, the Indo-Pacific bottlenose dolphin (*T. cf. aduncus*), and the larger, globally more widespread, common bottlenose dolphin (*T. tursiops*). In general, *T. cf. aduncus* is thought to be a coastal form found in near-coastal tropical waters, while *T. truncatus* also occurs in temperate waters and offshore (Hale *et al.*, 2000). Hale *et al.* compared the morphology of the two forms; the separation into two distinct species was said to be unresolved, although genetic analysis may show a degree of divergence, which would be consistent with them being distinct species.

In the present study bottlenose dolphins were recorded in a wide range of habitats including near shore, continental shelf and shelf edge, from shallow water to ocean over 1,000m deep. It seems possible that the groups observed inshore in both Sindh and Balochistan were *T. cf. aduncus*, while those observed offshore in Balochistan may have been *T. tursiops*. Similarly, Baird *et al.* (2009) found that in the Hawai'ian Islands bottlenose dolphin close inshore remained resident and did not mix with the offshore inter-island population. However in the present study no clear difference in visual appearance of inshore and offshore animals was evident and consequently bottlenose dolphins recorded in the present study have been classed as *Tursiops* spp. There is a case for further study and a genetic analysis is underway.

Bottlenose dolphins were observed when fishing gear or boats were present as well as when there was no other human

activity evident. In fact on at least one occasion the pod sometimes present near Clifton Beach (near Karachi, Sindh) appeared to be driving fish towards drift nets deployed by fishers, a manoeuvre from which both dolphins and fishers could potentially benefit. Bottlenose dolphins were also recorded during the seismic survey in both shelf edge and pelagic zones, when the airgun was firing and when it was not, although the numbers recorded per sighting were slightly greater when there was no firing. From these data it would appear that the bottlenose dolphin is relatively insensitive to human disturbance, although this is not to imply that the animals are not impacted, since clear propeller damage was observed on members of the bottlenose dolphin pod sometimes encountered near Karachi Harbour.

Spinner dolphin

Our data on spinner dolphins complement records of the species from adjacent waters. Afsal *et al.* (2008) found spinner dolphins in water between 1,000 and 3,000m deep in the Arabian Sea area off India; Ponnampalam (2009) has studied a population resident off the coast of Muscat, Oman; and Braulik *et al.* (2010b) recorded the species in Iran, based on a stranding, in the Sistan/Baluchistan area. Spinner dolphins were observed in both Pakistani provinces, usually in very large assemblages of adults or mixed age individuals and invariably on the outer shelf or around the shelf edge. These observations match evidence that the species is specialised in feeding on meso-pelagic squid and fish around the shelf edge (Ponnampalam, 2009). Like bottlenose dolphins, spinner dolphins were often observed despite human activities, including seismic airgun firing, occurring locally. Fishing boats were also often present, perhaps because both dolphins and fishers were attracted independently to a common potential resource.

Indo-Pacific humpback dolphin

In the present study humpback dolphins were frequently recorded in both NE and SW monsoons and also in the Spring Inter-monsoon period, but only in specific coastal areas (around the Indus Delta and in bays along the coast of Balochistan) in waters less than 30m deep. These observations match those from adjacent regions. Sutaria and Jefferson (2004) found humpback dolphins along the west coast of India, as far north as the Gulf of Kutch, just south of the border with Pakistan, as did Afsal *et al.* (2008) who reported humpback dolphins along the Arabian Sea coast of India in depths of up to 50m. Humpback dolphins were also the most frequently recorded cetacean in Oman (Baldwin *et al.*, 2004), occurring principally in coastal waters with soft sediments and low-energy sandy shorelines. However the species was not recorded during a survey of the Sistan/Baluchistan area of Iran (Braulik *et al.*, 2010a).

Two species of Indo-Pacific humpback dolphin have been distinguished: *Sousa plumbea* and *S. chinensis*. The animals observed in Pakistan had phenotypic characteristics of both forms, with a very distinctive hump but often heavy spotting on the head and hump areas. Jefferson and van Waerebeek (2004) studied skull morphology of *Sousa* spp. and suggested that Indo-Pacific specimens should be referred to a single species, *S. chinensis*, until further molecular genetics and morphological studies are undertaken. The Pakistan

population may thus represent an intermediate form within a single species cline. As noted by Jefferson and van Waerebeek (2004), irrespective of their taxonomic status, each geographic form should be treated as an evolutionary significant unit for conservation and management purposes.

The restricted use of selected coastal areas by this species has been described from other regions. In Zanzibar, Stensland *et al.* (2006) found that humpback dolphin concentrate their activities within only 2–11.5% of their range. In Mozambique humpback dolphins were found to be resident within selected bays, for example Maputo Bay (Guissamulo and Cockcroft, 2002). In Algoa Bay, South Africa, Karczmarski *et al.* (2000) mainly found humpback dolphins in water less than 15m deep and within 400m of shore. Similarly in Richards Bay, South Africa, humpback dolphins were found to stay within 2km (rarely 3km) of the shore and in water less than 20m deep (Atkins *et al.*, 2004); important feeding areas were around breakwaters and an estuary mouth, with resting areas being located further off shore.

Mean group size in the present study was small (3.7 animals), but larger, often mixed aged groups of up to 35 animals were sometimes seen, with groups being commoner than singletons. These data are comparable with those from other studies. On the west coast of India, Sutaria and Jefferson (2004) found that in shallow water ($\leq 10\text{m}$) mean group size was 3.9 (median 2), but in deeper water ($\leq 30\text{m}$) mean group size was 9.5. Similarly Parsons (1998) recorded group size of humpback dolphins in Goa, western India, as ranging from single individuals to nine, with a mean group size of 2.6. However, Razafindrakoto *et al.* (2004) found that humpback dolphins in west Madagascar had a mean group size of 13, and Guissamulo and Cockcroft (2002) reported that those resident in Maputo Bay, Mozambique, had a mean group size of 14.9, irrespective of season, daylight or tidal state.

Despite the fact they are sometimes exploited in Pakistan, humpback dolphins did not seem to avoid fishers, given that there was no significant difference in rate of sightings with presence or absence of fishing gear or boats.

Risso's dolphin, common dolphin and killer whale

Risso's dolphins were observed offshore and strandings were recorded in both provinces. The species is also known from neighbouring countries. Afsal *et al.* (2008) recorded them in depths of *ca.* 2,000m in the Arabian Sea off India, and Baldwin (2003) describes them as widespread in the Arabian Sea, Gulf of Aden and Gulf of Oman, where exceptionally large groups of up to 800 individuals are occasionally seen. Braulik *et al.* (2010a) recorded the species stranded in the Sistan/Baluchistan area of the Gulf of Oman. Baumgartner (1997) describes Risso's dolphins as being associated with steep areas of the upper continental slope, possibly due to the concentration of their prey (squid) along fronts that form in such areas. In the present study however, matching Baldwin's (2003) observation that they are more common seawards of the continental shelf, we recorded more Risso's dolphins in the pelagic than the shelf edge zone, although in Pakistan both areas possess a relatively steeply sloping sea floor.

Long-beaked common dolphins, generally recognised as a distinct subspecies, *Delphinus capensis tropicalis*, are

regarded as abundant in the Arabian Seas and Gulf of Aden (Baldwin, 2003). They have also been reported in the Gulf of Oman (Braulik *et al.*, 2010b) and western India, although not from the area adjacent to Pakistan (Afsal *et al.*, 2008). The species was observed twice during the seismic survey reported in the present study but not during the dedicated boat-based surveys, although the species may be among the unidentified dolphin remains collected during beach surveys and currently undergoing genetic analysis.

A single pod of killer whale was observed off Astola Island, Balochistan (by MG), apparently pursuing rays beneath the survey boat. Their presence is in keeping with other records from the northwest Indian Ocean region, where it appears to be rare but widespread. They have been observed only infrequently in Oman (Baldwin *et al.*, 1999) and there is one report from the Gujarat coast of India (James and Lal Mohan, 1987). However they were not recorded during the boat-based survey of the Indian Arabian Sea by Afsal *et al.* (2008), nor in the review for the Gulf of Oman by Braulik *et al.* (2010a). These reports may represent sightings of only one or two pods that travel very widely through the region.

Whales

The Bryde's whale is regarded as common in Southern Arabian waters (Baldwin, 2003), but none were observed with certainty during our boat surveys. Likewise James and Mohan (1987) failed to record Bryde's whales from the coastal waters of western India, although they did report the skeleton of a sei whale (*B. borealis*), which could possibly be a misidentified Bryde's. However in the present study a stranding of a Bryde's whale was recorded, as did Braulik *et al.* (2010a) in the Sistan/Baluchistan area of Iran; thus it is likely that Bryde's whales do occur regularly off the Pakistan coast, but perhaps mainly during the southwest monsoon when their food would be more abundant, but when it is very difficult to undertake small boat work.

Although a live Bryde's whale was not recorded in this study, a humpback whale was encountered in relatively shallow waters off the coast of Balochistan. Similarly humpback whales in the Arabian Sea are usually seen in water of less than 50m deep (Baldwin, 2003), so they are perhaps more likely to be encountered during inshore small boat surveys.

A blue whale was sighted off the Sindh coast northwest of the Swatch in the late 1960s (M. Khan and S.H.N. Rizvi, pers. comm.) and they have also been reported by Ahmad and Ghalib (1975). None were seen during the present survey work, but a locally-collected skeleton present in the Zoology Department Museum of Karachi University was inspected.

A Cuvier's beaked whale was identified from a skull found during a beach survey of Khobar Creek, Sindh (Gore *et al.*, 2007b), but the species was not observed during boat work. To date there have been about a dozen records of the species from the northwest Indian Ocean, all from the Gulf of Oman and the south-eastern coast of Arabia (Baldwin, 2003), although James and Mohan (1987) also reported the species from the Lakshadweep Islands off Calicut, south-west India, and it is uncommon in the Maldives (Anderson, pers. comm.). Their restricted distribution may reflect long-term site fidelity to areas of preferred habitat, such as McSweeney *et*

al. (2007) recorded in Hawai'i, where known individuals were observed over at least 15 yrs. When seen, the species is almost always encountered over very deep water in which it is presumed to feed, and Baird *et al.* (2008) noted that in Hawai'i they spend less time near the surface during the day, probably to avoid predation.

A single sperm whale was recorded, a young individual cast on Manjar beach, Sindh (Gore *et al.*, 2007a). Sperm whales were exploited commercially in the Arabian Sea off the coast of Southern Arabia during the 19th century and again briefly in the 1960s (Baldwin, 2003). More recently the species has been reported by Baldwin *et al.* (1999) off Oman, by Afsal *et al.* (2008) in the south-eastern Arabian Sea off India, and by Braulik *et al.* (2010a) (from a stranding) in the Sistan/Baluchistan area of Iran. Thus the species is still present in the region, though to what extent it is recovering from past exploitation remains unknown.

Confirmed cetacean species for Pakistan

Given the above data and information, the occurrence in Pakistan of 12 species of marine cetaceans can be confirmed, including a single porpoise species, six dolphin species (including killer whale) from six different genera, and five whale species representing four further genera, including both odontocetes and mysticetes (Gore *et al.*, 2007a; 2007b). Of these species, two are listed as endangered (blue and humpback whales) and two as vulnerable (sperm whale and finless porpoise) in the International Union for the Conservation of Nature Red List¹; eight are included within the Appendix to the Convention on Migratory Species².

As also remarked by Mikhalev (2000), the occurrence of good numbers of some of these species in this range may reflect the relatively high productivity of Pakistani waters. While during the NE monsoon there is thermohaline stratification both near and offshore, during the SW monsoon the waters become well mixed, returning nutrients to surface waters. As a result there is high primary productivity, especially in October and November (Rivzi *et al.*, 1995; Saeed *et al.*, 1995), and high secondary productivity and biomass of zooplankton, higher than that further south on the South Asian coast or in the Bay of Bengal.

Anthropogenic impacts

Direct evidence of anthropogenic impact was found on shore-stranded cetacean specimens, particularly finless porpoises, from which the flukes had been removed, presumably to facilitate removal from fishing nets in which they had become entangled. Baldwin (2004) likewise described not infrequent entanglement, especially of whales and of humpback dolphins, in inshore fishing nets in Oman. Similar mortalities have also been described from elsewhere in the Western Indian Ocean, for example affecting humpback dolphins in Maputo Bay, Mozambique (Guissamulo and Cockcroft, 2002). Bottlenose dolphins, a species that feeds in shallow water, may be affected, because when they focus on sonar echoes from their prey they suppress echoes from other objects (such as the nets) and

so may not detect them (Goodson, 1994 *in* Atkins *et al.*, 2004).

Occasional reports were received of both dolphin bycatch and intentional kills for bait, especially in Balochistan, or medicine or other purposes, particularly in Sindh. Baldwin *et al.* (2004) have likewise noted that opportunistic hunting of dolphins may occur in southern Arabia. Reports of cetacean meat being used as bait for shark fishing are of particular concern, since shark fishing has been intensifying as a consequence of the demand for shark for the Asian restaurant trade. More regular targeting of humpback dolphins as a source of meat in west Madagascar has been reported by Razafindrakoto *et al.* (2004). It is not easy to assess whether in Pakistan such intentional and unintentional exploitation will cause population decline, but Stensland *et al.* (2006) studying bottlenose and humpback dolphins in Zanzibar estimated that across the two species bycatch generated an annual mortality of about 12%.

Occasional boat strikes were also described to us during the present study, though whether such strikes or the more general disruption caused by boat activity generate the greater impact remains unclear. Ng and Leung (2003) investigated the effect that vessel traffic might have on humpback dolphins. The dolphins increased their dive duration and performed avoidance behaviour when oncoming vessels were detected; slow-moving vessels appeared not to cause immediate stress, but fast-moving vessels did disrupt behaviour.

In Pakistan various forms of pollution also seem likely to have affected inshore dolphin populations. There are very high levels of chemical pollution in creeks and tributaries near Karachi (such as Korangi and Gizri Creeks and Port Qasim), and around the Hub River and the ship-breaking area of Gadani, Balochistan (Ali and Jilani, 1995; Khan and Saleem, 1988; Rivzi *et al.*, 1988). Around Karachi untreated industrial effluents input toxic metals, pesticides, PCBs (polychlorinated biphenyls) and lubricating oils, while untreated municipal sewage causes high biological oxygen demand (BOD), and inputs organic nitrogenous compounds, suspended solids, soaps and detergents, nutrients, phenols, sulphur compounds and pathogenic bacteria (Ali and Jilani, 1995; Saleem and Kazi, 1995). At Gadani, up to 100 ships per year are dismantled leading to the release of large amounts of heavy metals, asbestos, dioxins and other persistent organic pollutants. The effects of such pollution on local dolphins have yet to be studied, but Parsons (2004) studied contaminants of humpback dolphins in similarly polluted Hong Kong and found very high levels of organochlorines and mercury.

In addition to pollution from terrestrial sources, chronic low-level oil pollution is generated by busy nearby shipping lanes, and there have since the 1980s been two major oil spills affecting the Sindh coast: 700 tons of crude oil in 1984; and 30,000 tons in 2003. Another potential impact in open water may be harmful algal blooms (HAB) due to phytoplankton such as *Gonyaulax* and *Lingulodinium* spp.; extensive blooms are common in coastal waters, as well as in more enclosed areas such as Korangi Creek and Manora Channel (Baig, 2004; Chaghtai and Saidullah, 2001), but have been a feature of the coast since before it became industrialised (M. Khan, pers. comm.).

¹ IUCN Red List website <http://www.iucnredlist.org> [Accessed April 2010]

² CMS website HTTP://WWW.CMS.INT/ACCOBAMS/ACC_SPP.HTM [Accessed 2008]

Views of fishers

The responses of fishers to our questionnaires suggested that many of them were observant of cetaceans, noting species, group size, body size and behaviour, and sometimes taking pleasure in their presence. The Balochi fishers were noticeably more knowledgeable, which may reflect the finding that Balochis interviewed were more likely to be full-time (rather than part-time) fishers. It was also noted, as also described by Grant and Berkes (2007), that in general fishers were very keen to improve their knowledge of marine life especially when relevant to fishing activities. Howard and Parsons (2006) have explored this effect in Scotland where they found that while noise pollution was of interest to the wider community, water pollution was of special concern to fishers. Likewise we found fishers concerned about water quality, particularly in Sindh and near the Gadani ship breaking area. In addition to the individual interviews, the Fisher Workshops provided valuable comment on species occurrence and the range of current threats to cetacean populations, pointing out for example that discarded nets could be a significant problem.

Conservation and management

The results of this study have been used in support of both national and regional cetacean conservation and management initiatives. Hitherto marine cetaceans have not been gazetted as protected species in either Sindh or Balochistan, largely because neither the species concerned nor their status were known. Consequently the findings of this study have been provided to the Convention on Biodiversity Working Group within the Ministry of Environment for further action. In addition, following discussion with the then Minister of the Environment for Pakistan during his visit to Astola/Haft Talar Island, the area proposed for Pakistan's first marine protected area (MPA), a proposal was developed (in collaboration with WWF-Pakistan and the government's own Pakistan Wetlands Programme) for extending full protection to all cetaceans within the MPA.

To further promote effective protection measures, an Action Plan for the Conservation of Marine Cetaceans of Pakistan (Gore, 2008) was agreed and circulated to the relevant government departments and non-government organisations. Recommendations included the establishment of a national cetacean conservation group (as a result of which the Pakistan Whale and Dolphin Society was established on 11 February 2007), and the trialling of whale and dolphin watching trips (the first of which was organised by WWF-Pakistan in 2008). It is intended that both activities should increase public awareness of whales and dolphins in Pakistan and involve an expanding cross-section of the local community in their conservation.

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Recent records of marine mammals in Tanzanian waters

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ABSTRACT

Marine mammal species diversity off Zanzibar and Tanzania, East Africa, has been recorded by the Marine Mammal Education and Research Group at the Institute of Marine Sciences, Zanzibar, Tanzania since 1998. The data presented in this report reflect the efforts of 10 years collection of information from marine mammals stranded and incidentally caught in Tanzanian waters. Additional information from dedicated surveys of cetaceans (whales and dolphins) and incidental sightings reported by the general public are also provided. From 1992 through 2008 a total of 235 specimens of 13 cetacean species and the dugong were recorded. 214 (90.7%) records referred to specimens from bycatch in drift and bottom-set gillnets and 22 (9.3%) referred to specimens from strandings. Based on incidental catch and sightings records, Indo-Pacific bottlenose, spinner and Indo-Pacific humpback dolphins, observed year-round, and humpback whales, observed seasonally during July to November, were the most common species in Tanzanian coastal waters.

KEYWORDS: STRANDINGS; BYCATCH; INDO-PACIFIC BOTTLENOSE DOLPHIN; INDO-PACIFIC HUMPBACK DOLPHIN; SPINNER DOLPHIN; HUMPBACK WHALE; SPERM WHALE; DUGONG; ZANZIBAR; TANZANIA

INTRODUCTION

Cetaceans (whales and dolphins) and dugongs are an integral part of the marine and coastal fauna of tropical and subtropical waters of the East African region (Berggren, 2009). For many species, these waters serve as key habitat for a range of primary activities including feeding, mating and calving (Amir *et al.*, 2005b; Stensland *et al.*, 2006). However, there is a lack of information about the distribution, ecology and abundance for most species due to limited coverage by dedicated research programmes (Berggren *et al.*, 2007; Kiszka *et al.*, 2008). This lack of information is significant, as the East African region is located within the Indian Ocean Sanctuary established by the International Whaling Commission (IWC) to encourage conservation and research of cetaceans in the region (IWC, 1980).

In 1998 a project was launched in Zanzibar, Tanzania with the objective to assess the status of cetaceans and build capacity for their conservation and management. This was facilitated through collaboration between the marine mammal research group at Stockholm University, Sweden (between 1998 and 2010) and since 2010 by Newcastle University, UK, and the Institute of Marine Sciences, University of Dar es Salaam, based in Zanzibar, Tanzania. The activities have focussed on two research areas; vessel based surveys to collect data for cetacean distribution, abundance, genetic population structure, ecology and behaviour and documentation of strandings and incidental catches of marine mammals occurring in Tanzanian coastal waters. A number of scientific papers and reports have been published documenting the results of these activities (see e.g. Amir *et al.*, 2002; Amir *et al.*, 2005a; Amir *et al.*, 2005b; Berggren, 2009; Berggren *et al.*, 2007; Christiansen *et al.*, 2010; Mwevura *et al.*, 2010; Sarnblad *et al.*, 2011; Stensland and Berggren, 2007; Stensland *et al.*, 2006). However, to

date there have been no scientific papers published documenting the diversity of marine mammals present in Zanzibar and Tanzanian waters. Therefore, the aim of this paper is to summarise and present information on the diversity of marine mammal species known to occur in Zanzibar and Tanzania waters using stranding and bycatch data supplemented by available sighting records. This paper also updates information on bycatch of marine mammals documented by Amir *et al.* (2005a)

MATERIALS AND METHODS

Study area

Most of the information on marine mammals was collected in the coastal waters around Unguja Island located at 06°2'S, 39°2'E about 40km off the central coast of the Tanzania mainland (Fig. 1). Unguja Island is often referred to as Zanzibar although the latter also includes Pemba Island.

Samples and sampling procedures

Since 2000, strandings and bycatch of marine mammals have been documented and collected by the Marine Mammal Education and Research Group based at the Institute of Marine Sciences, Zanzibar (Amir *et al.*, 2005b). The group coordinates and records all reported animals around Zanzibar with the help of a network of observers (beach recorders from Department of Fisheries Development, Zanzibar and the general public). Where possible, the reported carcasses are then necropsied, sampled and preserved at the Institute of Marine Sciences for further biological and ecological studies.

Strandings

The group often receives reports from beach recorders, fishermen or the general public stating that an animal has been found stranded. In most cases, members of the group

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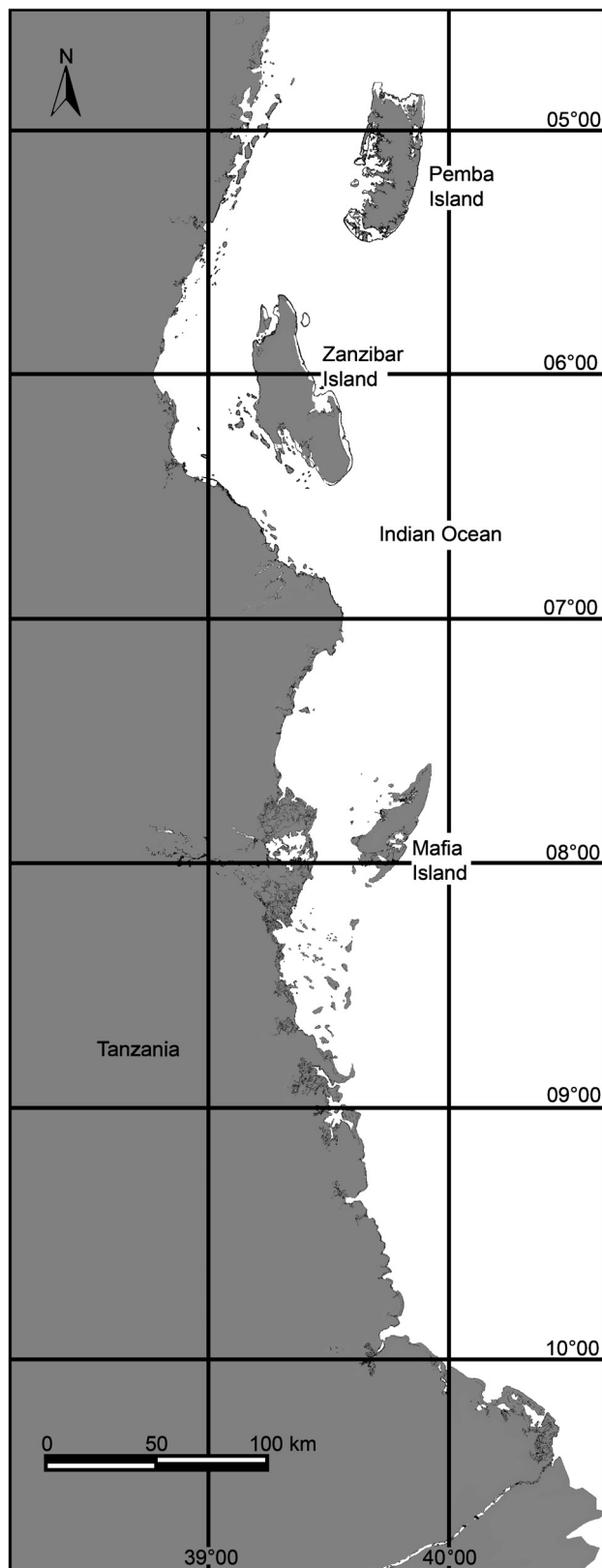


Fig. 1. Map of Zanzibar (Unguja and Pemba Island) showing the study area.

respond by going to the location of the event to examine the animal. A few records of stranded marine mammals exist from 1992 and 1993 collected during a sea turtle survey conducted in 1994. During this survey fishermen were also asked to answer questions regarding stranding of marine mammals (Fiona Clark and Asha Khatib, pers. obs.). These records were accepted into this study only if the information

provided allowed verification of species identification. All stranded animals were identified, measured and photographs taken. When possible, stranded dead animals were collected by the group members for further analyses.

Bycatches

Since fishermen's cooperation is on a voluntary basis, in order to encourage them to report and bring carcasses a nominal financial compensation has been paid (\$5 for small specimens and \$10 for larger animals) for the delivery of the carcass. This compensation was paid to cover fishermen's time and expenses to transport the fresh specimens to the location of the beach recorder or to Zanzibar central market (Amir *et al.*, 2005b). The respective authorities were advised of the importance of collecting and documenting all bycatches that occur in fisheries. Fishermen hand over any bycaught animal to the fisheries beach recorders of the landing site in the village or to a contact person in Zanzibar central market. These beach recorders or contact person then provide a report of the event to the member of the research group at the Institute of Marine Sciences. The incidentally caught animals were measured, weighed and photographed and later necropsied when possible.

RESULTS

Strandings

From 1992 to 2008, 22 marine mammals were reported stranded (Table 1). All of the strandings were found dead. Two species comprised the majority of stranding events; humpback whales (*Megaptera novaeangliae*) with 50% of the total strandings followed by sperm whale (*Physeter macrocephalus*) with 36.4%. The majority of the strandings (85.7%) occurred during the second half of the year between July and November (Fig. 2). Many of the stranded animals were found dead and exhibiting various stages of decomposition. For small cetaceans there were only single records of strandings for shortfinned pilot whale (*Globicephala macrorhynchus*), pygmy sperm whale (*Kogia breviceps*) and killer whale (*Orcinus orca*). However, two mass strandings have occurred on Zanzibar. In 1933, 44 false killer whales (*Pseudorca crassidens*) stranded along the Mtoni seashore on the west coast of Zanzibar (Zanzibar Natural History Museum collection) and on the night between 27-28 April 2006 a group of approximately 600 common bottlenose dolphins (*Tursiops truncatus*) stranded and died on the northwest coast of Zanzibar (Berggren, 2009).

Bycatches

From January 2000 to December 2008, 213 bycatches of cetaceans and one dugong were reported (Table 2). All the reported animals had been entangled in artisanal (drift- and bottom set) gillnets. Drift gillnet fishing is almost exclusively carried out during night-time, where nets are set in the evening and retrieved before moonrise. Bottom-set gillnets are usually set in the evening and hauled in the morning, soak time seldom exceeding 24 hours. Fishing takes place over about three weeks during the dark moon phase for both type of gillnets. A detailed description of these fishing methods can be found in Amir *et al.* (2002).

Table 1
Species and occurrence of marine mammals stranded off the Zanzibar coast between 1992 and 2008.

Scientific name	Body length range (cm)	1992	1993	1999	2000	2001	2002	2003	2004	2006 ¹	2007	2008	Total	%
<i>M. novaeangliae</i>	415–1,040	1	1	1	1	1	2	1	2	0	0	1	11	45.5
<i>P. macrocephalus</i>	900–1,520	1	0	1	1	1	1	0	0	0	3	0	8	36.4
<i>K. breviceps</i>	210	0	0	0	0	1	0	0	0	0	0	0	1	4.5
<i>G. macrorhynchus</i>	–	0	0	0	0	0	0	0	0	1	0	0	1	4.5
<i>O. orca</i>	–	0	1	0	0	0	0	0	0	0	0	0	1	4.5
Total		2	2	2	2	3	3	1	2	1 ¹	3	1	22	100

¹Approximately 600 common bottlenose dolphins stranded and died on the night between 27–28 April 2006 on the NW coast of Zanzibar (Unguja Island).

Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) was the most frequently reported species, with 45.8% of the total bycatch, followed by spinner dolphin (*Stenella longirostris*) with 32.7%, Indo-Pacific humpback dolphin (*Sousa chinensis*) with 7.5% and Risso's dolphin (*Grampus griseus*) with 7.0%. Other species that were only occasionally bycaught included: pantropical spotted dolphin (*Stenella attenuata*), humpback whale (*Megaptera novaeangliae*), common bottlenose dolphin (*Tursiops truncatus*), Fraser's dolphin (*Lagenorhynchus hosei*) and the dugong (*Dugong dugon*). The high percentages of bycatch for Indo-Pacific bottlenose and spinner dolphins do not reflect the abundance of the respective species (although only limited data is available for spinner dolphins). These species maybe more vulnerable to entanglement in gillnets or the species' distributions could have greater overlap with the distribution of gillnet fishing effort compared to other dolphin species in the area.

DISCUSSION

The result of these studies show that humpback and sperm whales are the most frequently stranded marine mammals (excluding the two incidences of mass strandings) on the coasts of Zanzibar and mainland Tanzania. This indicates that these two species are the most regularly occurring large whale species in Tanzanian waters. All of the stranding events ($n = 19$) reported for these species occurred between the months of July and November. These strandings thus

support the idea of seasonal occurrence of these species in the area. All of these documented strandings involved single dead animals (excluding the mass strandings) for which cause of death has not been determined. Some of the humpback whales may have died from net entanglement in drift and bottom-set gillnets. Fishermen usually try to disentangle the whales by cutting the ropes and nets but often fail to remove the whole net. It is difficult to establish either the cause of these strandings or cause of death as in most cases when we arrive at the site there are many people around that have already started to cut-up the stranded animal for consumption. This usually happens when the animals are fresh. However, even when the carcass is in an advanced stage of decomposition people use the meat and blubber for making oil which is used as medicine. There were few reported strandings for small cetaceans and it is not clear if these represent the total number of animals stranded or if strandings are not being reported because they are being used locally for bait and other products.

The seasonal occurrence (July–November) of strandings and bycatch of humpback whales is also supported by sightings records from vessel based surveys carried out off the south coast of Zanzibar (P. Berggren, pers. obs.). This may indicate that the humpback whales encountered off Zanzibar are part of the migrating stocks from the Antarctic Ocean that have their breeding grounds off South and East Africa (Ersts and Rosenbaum, 2003). However, the relationship between the humpback whales found off Zanzibar and Tanzania and those in neighbouring areas, and the discreet breeding stock in the northern Indian Ocean still needs to be investigated. Zanzibar fishermen complain that they lose their nets when humpback whales are entangled. There are a few incidences when bycaught humpback whales have been killed by fishermen. For example, in four cases involving bycaught humpback whales, only two were released from the nets alive in 2003 and 2004 due to the quick response of the Department of Fisheries Development. The other two animals were killed by villagers in 2002 and 2004 and the meat was distributed for consumption in the local villages.

The results of this study show that sperm whales are the second most frequently recorded stranded cetacean species. Despite the high frequency of strandings, sightings of this species in Tanzanian waters are rare and no survey efforts have been done for this species in the area. Carcasses of sperm whales have been found washed up on beaches between July and December, usually of animals which have already died at sea. Most of the sperm whale strandings

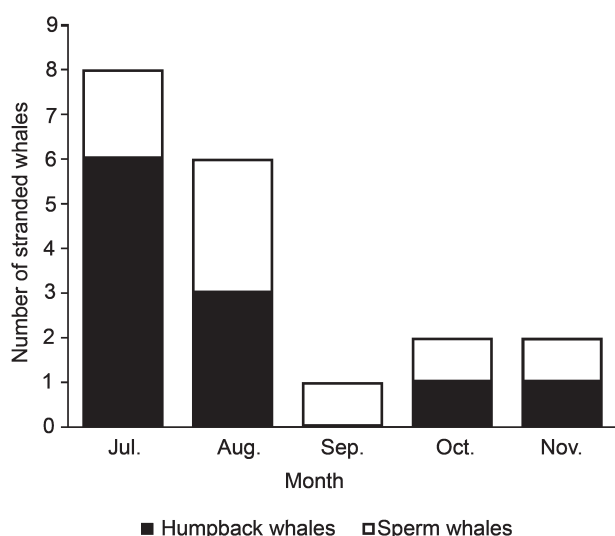


Fig. 2. Monthly distribution of humpback and sperm whales stranded off Zanzibar between 1992 and 2008.

Table 2
Species and occurrence of marine mammals bycaught in gillnet fisheries between 2000 and 2008.

Scientific name	Body length range (cm)	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total	%
<i>T. aduncus</i>	103.5–238	32	12	14	15	9	5	1	2	9	98	45.8
<i>S. longirostris</i>	101–213.5	20	18	0	10	1	2	10	8	1	70	32.7
<i>S. chinensis</i>	128–250	1	5	1	4	0	4	0	0	1	16	7.5
<i>G. griseus</i>	164–251	1	11	0	1	1	0	1	0	0	15	7.0
<i>S. attenuata</i>	173–228	0	4	0	2	1	0	0	0	0	7	3.3
<i>T. truncatus</i>	167–230	0	0	1	1	0	0	0	0	0	2	0.9
<i>L. hosei</i>	158	0	0	0	0	1	0	0	0	0	1	0.5
<i>M. novaeangliae</i>	415–1,040	0	0	1	1	2	0	0	0	0	4	1.9
<i>D. dugon</i>	235	0	0	0	0	0	1	0	0	0	1	0.5
Total		54	50	17	34	15	12	12	10	11	214	100

occurred on the east coast of Unguja Island which is very close to deep water (>1,000m within 10 n.miles).

The number of incidental catches of (mostly) small cetaceans varied from year to year but there has been a notable decrease in the number reported during the survey period. The decrease in incidental catch could be due to depletion of populations, the decrease in effort by beach recorders or increased awareness of fishermen to the conservation issues of marine mammals and fear that reports of incidental catch may lead to fisheries restrictions.

The results of this study show that Indo-Pacific bottlenose dolphins are the most widespread of all dolphins and occur all around the coast of Zanzibar. The species occurs in small resident populations, e.g. in the inshore waters of Menai Bay, south coast of Unguja with an estimated population size of between 136–179 bottlenose dolphins (Stensland *et al.*, 2006).

The bycatch data indicate that spinner dolphins are distributed in all coastal waters of Unguja Island except off the west coast where no specimens were retrieved from fisheries bycatch. This area is relatively shallow (maximum depth <50m) and may not meet the habitat requirements for the species. However, most of the spinner dolphin bycatch was reported from northwest of Unguja Island and in the area between Unguja Island and along the coast of Tanga, Tanzania mainland. Few bycatches of spinner dolphins have been reported from the south of Unguja Island. Sightings of spinner dolphins have been reported off Unguja Island along the coast of Nungwi and Matemwe (N. Ortland, pers. obs.) and on the west coast of Pemba Island (L. Karczmarski, pers. comm.).

Bycatch of Indo-Pacific humpback dolphins have been reported mainly from southwest and northwest of Unguja Island especially in the inshore areas and bays. This species is also known as resident in Menai Bay, off the south coast of Unguja with population estimates of about 58–65 animals (Stensland *et al.*, 2006).

Pantropical spotted, Risso's and Fraser's dolphins have only been reported as bycatch off the northeast coast of Unguja Island. This indicates that these species are rare in the coastal waters of Zanzibar. However, Pantropical spotted dolphins have been observed in mixed groups with spinner dolphins off the coasts of Nungwi and Matemwe on the north coast of Unguja Island (O. Amir and P. Berggren, pers. obs.). No Fraser's dolphin sightings have been recorded in the waters of Tanzania.

The two common bottlenose dolphins recorded were bycaught off the southwest and northwest coasts of Unguja Island. This gives an indication that this species is rare in the coastal waters of Tanzania, though it may be common offshore. The mass stranding of about 600 common bottlenose dolphins in April 2006 shows that the species can be present in the region in relatively large numbers. These animals were live stranded and died on the beaches. The cause of the mass stranding could not be established although all of the 66 specimens sampled on site had empty stomachs indicating that the animals may have stranded on an unfamiliar shore in search for prey.

The bycatch of a dugong, which occurred in 2005, is the first case to be recorded in Zanzibar. Dugongs have also been recorded as bycatch off the Tanzanian mainland. For example, 26 dugongs were bycaught in the Rufiji Delta and off Kilwa, along the coast of the Tanzanian mainland from 2000 to 2004 (WWF Eastern African Marine Ecoregion (EAME), 2004). A single dugong was also found stranded on Pemba Island in 2006. These records indicate that dugongs are still present in Tanzanian waters although their status remains unclear.

A pilot aerial survey conducted in Zanzibar and Tanzanian coastal waters in February 2000 revealed the occurrence of several other cetacean species including; rough-toothed dolphin (*Steno bredanensis*), Cuvier's beaked whale (*Ziphius cavirostris*) and Longman's beaked whale (*Indopacetus pacificus*) (Berggren *et al.*, 2001).

CONCLUSIONS

The results of this study demonstrate a relative high diversity of dolphin species present in the coastal waters of Tanzania. This information is important to the region since it demonstrates the potential for tourism based on whale and dolphin watching activities. The results are also cause for concern regarding the possible impact of the high mortality due to the gillnet fishery on local populations and this warrants further investigation. Hence, there is a need for more research in order to understand the ecology, abundance and conservation status of marine mammals in the region and to monitor their populations, especially for those species and geographical areas where no studies have been conducted. There is also a need for further cooperation and the building of trust between fishermen and Fisheries authorities in order to get precise information for the incidental catch to allow assessment of impact on populations.

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Occurrence and residency patterns of humpback whales off Réunion Island during 2004–10

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ABSTRACT

Dedicated humpback whale surveys were conducted around Réunion Island during 2004–10. Boat-based surveys were conducted from June to October, in the main objective of collecting photo-identification data. For 2004–10, a total of 501 survey trips, representing 1,530 hours of on-searching effort, and 724 humpback whale sightings were achieved. Although effort had a significant influence on the number of sightings, sighting rate was shown to increase significantly from 2007 onwards, with a peak in 2008. Seasonal variations were observed, with significantly higher numbers of sightings occurring in July–September. Larger number of whales, together with increased survey effort, led to larger datasets collected in 2008–10, allowing further investigation of residency pattern. Within-year recaptures from fluke photographs showed that a relatively large proportion (30%) of the identified whales was recaptured on more than one day around the island. Maximum recapture interval reached 64 days, with a mean ranging 22–29 days for 2008–10. Mean residency, estimated from expected lagged identification rate, was 25 days. Mothers with a calf were shown to reside around the island for longer period of time than other individuals. A seasonal pattern of residency was demonstrated, with single capture individuals occurring early in the season, mainly as singleton or pairs, while individuals showing higher recapture interval were present around the island from August to October. Between-year recaptures were reported for 2009–10, with five individuals re-sighted on consecutive years. The fluke catalogue for Réunion includes 312 distinct individuals identified during 2004–10 surveys, together with 21 additional whales captured opportunistically since 2001. The increasing trend in the number of whales, the high residency time observed for 2008–10 and the recent occurrence of inter-annual recaptures suggest that Réunion Island has become an important migratory site for humpback whales within the south-western Indian Ocean (Breeding Stock C). The species might expand its spatial range by occupying new breeding sites (or re-occupying old ones) within the south-western Indian ocean, as a result of population growth.

KEYWORDS: HUMPBACK WHALE; INDIAN OCEAN; BREEDING GROUND; RESIDENCY PATTERN; PHOTO-ID; SURVEY-VESSEL

INTRODUCTION

Réunion Island is a French overseas territory. It is a small (72km long), oceanic island in the south-western Indian Ocean, located 700km east of Madagascar and 250km west of Mauritius. The island shelf is very narrow (200m depth contour lies 3km from the coast on average) and sea depth increases very rapidly near the shore, down to 3,000m deep. Since 2004, ongoing cetacean surveys have been carried out in Réunion's coastal waters (<5 n.miles offshore), and 21 species have observed to date (Dulau-Drouot *et al.*, 2008; Globice, unpubl. data). The humpback whale (*Megaptera novaeangliae*) is one of the most frequent species seen in shallow waters during the southern winter.

The humpback whale is the only species showing a clear seasonal pattern in Réunion. Sightings occur from early June to late October (although few sightings are made in November and rare sightings occurred in December 2007 and 2008 and in February 2009), which is consistent with the general migration pattern of the species. Humpback whales undertake annual migration between high latitude summer feeding areas and low-latitude winter breeding areas (Dawbin, 1966). Although major migratory corridors have been described at the basin scale (Best *et al.*, 1998), knowledge of humpback whale migration pattern in the south-western Indian Ocean is still incomplete. Best *et al.* (1998) proposed three principal migratory streams: one on the east coast of southern Africa, one along the Madagascar Ridge, and one in the central Mozambique Channel. The

International Whaling Commission (IWC) designated seven breeding population (stocks A–G) in the Southern Hemisphere (IWC, 1998). The south-western Indian Ocean is considered as Breeding Stock C, sub-divided into 3 major subpopulations (IWC, 2000): C1, along the east coast of South Africa to Mozambique; C2, central Mozambique channel islands (Comoros, Aldabra, Eparses islands); and C3, coastal waters of Madagascar. The possibility of a further breeding sub-region, C4, in the Mascarene Islands (Réunion, Mauritius and Rodrigues) has been proposed (IWC, 2011b). However, because limited information was available, humpback whales from this region were not considered in the assessment of Breeding Stock C conducted recently by the Scientific Commission of the IWC (IWC, 2011a). Although the presence of the species has been reported in Réunion, Mauritius and Rodrigues little published data exist (Corbett, 1994; Dulau-Drouot *et al.*, 2008). There is evidence that whaling on humpback whales took place in Mauritius at the end of the 18th century (logbook from the ship *Asia*, 1791–94), but the Mascarene Islands did not appear to represent a whaling ground for humpback whales in the 19th century (Townsend, 1935). In the 20th century, although modern whaling expanded in South Africa, Mozambique and Madagascar (Tønnessen and Johnsen, 1982), no catch records are available from the Mascarene Islands. Therefore, there is no existing long term data for the species in this area. In this paper results are presented on sighting rate, residency patterns and movements of

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humpback whales in Réunion, from data collected during 2004–10 southern winters.

MATERIAL AND METHODS

Data collection

Dedicated boat surveys were conducted throughout the year off La Réunion (55°33'E, 21°07'S) from 2004 to 2010. Humpback whale data were collected, from June to October, in the coastal waters of the island. Surveys boats of similar sizes (5m long on average) were used and were launched at different locations along the coast: Saint Pierre; Etang sale; Saint-Leu; Saint Gilles; Le Port; and Sainte Marie. The spatial distribution of effort was constrained by general weather conditions, port locations and boat availability. The west coast is sheltered from dominant winds and was therefore mostly covered. Surveys off the northern coast were limited due both to difficult weather conditions during winter and lack of boat available in this area. No boat was available in Saint Rose, so the eastern coast of the island, exposed to dominant winds, was not covered during this study.

During surveys, watches were undertaken by 3–5 observers, searching the sea surface with the naked-eye. The same type of survey boats were used across years, thus the observers were surveying at a consistent height above the water surface. Searching effort was recorded by noting time, GPS position and sea state condition every 15 minutes. When humpback whales were sighted, the group size and composition were recorded, together with behavioural data. This sighting phase dedicated to data collection was considered off-effort. Groups of whales were classified into five categories based on group size and composition and according to behavioural characteristics previously described for this species (Tyack and Whitehead, 1983): singletons, pairs, mother-calf pair, mother-calf-escort and competitive groups. Groups that did not fall into one of these categories were classified as 'undetermined'. Whenever possible during humpback whale encounters, photographs were taken of the ventral side of the fluke and of both sides of the dorsal fin. Digital cameras (*Canon 10-50D*, *Sony A100*) equipped with 75–300mm lenses were used.

Data analysis

Humpback whale sighting rate was computed for each survey trip, by dividing the number of humpback whale sightings by the number of hours on-effort (include only searching phases and excluding time spent on sighting of any cetacean species) and expressed as the number of sightings per hour of searching effort. Mean sighting rates were calculated monthly and annually. A Generalised Linear Model (GLM) analysis was applied to determine whether variations in sightings numbers could be attributed to annual differences, and/or if other factors, such as month surveyed, area prospected and survey effort were expected to have a significant influence. The response variable being count data (number of sightings), a Poisson loglinear regression was applied, including three categorical variables as predictors: 'year'; 'month'; and 'area', with 'effort' as a covariate. The study area was divided into three zones: northern; western; and the southern part of the island (the eastern coast was not surveyed). All statistical tests were conducted using *SPSS*.

Within-year recaptures were assessed by comparing all fluke photographs taken within each year survey. For each individual, the best image of the fluke and, when available, of the right and left side of the dorsal fin were catalogued. The choice of the most representative image was based on both the quality of the photograph and the distinctiveness of pigmentation features of the ventral fluke (Friday *et al.*, 2000). In cases where multiple pictures were needed to allow a complete identification, several fluke photographs were chosen to represent an individual in the catalogue. All photographs of the catalogue were rated for quality on a five-level scale: excellent; good; fair; poor; and not useable. Photographs in the latter category were discarded from the comparison process. The portion of the fluke visible above the surface was also recorded. Flukes were classified into the nine pigmentation categories of the Antarctic Humpback Whale Catalogue (AHWC, <http://www.coa.edu/antarctic>). Photograph not selected for the catalogue were saved in archive files. Comparisons of the fluke catalogue of each year were undertaken to assess between-year recaptures. A 'capture' was defined as the first identification of an individual (based on a photograph of the pigmentation pattern in the ventral surface of the fluke), and a 'recapture' was defined as the subsequent photographic re-identification of the same individual.

Due to the small number of photographs available from 2004–07 and the small number of recaptures recorded these years, only 2008–2010 data were used to assess residency and movement pattern from within-year recaptures. Recaptures of animals identified more than once during the same day were not taken into account, so that within-year recaptures relate only to individuals identified in different days. For individuals re-sighted on multiple days, residence time was assessed by calculating the maximum recapture interval: time interval (in days) between the first capture and the last recapture of the whale. Residency was also investigated using the sighting histories of all individuals (including those seen only once), by computing the lagged identification rate (LIR). The LIR is an estimate of the probability that an individual identified in the study area at any time will be identified again in the study area some time lag later (Whitehead, 2001) and is calculated as follows:

$$R(\tau) = \frac{\sum_{j,k | (t_k - t_j) = \tau} m_{jk}}{\sum_{j,k | (t_k - t_j) = \tau} n_j \cdot n_k}$$

Where n_j is the number of individuals identified on occasion j ; m_{jk} is the number of individuals identified on both occasions j ; and t_j is the time of identifications at occasion j .

Lagged identification rates were first calculated for all adult whales identified in 2008–10. The LIR was then computed for mothers with a calf separately, to assess any difference in their residency pattern compared to other individuals. The observed lagged identification rates were fitted to exponential mathematical models of residency (Whitehead, 2001). Models were fitted with maximum likelihood methods. The Akaike Information Criterion (AIC) was used to determine the best fitting model and bootstrap

techniques were used to calculate 95% confidence interval and standard errors of LIR and model parameters (Whitehead, 2007). Lagged identification rates computation and residency model fitting were carried out using the computer software *SOCPROG* 2.4 (Whitehead, 2009).

RESULTS

Survey effort and data collected

Searching effort deployed from June to October increased with year, ranging from 120 hours on-effort (29 survey trips) in 2004 to 378 hours (141 survey trips) in 2008 (Table 1). In 2008–10, survey effort was intensified, as a response to the increase abundance of whales; an average of 21, 26 and 34 survey trips were conducted per month in 2008, 2009 and 2010 respectively (Table 1). The spatial coverage of effort tended to expand across years as well, with the northern part of the island being only covered in 2008–10 (Fig. 1). The western and southern parts of the island were covered every

year, while the eastern part had never been surveyed during the whale season (Fig. 1).

A total of 720 humpback whale sightings were undertaken from June to October during 2004–10 surveys. The number of humpback whale groups sighted increased with year, to reach a maximum of 272 sightings in 2010 (Table 1). More photo-identification data were collected during 2008–10, as a result of increased survey effort and increased number of whale sightings. Subsequently, the number of individuals identified from fluke photograph increased across years. In 2004–06, 7 individuals were identified per year and 17 in 2007. The number of identified whales increased notably in 2008, 2009 and 2010, with respectively 83, 80 and 116 adult individuals captured. In addition, 12 individuals were photographically identified in years prior to the present survey (9 in 2003, 2 in 2002 and 1 in 2003), although these were not associated with effort data. Furthermore, 9 individuals were identified from fluke photograph taken

Table 1

Details of survey effort carried out during the humpback whale season (June–October) at Reunion Island in 2004–10.

	Number of survey trips	On-effort survey (in hour)	Number of HW sightings	Mean sighting rate (sighting/hour)	Number of identified individuals
2004	29	120.5	12	0.1	7
June	5	22.3	1	0.04	1
July	7	28.5	6	0.21	5
August	7	27.5	2	0.06	0
September	4	18	2	0.11	0
October	6	24.3	1	0.04	1
2005	36	171.5	10	0.06	7
June	13	70	7	0.10	5
July	7	36.5	1	0.03	1
August	3	16.5	0	0.00	0
September	5	18.5	2	0.11	1
October	8	30	0	0.00	0
2006	42	192.3	13	0.08	7
June	18	90.8	3	0.03	0
July	3	10	2	0.20	2
August	4	15	2	0.13	2
September	7	30	1	0.03	2
October	10	46.5	5	0.11	1
2007	55	153.5	53	0.52	17
June	19	52.4	14	0.27	6
July	13	30.4	12	0.39	6
August	5	12.18	10	0.82	2
September	14	44.6	16	0.36	2
October	4	13.9	1	0.07	1
2008	91	207	168	1.06	83
June	7	16.6	3	0.18	1
July	19	39.6	24	0.60	7
August	21	53.2	60	1.13	44
September	25	50.3	53	1.05	26
October	19	47.2	28	0.59	4
2009	107	306.3	196	0.81	80
June	4	12.6	0	0.00	0
July	27	67.8	53	0.78	36
August	33	98.8	50	0.51	30
September	26	77.7	68	0.88	7
October	17	49.4	25	0.51	7
2010	141	378.5	272	0.92	116
June	5	16.7	0	0.00	1
July	26	76.7	26	0.34	19
August	43	102.7	118	1.15	59
September	36	94.7	105	1.11	31
October	31	87.7	23	0.26	6

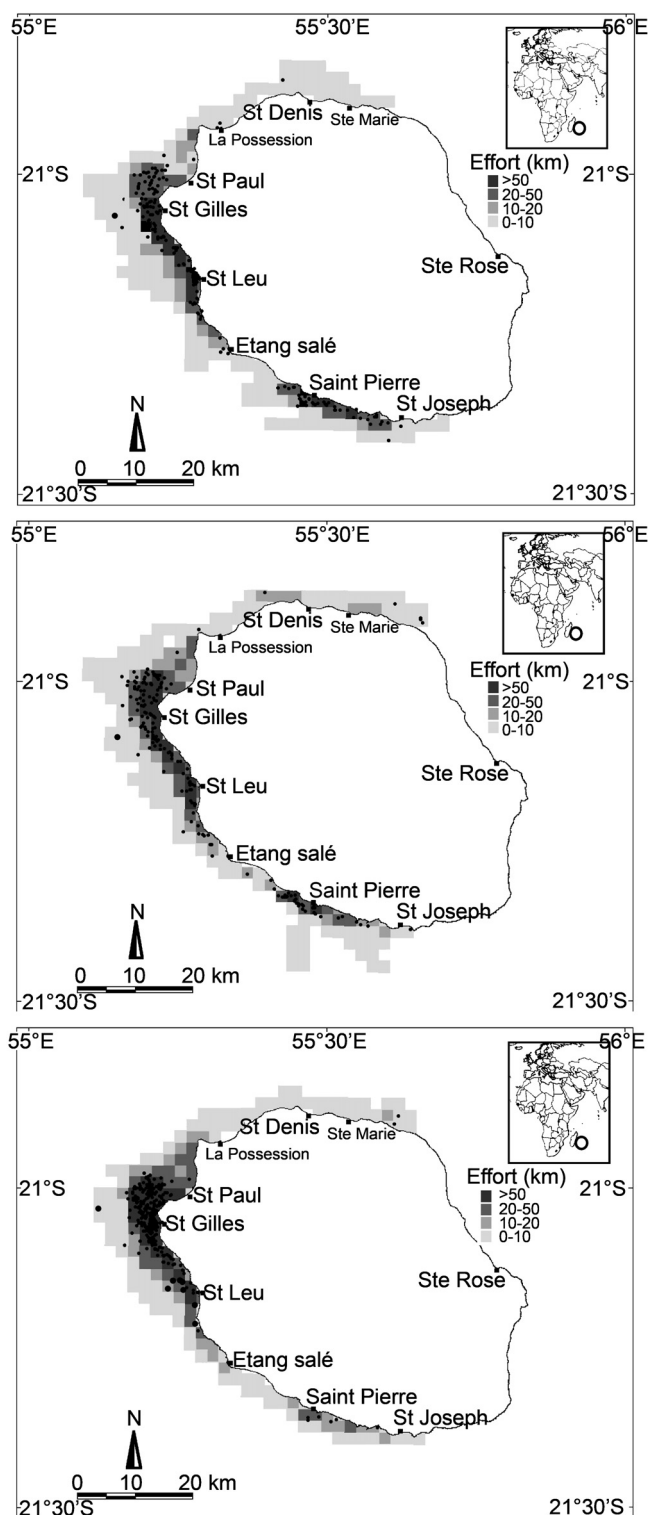


Fig. 1. Map of Réunion showing distribution of effort (2×2km grid) and humpback whales sightings from (A) 2008, (B) 2009 and (C) 2010 surveys.

opportunisticly in 2009 and 2010. These additional data were included in when undertaking between-year comparisons.

Sighting rate

The annual sighting rate increased from a mean of less than 0.1 sighting hr^{-1} during 2004–06 to a mean of 0.5 sighting hr^{-1} in 2007, and reached a peak of 1.1 sighting hr^{-1} in 2008 (Table 1). In 2009 and 2010, the mean sighting rates

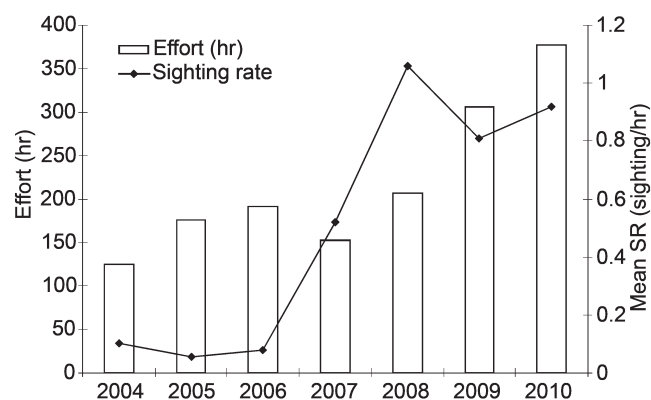


Fig. 2. Humpback whale mean encounter rate (sighting hr^{-1}) observed in 2004–08 in Réunion. Error bars indicate SE. Dotted line indicate a rate of increase of 10.3% from 2004 value.

remained relatively consistent (0.81 and 0.92 sighting/hour respectively), although higher effort was achieved (Fig. 2).

The output of Poisson regression indicates that years, months and effort were highly significant in determining the observed variation in the number of whale sightings, while the area did not appear to be a significant explanatory variable (Table 2). Therefore, for a given month and effort, there was no significant difference in the number of sightings made in different survey areas whereas there was a significant effect of year. The results of the Wald χ^2 tests indicate that the number of sightings was significantly higher in July, August and September, than in October and June (Table 3). Negative parameters for years 2004–07 indicate that the number of sightings was lower over this period than in 2010 (reference year), and the difference was statistically significant for years 2005 and 2006 ($\chi^2 = 1.505$, $p = 0.017$, $\chi^2 = 1.543$, $p = 0.01$, respectively). In 2007 and 2009, the number of sightings was not significantly different to 2010, while in 2008 significantly higher numbers of sightings were observed ($\chi^2 = 1.018$, $p = 0.001$). Therefore, the regression analysis confirms, for a fixed month and effort, an increased humpback whale occurrence in 2007–2010, with a peak observed in 2008. The odd ratios indicated there were 4 times less sightings in 2005 and 2006 than in 2010 and 2.7 times more sightings in 2008 compared to 2010.

Group size and structure

Groups ranged from 1 to 8 individuals, with a mean group size of 2.2 individuals. Of the 720 groups sighted, 26.7% were singletons, 20.7% pairs, 24.9% mother-calf pairs, 8.5% mother-calf-escort, 11.3% competitive groups and 8.3%

Table 2

Overall test of significance of the effect of zone, year, month and effort in the loglinear model.

Tests of model effects (Type III)			
	Wald χ^2	df	p
Intercept	0.215	1	0.643
Area	5.202	2	0.074
Year	53.591	6	<0.001
Month	33.993	4	<0.001
Effort	47.113	1	<0.001

Table 3

Analysis of coefficient estimates and the significance of each of the variables included in the loglinear regression.

Parameter	Estimate (β)	Std. error	95% Wald confidence interval		Hypothesis test			Odd ratio Exp(β)
			Lower	Upper	Wald χ^2	Df	<i>p</i>	
(Intercept)	0.279	0.3828	-0.472	1.029	0.530	1	0.467	1.322
Zone=North	-0.752	0.3653	-1.468	-0.036	4.235	1	0.049	0.471
Zone=West	0.123	0.2619	-0.390	0.636	0.221	1	0.638	1.131
Zone=South	0 ^a	—	—	—	—	—	—	1
Year=2004	-1.062	0.6084	-2.254	0.130	3.047	1	0.081	0.346
Year=2005	-1.505	0.6307	-2.741	-0.268	5.690	1	0.017	0.222
Year=2006	-1.543	0.5973	-2.714	-0.373	6.678	1	0.010	0.214
Year=2007	-0.043	0.3552	-0.739	0.653	0.014	1	0.904	0.958
Year=2008	1.018	0.2968	0.436	1.600	11.768	1	0.001	2.768
Year=2009	0.399	0.2108	-0.014	0.812	3.583	1	0.058	1.490
Year=2010	0 ^a	—	—	—	—	—	—	1
Month=6	-0.246	0.4147	-1.059	0.567	0.352	1	0.553	0.782
Month=7	0.558	0.2644	0.040	1.076	4.452	1	0.035	1.747
Month=8	0.656	0.2451	0.175	1.136	7.159	1	0.007	1.927
Month=9	1.140	0.2352	0.679	1.601	23.513	1	<0.001	3.127
Month=10	0 ^a	—	—	—	—	—	—	1
Effort (hours)	0.038	0.0056	0.027	0.049	47.113	1	<0.001	1.039
(Scale)	3.307 ^b	—	—	—	—	—	—	—

^aSet to zero because this parameter is redundant (reference variable). ^bComputed based on the Pearson chi-square.

were undetermined. This latter category included mainly groups of 3–4 individuals not showing any surface active behaviour. Therefore, calves were observed in 33% of the sightings. The proportion of each group type varied across months (Fig. 3). Early in the season, in June and July, more than 80% of the sightings consisted of singletons or pairs of individuals. During the season, the number of groups including a calf increased consistently. By October, 64.1% of the sightings consisted of mother-calf pairs or mother-calf-escort groups. Competitive groups were mainly observed in August and September (Fig. 3).

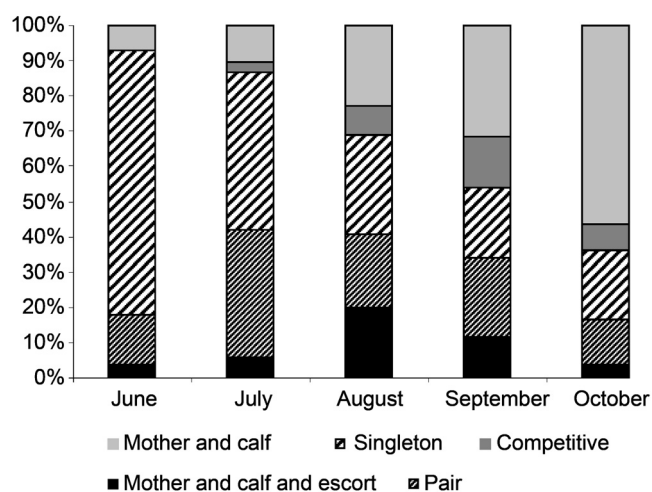


Fig. 3. Monthly distribution of sightings according to group types (2004–2010).

Within-year recaptures and time residency

In 2008, 2009 and 2010 within-year recapture rates were relatively high, reaching 30%, 20% and 42% of the 83, 80 and 116 individual identified respectively. Therefore, on average over these three years, 69.4% of the identified individuals were captured only once, while 30.6% were recaptured on more than one day over the season. Overall,

there was a trend for individuals captured only once to occur early in the season: 79% of the whales photographically identified in July were single capture individuals while in September and October the majority of the whales identified consisted of recaptures (65 and 68% respectively).

The number of recaptures per individual ranged from 2–7 in 2008 and 2009 and up to 12 in 2010, with most recaptured whales been seen 2–7 times on different days (88%). Although most of the recaptured whales were not seen often, their maximum recapture interval was relatively high and consistent, with a mean of 22 ($\pm$ SE = 2.8) days in 2008, 29 ($\pm$ SE = 5.3) days in 2009 and 23 ($\pm$ SE = 2.3) days in 2010. The longest interval between first and last recaptures was 45, 64 and 60 days in 2008, 2009 and 2010 respectively. Thus, no whale has been observed in Réunion over a period of more than two months within the same year. Among all individuals recaptured on more than one day, 31% were re-sighted after an interval of less than 10 days (28 individuals), 32% were sighted around the island between 11 to 30 days (29 individuals) and the remaining 36% stays over more than 31 days (33 individuals) (Fig. 4). Of the 90 individuals recaptured within 2008, 2009 and 2010 seasons, 11 were females accompanied by a calf and 8 were 'escort'. Mother-calf pairs showed a significantly longer residency than other individuals, with a capture interval of 36 days on average (Table 4), ranging from 19 to 60 days (T-test = 3.59, p = 0.003). Individuals escorting a female with a calf tended to have relatively long residency as well, with a mean capture interval of 28 days, ranging from 19 to 56 days, however, the difference was not significant statistically (T-test = 1.136, p = 0.286).

The residency model best fitting the overall lagged identification rate (Goodness of fit χ^2 = 39.9, df = 39, p = 0.4291) indicates that there were approximately 32 whales ($31.7 \pm$ SE = 3.7, 95% CI = 26.3–41.9) in the study area at any one time and the estimated mean residence time of individuals was 25 days ($25.1 \pm$ SE = 2.92, 95% CI = 20.5–31.5).

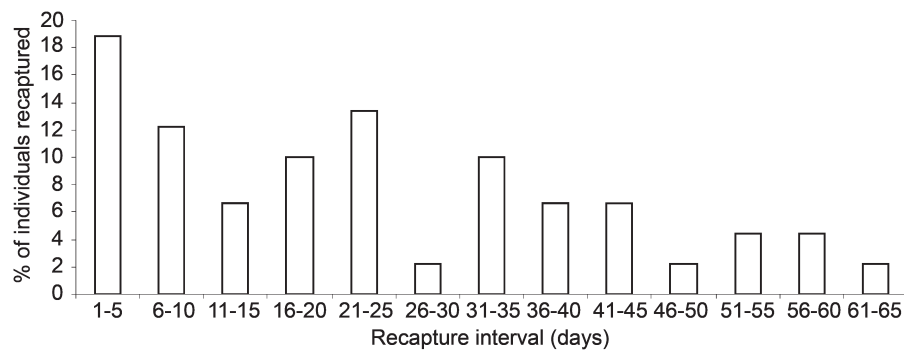


Fig. 4. Distribution of the individuals captured in 2008, 2009 and 2010 off Réunion (in percentage), according to the maximum recapture interval (in days).

When computed separately, the LIR of mother with calf appeared to be higher than those of other individuals, with the observed rates remaining relatively high for up to 45 days (Fig. 5). Therefore, the probability of recapturing a mother with a calf after its first capture was higher than for other whales, indicating that mothers with calves tended to reside longer in the study area compared to other individuals. The parameter estimates of the fitted model indicate that there were five ($4.7 \pm \text{SE} = 1.37$, 95% CI = 2.7–7.8) mothers with a calf at any one time in the study area and their mean residence time was 53 days on average. Other individuals (males or females without a calf) showed a lower probability of being recaptured with lag time (Fig. 5). They occurred in greater numbers, with approximately 30 individuals present at any given time in the study area ($29.9 \pm \text{SE} = 4.1$, 95% CI = 23.5–40.9) and were expected to reside for a shorter period of time (24 days $\pm \text{SE} = 3.0$, 95% CI = 19.3–30.9).

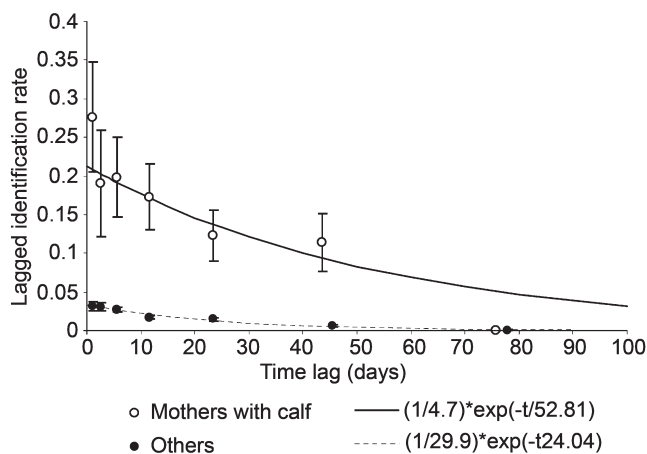


Fig. 5. Lagged identification rate of mother with calf and other individual humpback whales identified in 2008–10 in Réunion, together with the expected lagged identification rates from residency models. Vertical lines are standard error.

Spatial movement

The distance between recaptures of individuals ranged from 0.2 to 75 km. On average, the whales moved along the coast at a rate of 3.3 km per day, with displacement rate ranging from 0.02 km to 52 km day⁻¹ (Table 4). The maximum distance travelled in one day (52 km) correspond to a whale sighted off Saint-Gilles and resighted south of Saint-Pierre the day after. There was no difference in mean displacement

rate between mother-calf pairs, escorts and other individuals (Kruskal-Wallis Test = 0.672, $p = 0.715$). Displacement was not significantly correlated with time lag and there was no evidence of any coordinated movement pattern of whales: different whales could either move long distance in one day or remain in the same area for several days. Individuals recaptured on at least seven occasions during 2008–10 are presented in Fig. 6, where re-sightings of mother-calf pairs ($n = 6$), escort ($n = 3$) and other individuals ($n = 3$) were linked with direct separated lines to better visualise long-distance movements. Although most recaptures occurred off Saint Gilles, where most effort was conducted, whales appear to be travelling around the island, and thus using all of the coastline, during their stay in Réunion, independent of whether they are mothers with a calf, escorts or other individuals (Fig. 6).

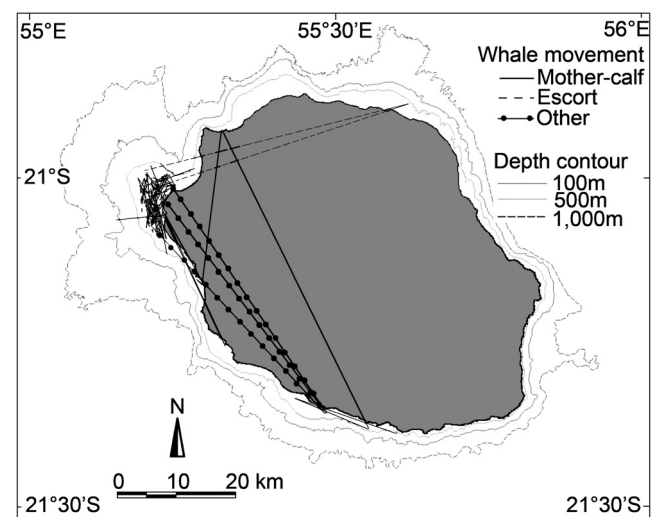


Fig. 6. Map showing re-sightings of whales recaptured seven times or more during 2008–10 season, linked by a direct line to illustrate movements of mother-calf, escort and other individuals separately.

Between-year recaptures

Five between-year recaptures were found during the study period (2004–10). All were first captured in 2009 and recaptured in 2010 at Réunion. Therefore of the 80 individuals identified in 2009, five came back to Réunion the following year. Among them, one individual appeared to be a female, observed with a calf in 2010. The gender of the four other recaptured individuals was not known, although they were all sighted at least once in competitive groups and

Table 4

Descriptive statistics of recapture intervals and displacement rates of individuals recaptured on different days during 2008–10 seasons.

	N	Recapture interval (days)				Displacement rate (km/day)			
		Mean	SD	Min	Max	Mean	SD	Min	Max
Overall	86	23.1	17.9	1	64	3.26	5.10	0.04	28.78
Cow-calf	12	36.6	14.1	19	60	2.17	2.46	0.45	8.55
Escort	8	27.9	17.7	3	56	3.59	3.83	0.68	10.68
Other individuals	68	20.4	17.4	1	64	3.38	5.52	0.04	28.78

were thus involved in reproductive activity. An additional between-year recapture was recorded from an individual first identified in 2003 (before the study period) and recaptured during the 2010 survey at Réunion, when it was sighted 8 times over a 56 day period. This individual was observed both in 2003 and 2010 as escorting a mother with a calf, and was thus suspected to be a male. There was no consistency in the timing of the first capture day between years, with sightings occurring from 2 to 33 Julian days from the date of their initial capture year.

Therefore, taking account of between-year matches, the final catalogue included 312 different individuals captured in Réunion Island during 2004–10 surveys, five of which were recaptured on consecutive years. Fluke photographs of 21 individual whales were also available from previous years (2001–03) and opportunistic photographs (2009–10), allowing a seven year interval recapture. Altogether, the catalogue from Réunion includes 322 individuals identified from fluke photographs up to 2010.

DISCUSSION

The results show a significant increase in humpback whale numbers visiting Réunion during 2007–10 compared to previous years (2004–06). Increases in humpback whale numbers have been inferred in others sites of the south-western Indian Ocean such as in Sainte Marie, on the East coast of Madagascar (F.X. Mayer, pers. comm.) and in Zanzibar (P. Berggren, pers. comm.), although no published data are available from these areas. The increase in sighting frequency observed in Réunion or other localised places might result from an increase in humpback whale population at a regional scale. Using mark-recapture data collected from Antongil Bay in 2000–07 (Cerchio *et al.*, 2008), an annual growth rate of 8% has been estimated for Madagascar (breeding sub-stock C3, Johnston and Butterworth, 2008). However, the increase in humpback whale sightings observed in 2008–10 in Réunion appears to be larger than the medium rate of population increase estimated for Madagascar and exceeds the maximum plausible rate of increase of 11.8% yr⁻¹ established from the examination of life-history parameters in humpback whales (Zerbini *et al.*, 2010). Therefore, although part of the rise observed in recent years in Réunion might result from a population growth at a regional level, other factors have to be considered. An increased immigration to Réunion Island might reflect a density-dependent response of whales within Breeding Stock C, whereby whales investigate new sites (or re-occupy historical ones) as other sites are becoming saturated because of recent population growth. First movements of individual

humpback whales from Madagascar to Réunion have been reported recently (Dulau-Drouot *et al.*, 2011). Although an analysis of exchange probability has not been conducted yet, these preliminary results tend to support the hypothesis that Réunion might represent an extension of the Madagascar wintering area as oppose to a separate entity (sub-stock C4) within the south-western Indian Ocean. Furthermore, the recent between-year recaptures reported in the present study suggest that some degree of site fidelity might have begun to occur at Réunion. However, most whales captured at Réunion have been sighted in only one year indicating a general trend for whales to use different breeding sites across the years. Studies on major breeding areas of the south-western Indian Ocean have shown low site fidelity between years (Cerchio *et al.*, 2008; Ersts *et al.*, 2006) and evidence of exchanges of individuals between eastern Madagascar and the northern Mozambique Channel (Ersts *et al.*, 2011). Therefore migration movement of humpback whales between breeding sites of the south-western Indian Ocean might be particularly complex. Other environmental factors such as changes in water temperature, might also affect migration routes and choice of breeding areas. However, to date, the forces driving migrations on a fine scale remain unclear (Rasmussen *et al.*, 2007).

Humpback whales were present in coastal waters of Réunion from early June to late October, with a peak in July–September. The consistent occurrence of newborn calves and competitive groups in the present study confirm that Réunion Island represents a breeding area for the species in the south-western Indian Ocean, as suggested in previous studies (Dulau-Drouot *et al.*, 2008).

Within-year recapture results from 2008–10 data showed that an average of 30% of the captured whales were observed on multiple days, with a mean recapture interval ranging from 22–29 days and a maximum residency of 64 days. These recapture rates and intervals are respectively higher and longer when compared to other studies. In Antongil Bay (Madagascar), within-year recapture rate ranged 6–18% of individuals captured on more than one day and mean recapture interval ranged from 3–8 days (Cerchio *et al.*, 2008). In the Pacific, Cerchio (1998) reported that the percentage of recaptured whales in Kauai Island (Hawai'i) ranged from 5–14%, with a mean re-sighting interval of 15 days. Thus, within-year recapture intervals demonstrate relatively high residency of humpback whale in Réunion. These variations might be explained by differences in the size and remoteness of the survey area and survey effort, together with differences in the size and composition of the population. In fact, the probability of recapturing a whale

decreases with increasing survey area and population size. Réunion Island is isolated and relatively small (207km of coastline) with steep underwater slope, restricting humpback whale habitat within 2km from the coast, excepted off Saint Gilles where 100m contour lies 7km from the coast (Dulau-Drouot *et al.*, 2008). Overall, the habitat used by humpback whales around Réunion corresponds to an area of 345km², while Antongil Bay (Madagascar) for example encompasses 1,800km² (Cerchio *et al.*, 2008) with adjacent potential habitat. Furthermore differences in survey effort are observed between studies. In Antongil Bay, Cerchio *et al.* (2008) reported a mean sampling effort of 31 days per season spanning from mid-July to mid-September, while in this study, an effort of 91 to 141 survey trips was achieved from early June to late October in 2008–10. Thus, larger sampling effort, spanning a larger period, might explain the larger recapture intervals obtained in Réunion compared to Madagascar. Réunion being located at a higher latitude compared to Antongil Bay, the breeding season might span a longer period (allowing extended survey effort), as whales might afford to stay longer in southern sites before heading back to Antarctic feeding grounds. Despite an increased effort deployed in 2009 and 2010, relatively consistent recapture intervals were found in 2008–10 in Réunion, suggesting that they are representative estimates of time residency in the survey area. This was confirmed by the lagged identification rate analysis, leading to similar expected residency (25 days).

The results demonstrate a significantly higher residency time for mothers accompanied by a calf compared to other individuals. Furthermore, a seasonal trend was observed in recapture rates, whereby individuals captured in July tended to be sighted only once while the proportion of recaptured individuals increases from August to October. These results suggest that the earlier part of the season encompass mostly individuals with transient residency, while the later part of the season hosts individuals using Réunion coastal waters for a longer period. Therefore, the island seems to represent an 'endpoint destination' for at least some of the whales migrating to Réunion, which remain in coastal waters for a relatively long period (maximum of two months). This seems to be particularly the case for mothers with calves, showing a recapture interval of 36 days on average and expected mean residency (from LIR) of 53 days. Other individuals, including escorts, have also been observed for extended lengths of time (maximum recapture interval of 28 days on average). A seasonal pattern in group structure was also demonstrated, with sightings made early in the season consisting mostly of singletons and pairs of individuals, competitive groups being most frequently observed in August, and mother-calf pairs mainly occurring later in the season, in September and October. This seasonal trend is consistent with the migratory timing described for the species. Both historical catch data and photo-identification studies have demonstrated that humpback whale migration to and from the winter grounds were segregated on the basis of age, sex and reproductive condition (Dawbin, 1997; Graig *et al.*, 2003). Females in late pregnancy or with newborn calves are among the last whales to arrive at the wintering grounds and the last to migrate back to the feeding ground. The year they give birth, females might tend to extend their

stay in the feeding ground to maximise their food intake prior to parturition and lactation and to delay their departure from the breeding ground until their calf is sufficiently robust to enhance their chance of survival during their first migration to higher latitude (Graig *et al.*, 2003).

Analysis of spatial movement showed that whales resighted on multiple days moved around the island at a rate of 3.3km per day on average. Although the eastern and northern coasts were not or poorly surveyed, opportunistic sightings from land were consistently reported from these areas (Globice, pers. comm.), supporting the view that whales are using the coastal waters of the entire island. In contrast, the majority of captured whales (69% on average for 2008–10) were observed only once. These individuals showing transient residency were mostly encountered early in the season, suggesting a trend for individuals arriving early in the season to stopover in Réunion, before moving to other breeding area such as Mauritius, the Seychelles archipelago or the Tromelin islands. Land based surveys conducted in Tromelin, indicate that this small island of 1km² located 535km North of Réunion also hosts humpback whales during the austral winter, with competitive groups and new born calves being observed there (Globice, unpublished data). Interestingly, no peak of newly identified individuals was observed at the end of the season (the discovery curve flattens out in September–October), suggesting that no (or very few) whales from lower latitude breeding grounds are transiting to Réunion on their southward migration. To date, no inter-regional recaptures of individuals from Réunion have been reported with other sites of the south-western Indian Ocean on the same year, so migration routes are still largely unknown. Further inter-regional comparisons will be encouraged to improve knowledge and understanding of humpback whales migratory movements.

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Organ weights of three dolphin species (*Sousa chinensis*, *Tursiops aduncus* and *Delphinus capensis*) from South Africa: implications for ecological adaptation?

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ABSTRACT

Data from bycaught, but otherwise presumed healthy individuals can contribute important biological data on species of cetaceans that are otherwise lacking. This study utilises data collected from systematic necropsies performed between October 1970 and May 2010 on 142 Indo-Pacific humpback dolphins (*Sousa chinensis*), 607 Indo-Pacific bottlenose dolphins (*Tursiops aduncus*), and 640 long-beaked common dolphins (*Delphinus capensis*) incidentally caught and drowned in the shark nets off KwaZulu-Natal, South Africa. The aim of this analysis was to: (1) determine average absolute and relative organ weights for the three taxa as baseline values for later pathological examinations; and (2) examine potential correlations with the physiology and ecology in the three genera. Body length-weight relationships were described for the three species, indicating that *S. chinensis* is more robust than *T. aduncus*, with *D. capensis* being the smallest species out of the three taxa. Organ weights, as a percentage of total body weight were examined for the three delphinids. Organs examined included heart, lungs and trachea, liver, kidneys, spleen, and testes. Relative heart, liver and kidney weights were significantly larger in the small-bodied, fast-swimming *D. capensis*, than in the slower, more coastal *S. chinensis* and *T. aduncus*, possibly reflecting differences in activity patterns between the three species. Relative lung and trachea weights were not significantly different in the three species. Combined testes weight, as a percentage of total body weight, in combination with information on group size and sexual dimorphism suggested a monogamous or extreme polygynous (harem) mating system in *S. chinensis*, frequent copulations in *T. aduncus*, and sperm competition in *D. capensis*. The results of the present study suggest that the relative sizes of the major organs in the three genera are a reflection of the differing life histories and ecologies of the species examined.

KEYWORDS: INCIDENTAL CATCHES; AFRICA; INDO-PACIFIC HUMPBACK DOLPHIN; INDO-PACIFIC BOTTLENOSE DOLPHIN; LONG-BEAKED COMMON DOLPHIN

INTRODUCTION

Allometric relationships between organ weights and body weights have been the topic of numerous studies of mammalian taxa (Calder, 1983; Davis, 1962; Jürgens *et al.*, 1981; Lindstedt and Calder, 1981; Piscitelli *et al.*, 2010; Stahl, 1965; 1967; Western, 1979). Data from the Order Cetacea, however, are generally lacking. Information on organ weights in wild cetaceans is valuable for a number of reasons: to further the understanding of the physiology and overall biology of these animals, to provide comparative data with other species (both marine and terrestrial), and to establish baseline data that may be used to evaluate pathological change. Allometry is an important tool in comparative anatomy and physiology; the weight of an organ must, however, be examined in relation to the absolute size of the body to determine whether its weight is above or below the average value normally observed (Prothero, 1982; Slijper, 1958).

A number of previous studies have examined organ weights in odontocetes (for example Cowan, 1966; Cowan and Tajima, 2006; Gahr and Pilleri, 1969; Innes *et al.*, 1986; Kastelein and van Battum, 1990; McLellan *et al.*, 2002; Miyazaki *et al.*, 1981; Perrin and Roberts, 1972; Pilleri and Gahr, 1969; Piscitelli *et al.*, 2010; Turner *et al.*, 2006) and pinnipeds (Bryden and Erickson, 1976; Oftedal *et al.*, 1989;

Stewardson *et al.*, 1999). However, studies that examine organ weights in relation to body weights in an ecological context are rare for cetaceans (McLellan *et al.*, 2002; Miyazaki *et al.*, 1981; Perrin and Roberts, 1972; Ridgway and Kohin, 1995). There is therefore a lack of consideration as to the physiological and ecological pressures that may have shaped the observed patterns. This may in part be due to the logistical constraints in obtaining total body weight measurements from cetaceans. Body length measurements are taken as part of standard necropsy protocols of cetaceans (Norris, 1961), but body length is not always sufficient to accurately calculate body weight in these animals (Kastelein and van Battum, 1990). Although Slijper (1958) remarked that organ weights for a number of large baleen whale species were available as a byproduct of the economic importance of these animals at that time, enormous logistical challenges and time constraints are involved in weighing baleen whale carcasses, either whole or piecemeal (Lockyer, 1976; Lockyer and Waters, 1986; Omura, 1950). Thus due to logistical reasons, body weight measurements often pose a problem, even in smaller odontocetes (Cowan, 1966).

Baseline data on the normal variability in organ size in relation to body weight as well as histology are necessary to better interpret pathological changes in these genera (Cowan and Tajima, 2006; Turner *et al.*, 2006). Such data from

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stranded animals are sometimes compromised because the animals can be desiccated or emaciated, and as a result may not yield a normal organ weight/body weight ratio (Cowan and Tajima, 2006). As the animals used in the present study were incidentally caught in shark nets off the South African coastline and subsequently died, it was assumed that they were in a normal condition and therefore may be considered representative of a wild population.

Indicators such as testes weight to body weight ratio, sexual dimorphism and group size have been used to provide information on the mating systems of terrestrial mammals (Harcourt *et al.*, 1981; Kenagy and Trombulak, 1986; Rose *et al.*, 1997). This approach has been applied in cetaceans as a basis to formulate hypotheses about the mating system of a species (e.g. Aguilar and Monzon, 1992; Brownell and Ralls, 1986; Cockcroft, 1993; Slooten, 1991; Van Waerebeek and Read, 1994). In odontocetes, small testes in relation to body weight, together with a large degree of sexual dimorphism and small group sizes, are thought to be indicative of a monogamous or extreme polygynous mating system, such as a harem or roving male strategy. Conversely, large relative testis weights, the absence of sexual dimorphism, and large group sizes are attributed to frequent copulations and sperm competition (Cockcroft, 1993; Connor *et al.*, 2000; Plön and Bernard, 2007; Van Waerebeek and Read, 1994).

Shark net installations along the KwaZulu-Natal coastline of South Africa have been in place since 1952 and today cover 23km in total along a 320km stretch of coast (Fig. 1) (Cliff and Dudley, 1992; Cliff, pers. comn). The nets are checked and maintained about 20 times per month by the KwaZulu-Natal Sharks Board (KZNSB). As part of a long-term agreement, data and samples from dolphins incidentally caught in these nets are being accessioned to the Graham Ross Marine Mammal collection at the Port Elizabeth Museum (PEM) in the Eastern Cape province of South Africa. These data and samples provide invaluable information on the natural history and ecology of the individual species caught, as well as information on diseases and any potential adverse effects of environmental conditions on the dolphins. The three main species incidentally caught in the nets are the long-beaked common dolphin *Delphinus capensis*, the Indo-Pacific bottlenose dolphin *Tursiops aduncus*, and, to a lesser extent, the Indo-Pacific humpback dolphin, *Sousa chinensis* (Best, 2007).

As the data from the present study are examined in view of the different mating styles shown by the three dolphin species considered, a brief overview is given here on different ecological aspects of the individual species, such as body size, group size and distribution.

S. chinensis is thought to exhibit sexual dimorphism – males are larger, with a maximum length of up to 279cm, compared to females, which have been recorded of reaching up to 249cm (Best, 2007; Ross and Best, 1989). The average group size is less than 10 animals for the species off South Africa (Karczmarski *et al.*, 1999; Ross, 1984; Ross *et al.*, 1994). These dolphins are coastal and are usually not observed in water depths over 25m or more than 400m offshore (Karczmarski *et al.*, 2000) and are found most often in the surf zone (less than 15m deep) (Friedmann and Daly, 2004; Ross *et al.*, 1994).

Despite bottlenose dolphins being cosmopolitan and widely studied, their taxonomy is unresolved (Fury and Harrison, 2008; Hale *et al.*, 2000; Rice, 1998). *T. aduncus* was first described from South Africa (Ross, 1977), and later confirmed genetically (Natoli *et al.*, 2004). It occupies inshore areas along the coastline compared to *T. truncatus*, which is found further offshore (Rice, 1998; Ross, 1977; 1984). Although it is not always possible retrospectively to discern which form/species some of the past records apply to, it has been assumed that all coastal records belong to the *aduncus* form (Best, 2007). Average adult lengths are 243cm in males and 238cm in females, and the form is smaller than *T. truncatus* (Best, 2007; Ross, 1984). Group sizes for this species range from 40 to 100 animals (Cockcroft *et al.*, 1992; Saayman *et al.*, 1973). *T. aduncus* mostly occupies the coastal regions in waters less than 50m deep, and is found all along the South African coastline between False Bay and Mozambique (Best, 2007) in a wide range of habitats, including lagoons and estuaries (Findlay *et al.*, 1992).

Although both *D. delphis* and *D. capensis* have been reported from the South African subregion (Best, 2007), prior genetic (Natoli *et al.*, 2006) and morphometric (Samaai *et al.*, 2005) analyses of specimens caught in the shark nets off KwaZulu-Natal have identified the specimens as *D. capensis* and thus all animals included in the present sample are assumed to belong to that species. *D. capensis* off South Africa show a maximum adult body length of 254cm in males and 222cm in females (Heyning and Perrin, 1994; Ross, 1984; Ross and Best, 1989). This species is found in groups of 100s to 1,000s of individuals, with an average group size of 302, but appear to have social units of around 30 animals (Cockcroft and Peddemors, 1990; Evans, 1994). Along the South African coastline *D. capensis* occupies waters of less than 500m in depth (Findlay *et al.*, 1992; Rice, 1998). Annual migrations in winter along the east coast are common, following the annual ‘Sardine Run’, which begins in the Eastern Cape and travels up to the north coast of KwaZulu-Natal (Findlay *et al.* 1992). However, sightings of *D. capensis* in KwaZulu-Natal waters have been made in both summer and winter (Findlay *et al.*, 1992).

The aim of the present study was to: (1) provide baseline data on absolute and relative organ weights of three dolphin species incidentally caught in the shark nets along the KwaZulu-Natal coastline of southern Africa; and to (2) explore potential correlations between the relative weight the individual organs contribute to the total body weight and the ecology of the three species examined.

MATERIALS AND METHODS

Sample

For the present study, data for 142 *S. chinensis*, 607 *T. aduncus*, and 640 *D. capensis* were analysed. All data were available from the Graham Ross Marine Mammal Collection at the Port Elizabeth Museum, Port Elizabeth, South Africa, and originate from animals incidentally caught and drowned in the shark nets off KwaZulu-Natal (Fig. 1). No stranded specimens were included in the analyses. All data from carcasses that were noted as either rotten, shark bitten, or pregnant were removed from the dataset. The data analysed included total body weight and length as well as weights for the heart, lung and trachea, liver, kidneys, spleen and testes.

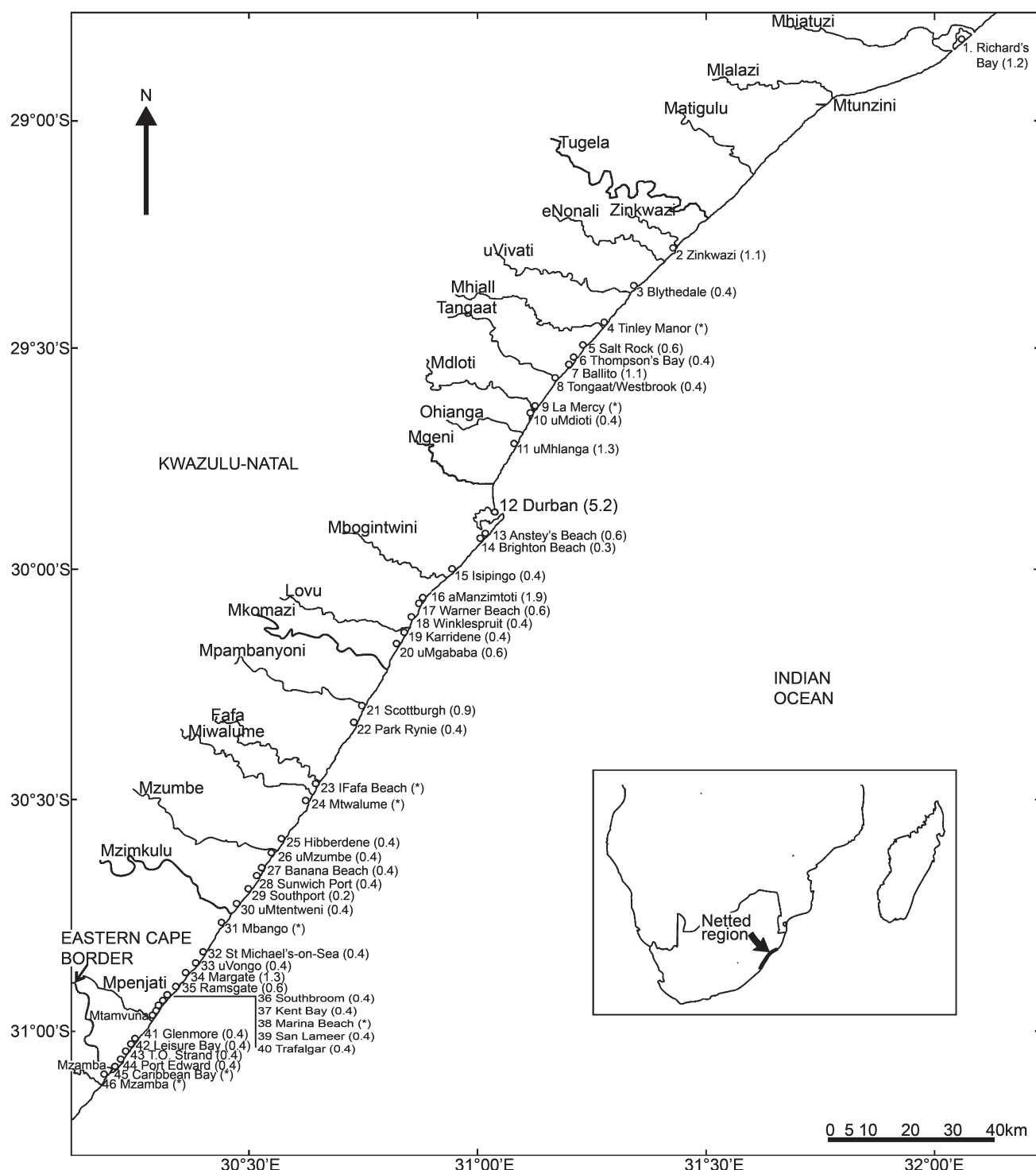


Fig. 1. Shark net installations along the KwaZulu-Natal coastline. Numbers in parentheses show the length of netting in km as of November 2006. Source: KZNSB.

As datasets may not have been complete for each individual, sample sizes vary for the individual organ weights as stated in the text. The time period over which these data were collected for the individual species was as follows: *S. chinensis*: 28 November 1979–29 April 2010, *T. aduncus*: October 1970–11 May 2010, and *D. capensis*: 14 Aug 1974–16 Nov 2009.

Standard body length and weight measurements of the dolphin carcasses were determined as the carcasses arrived at KZNSB. Body length measurements were carried out following the guidelines of Norris (1961). Thereafter the

carcasses were frozen until further analyses were conducted. The carcasses were defrosted prior to systematic necropsies. The heart, lung and trachea were removed together from the thoracic cavity and the heart was separated out by severing the dorsal aorta and all major blood vessels at the entrance to the heart. It was then drained of blood and blood clots were washed out prior to weighing. The lung and trachea (including the larynx) were weighed together, and, in some instances, the lungs were dissected free at the level of the principal bronchus and weighed individually. Organs up to 3kg were weighed to the nearest gram on a digital balance (Nagata). Organs over

3kg were weighed using a hand-suspended Salter balance. The reproductive status of the animals was noted upon necropsy based on macroscopic examinations of the reproductive organs (i.e. presence/absence of sperm in the epididymis, presence of corpora on the ovaries). The epididymides were removed from the testes before a combined testis weight was obtained for each individual.

Total body length-weight relationships were established for all three dolphin species and described by allometric equations of the form $y = ax^b$, where a = y-intercept, b = slope, x = total body weight (kg), and y = total organ weight (g). Relative organ weights were calculated for each individual and expressed as a percentage of body weight. To compare the relative organ weights between the three genera, the percentage data were arc-sine transformed (Zar, 1999) before an ANOVA and *post-hoc* Tukey test were carried out. To examine potential differences between males and females for each of the three species, individual organ weights and body weights were log-transformed and allometric equations generated for either sex for each of the three species. Slopes and y-intercepts were compared using an ANCOVA multiple regression analysis with a predetermined alpha (α) set at 0.05. All statistical analyses were conducted using *STATISTICA* v. 9 (StatSoft Inc.).

To evaluate the contribution the testes made to the overall body weight, the combined testes weights of only mature males of the three dolphin species were analysed. While no previous data on maturity of male *S. chinensis* were available, an increase of combined testes weight was observed at about 223cm body length and 200g combined testes weight in the sample. Thus subsequently only data for animals over 223cm in body length and/or over 200g combined testes weight were used to determine combined testes weight as a percentage of total body weight ($n = 23$).

For *T. aduncus* only males over 225cm in body length and/or over 300g combined testes weight were analysed ($n = 90$) (following Cockcroft and Ross, 1990a), and for *D. capensis* only males over 220cm body length and/or over 200g combined testes weight were analysed ($n = 172$) (following Mendolia, 1989).

RESULTS

Body length-weight relationships

Individual plots of body weight versus length for males, females and sexes combined for all three species are shown in Figs 2, 3 and 4, respectively. Allometric equations for these relationships are provided in Table 1.

Out of 92 male and 50 female *S. chinensis* examined, the shortest animals measured 145cm and 150cm and weighed 43kg and 46kg, respectively. The longest specimens of *S. chinensis* in the present study were a 276cm long male, weighing 280kg and a 251cm long female, weighing 188kg (Fig. 2).

Of 299 male and 308 female *T. aduncus* examined, the shortest animals were a 100cm long male, weighing 9.75kg and a 120cm long female, weighing 19kg (Fig. 3). The heaviest male specimen was 246cm long and weighed 248kg, although the longest male measured 262cm, but only weighed 226kg (Fig. 3). The longest female *T. aduncus* measured 256cm and weighed 190kg (Fig. 3).

For *D. capensis* length and weight data for 328 males and 312 females were available. The shortest male measured 114cm and weighed 18kg, while the shortest female was 107cm long, weighing 21kg (Fig. 4). The longest male was 265cm long and weighed 192kg (Fig. 4). A 252cm long female, weighing 80kg may be considered unrepresentative for animals from this population; thus the longest female measured 240cm and weighed 148kg (Fig. 4).

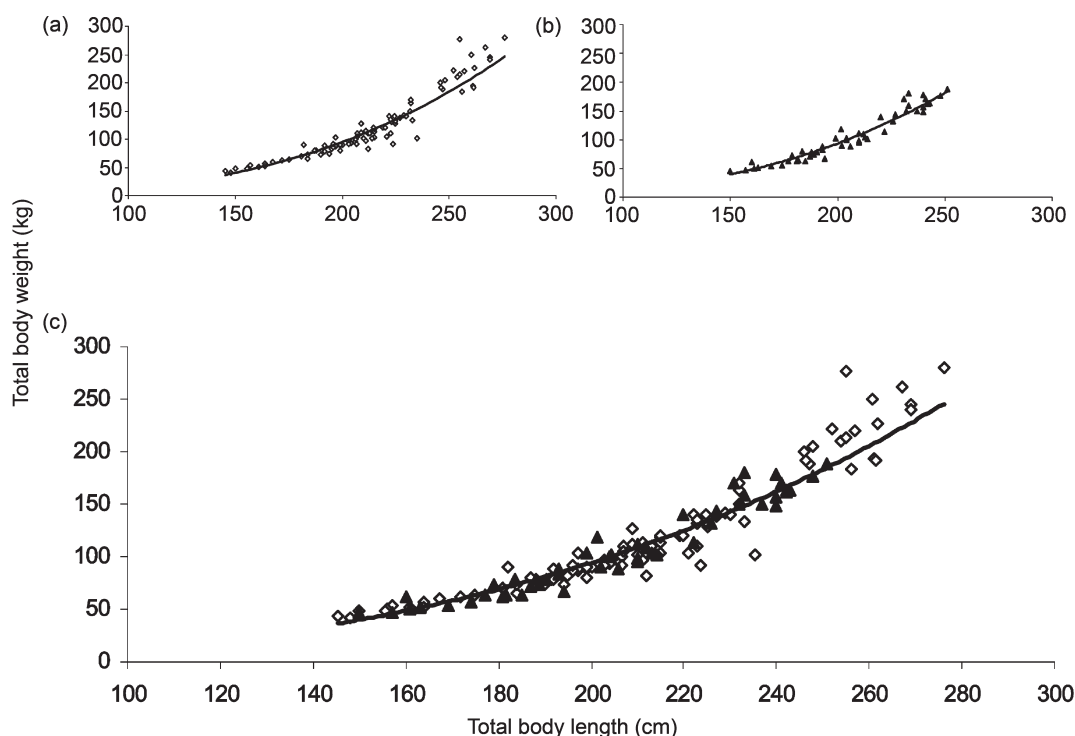


Fig. 2. Body length-weight relationships for (a) male *S. chinensis*, (b) female *S. chinensis*, and (c) both sexes of *S. chinensis* (diamond = males; triangle = females).

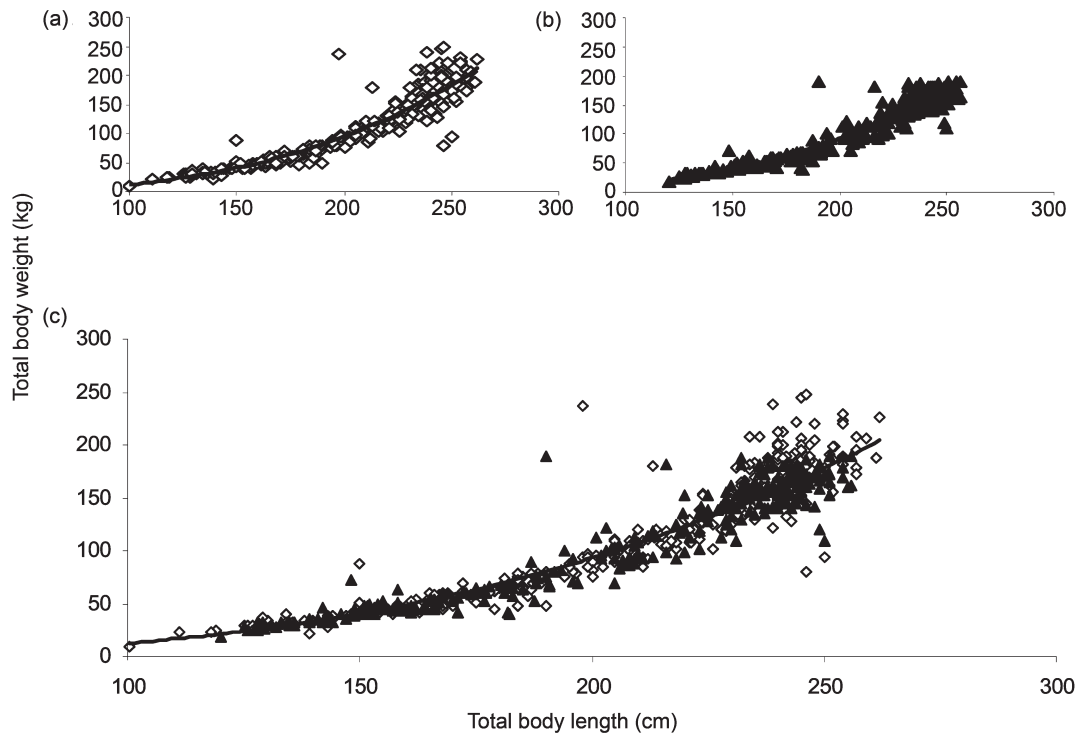


Fig. 3. Body length-weight relationship for (a) male *T. aduncus*, (b) female *T. aduncus*, and (c) both sexes of *T. aduncus* (diamond = males; triangle = females).

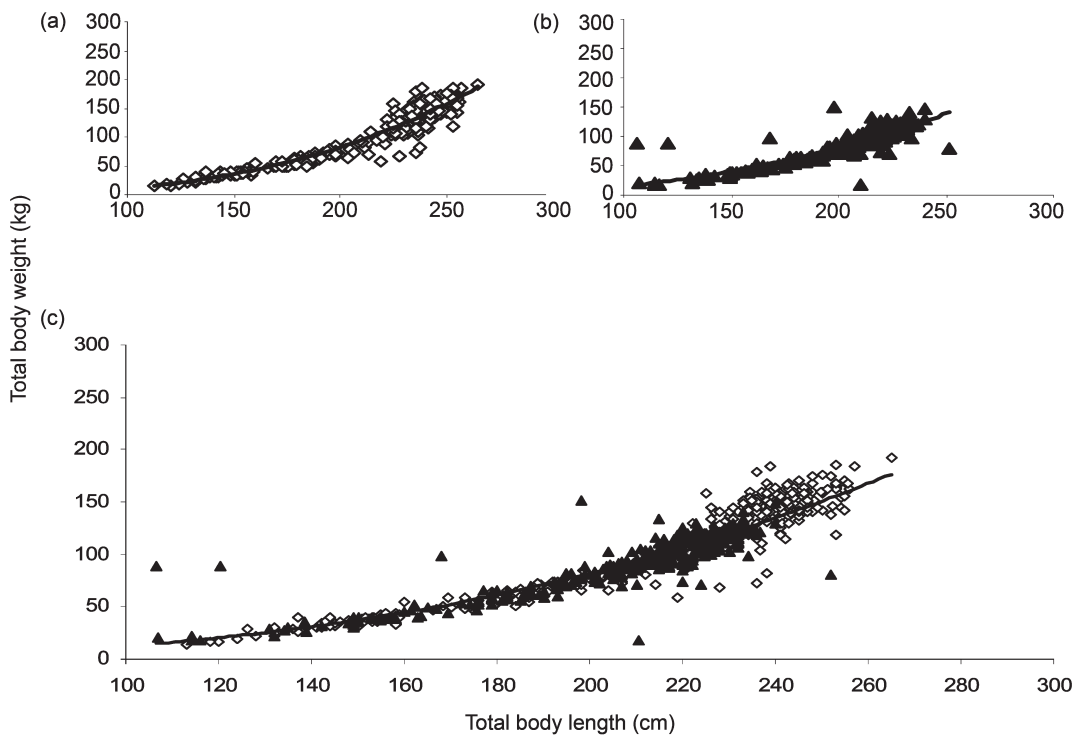


Fig. 4. Body length-weight relationship for (a) male *D. capensis*, (b) female *D. capensis*, and (c) both sexes of *D. capensis* (diamond = males; triangle = females).

These length-weight relationships indicate the differences in body size between the three species (Figs 2, 3 and 4), with the largest *S. chinensis* male being substantially larger (14cm longer and 32kg heavier) than the largest *T. aduncus* male. In females of the two species, however, there was little difference in body size, the largest *S. chinensis* female being 5cm shorter than the largest *T. aduncus* female and weighing 2kg less. Similarly, the difference in body length between

the longest male *T. aduncus* and the longest *D. capensis* male was negligible (262cm vs. 265cm, respectively), but the heaviest *T. aduncus* male was 56kg heavier than the heaviest *D. capensis* male. In females this difference between the species was 16cm and 42kg. The observed difference between *T. aduncus* and *D. capensis* was substantially larger than between *S. chinensis* and *T. aduncus*, indicating that *D. capensis* is considerably smaller than the other two species,

Table 1

Allometric equations for length-weight relationships for all three species of delphinids.

Species	Sex	N	Equation	R ²
<i>Sousa chinensis</i>	M	92	$y = 0.00001x^{2.9692}$	0.9335
	F	50	$y = 0.00001x^{2.9765}$	0.9434
	M & F	142	$y = 0.00001x^{2.9762}$	0.9372
<i>Tursiops aduncus</i>	M	299	$y = 0.00001x^{2.9605}$	0.932
	F	308	$y = 0.00003x^{2.8429}$	0.9468
	M & F	607	$y = 0.00002x^{2.9011}$	0.9379
<i>Delphinus capensis</i>	M	328	$y = 0.00002x^{2.9229}$	0.9538
	F	312	$y = 0.00002x^{2.4169}$	0.7918
	M & F	640	$y = 0.00004x^{2.7408}$	0.8938

with *S. chinensis* being the most robust out of the three species.

Organ weights as a percentage of body weight

The trend in absolute organ weights between the three species of dolphins was such that the largest absolute weights were usually present in *T. aduncus*, followed by *D. capensis*, with *S. chinensis* having the smallest absolute organ weights (Table 2). One exception were the absolute liver weights, which were slightly higher in *D. capensis* than *T. aduncus* (Table 2).

This general trend was reversed in the spleen, which was largest in *S. chinensis* (mean = 94.04g ± 38.52), followed by *D. capensis* (mean = 80.39g ± 55.95), with *T. aduncus* having the smallest spleen in terms of absolute size out of the three species (mean = 66.68g ± 33.28) (Table 2).

If, however, the organ weights are considered relative to body weight of the three delphinid species, a different pattern emerges. The relative heart weights showed the reverse trend observed in absolute body size between the three species as the heart was larger in relation to the overall body weight in *D. capensis* (mean = 0.62% ± 0.11), than it was in *T. aduncus* (mean = 0.6% ± 0.14) or *S. chinensis* (mean = 0.52% ± 0.08). This trend was supported by results from an ANOVA and *post-hoc* Tukey test, which showed that the relative heart weights of *S. chinensis*, *T. aduncus* and *D. capensis* were significantly different from each other (*F*-value = 70830.01, *p* < 0.001).

The same trend of largest relative organ weights in the smallest species was true for the relative weights of liver and kidneys: both made up the larger percentage of body weight in *D. capensis* (mean = 2.47% ± 0.58 and 0.85% ± 0.19, respectively) than in *T. aduncus* (mean = 2.03% ± 0.47 and 0.8% ± 0.19, respectively) and *S. chinensis* (mean = 1.93% ± 0.39 and 0.67% ± 0.12, respectively). This result was supported by the ANOVA analysis and Tukey test, which showed that the relative liver weights of *D. capensis* were significantly larger than those of *T. aduncus* and *S. chinensis* (*F*-value = 32427.98, *p* < 0.001); no significant difference in organ weights was found between the latter two species. Kidney weights proved to be significantly different for all three species, with *D. capensis* having the largest kidneys and *S. chinensis* the smallest ones (*F*-value = 42225.54, *p* < 0.05).

Relative weights for the lungs and trachea combined were larger in *T. aduncus* (mean = 4.33% ± 0.88) than they were

Table 2

Absolute and relative organ weights from three dolphin species incidentally caught in the shark nets off the KwaZulu-Natal coast of South Africa.

Species:	<i>Sousa chinensis</i>	<i>n</i>	<i>Tursiops aduncus</i>	<i>n</i>	<i>Delphinus capensis</i>	<i>n</i>
Heart						
Minimum weight (g)/(%)	240/0.36	131	118/0.23	350	84/0.09	308
Maximum weight (g)/(%)	1,250/0.88		1,550/1.91		1,367/1.11	
Mean weight (g) (±SD)/	591.11 (±219.91)/		637.83 (±311.98)/		635.45 (±256.91)/	
Mean % of body weight (±SD)	0.52 (±0.08)		0.6 (±0.14)		0.62 (±0.11)	
Lungs and trachea						
Minimum weight (g)/(%)	1,550/2.39	131	962/1.43	333	720/1.33	296
Maximum weight (g)/(%)	8,675/6.11		11,050/9.05		8,430/7.27	
Mean weight (g) (±SD)/	4,420.59 (±1808.52)/		4,789.92 (±2,514.66)/		4,227.27 (±1,809.32)/	
Mean % of body weight (±SD)	3.88 (±0.57)		4.33 (±0.88)		4.1 (±0.81)	
Lungs						
Minimum weight (g)/(%)	1,900/2.97	9	1,350/0.78	24	3,050/2.61	7
Maximum weight (g)/(%)	4,700/3.96		8,300/6.14		5,161/4.29	
Mean weight (g) (±SD)/	3,396.11 (±1047.86)/		3,276.49 (±2,037.36)/		4,243 (±745.1)/	
Mean % of body weight (±SD)	3.25 (±0.33)		3.8 (±0.98)		3.7 (±0.62)	
Liver						
Minimum weight (g)/(%)	718/0.77	92	109.9/0.16	323	53/0.19	307
Maximum weight (g)/(%)	6,100/3.2		5,500/3.87		6,512/4.52	
Mean weight (g) (±SD)/	2,290.23 (±1049.47)/		2,356.31 (±1,357.69)/		2,605.25 (±1,224.24)/	
Mean % of body weight (±SD)	1.93 (±0.39)		2.03 (±0.47)		2.47 (±0.58)	
Kidneys						
Minimum weight (g)/(%)	263/0.45	92	160/0.32	312	115/0.34	289
Maximum weight (g)/(%)	2,080/0.96		2,970/2.09		3,250/2.32	
Mean weight (g) (±SD)/	790.64 (±363.93)/		918.97 (±530.96)/		910.3 (±425.23)/	
Mean % of body weight (±SD)	0.67 (±0.12)		0.8 (±0.19)		0.85 (±0.19)	
Spleen						
Minimum weight (g)/(%)	43/0.02	61	11/0.01	181	8/0.01	192
Maximum weight (g)/(%)	211/0.2		192.4/0.2		460/0.33	
Mean weight (g) (±SD)/	94.04 (±38.52)/		66.68 (±33.28)/		80.39 (±55.95)/	
Mean % of body weight (±SD)	0.09 (±0.04)		0.07 (±0.04)		0.08 (±0.05)	

in either *D. capensis* (mean = $4.1\% \pm 0.81$) or *S. chinensis* (mean = $3.88\% \pm 0.57$). If just lung weights were considered, the same trend was observed (*T. aduncus*: mean = 3.8 ± 0.98 ; *D. capensis*: mean = $3.7\% \pm 0.62$; *S. chinensis*: mean = $3.25\% \pm 0.33$). However, sample sizes for lung weights were very small and may therefore not be representative for the species. The ANOVA results using combined lung and trachea weights showed no significant differences between the three species (F -value = 26364.09, $p > 0.05$).

Examining the relative spleen weights between the three species the trend seemed reversed, with *S. chinensis* showing the largest relative weights (mean = $0.09\% \pm 0.04$), followed by *D. capensis* (mean = $0.08\% \pm 0.05$) and *T. aduncus* having the smallest spleen (mean = $0.07\% \pm 0.04$). The ANOVA results confirmed that (F -value = 5077.023, $p < 0.001$).

A summary of the allometric relationships of the various organs with body size in all three delphinids is supplied in Table 3. All organs showed a strong correlation with body size, with the exception of the spleen in all three species (Table 3).

The ANCOVA analysis indicated no significant differences between males and females of *S. chinensis* for the lungs and trachea, liver, kidney and spleen ($p > 0.05$ in all cases), but showed that males had significantly larger hearts than females ($p < 0.05$) (Fig. 5). No significant differences between males and females were found in *T. aduncus* ($p > 0.05$) or *D. capensis* ($p > 0.05$) in all cases (Figs 6 and 7).

Table 3

Allometric equations for organ-weights versus body weight relationships for all three species of delphinids.

Organ	Sex	n	Equation	R ²
<i>Sousa chinensis</i>				
Heart	M	86	$y = 1.8367x^{0.5686}$	0.9002
	F	46	$y = 0.4492x^{1.4913}$	0.9368
Lungs and trachea	M	83	$y = 2.5751x^{0.4779}$	0.883
	F	46	$y = 2.467x^{0.5456}$	0.9338
Liver	M	64	$y = 2.1638x^{0.5981}$	0.8127
	F	28	$y = 2.1432x^{0.6171}$	0.7476
Kidneys	M	62	$y = 1.7207x^{0.7065}$	0.8411
	F	30	$y = 1.6918x^{0.7467}$	0.9088
Spleen	M	42	$y = 1.5096x^{0.3705}$	0.1325
	F	21	$y = 1.6881x^{0.1362}$	0.0278
<i>Tursiops aduncus</i>				
Heart	M	170	$y = 1.8426x^{0.5864}$	0.866
	F	180	$y = 1.7845x^{0.6356}$	0.9102
Lungs and trachea	M	158	$y = 2.5975x^{0.483}$	0.9106
	F	165	$y = 2.5444x^{0.5183}$	0.8978
Liver	M	164	$y = 2.1345x^{0.6202}$	0.7691
	F	159	$y = 2.0885x^{0.6626}$	0.7394
Kidneys	M	151	$y = 1.8233x^{0.661}$	0.8865
	F	161	$y = 1.7612x^{0.7226}$	0.9058
Spleen	M	80	$y = 1.1405x^{0.666}$	0.4399
	F	101	$y = 1.2889x^{0.4458}$	0.2646
<i>Delphinus capensis</i>				
Heart	M	165	$y = 1.7813x^{0.6476}$	0.9148
	F	143	$y = 1.8187x^{0.6136}$	0.7475
Lungs and trachea	M	158	$y = 2.5163x^{0.5165}$	0.9047
	F	136	$y = 2.5367x^{0.5105}$	0.7787
Liver	M	167	$y = 2.1752x^{0.6322}$	0.9134
	F	140	$y = 1.9798x^{0.7858}$	0.7267
Kidneys	M	155	$y = 1.7478x^{0.7303}$	0.9093
	F	134	$y = 1.7045x^{0.7918}$	0.8654
Spleen	M	106	$y = 1.2789x^{0.538}$	0.1789
	F	87	$y = 1.2652x^{0.4842}$	0.1185

Testis weight as a percentage of body weight

The smallest combined testis weight in relation to total body weight was observed in *S. chinensis*, where it constituted on average 0.43% of the total body weight (Table 4). The testes were somewhat larger in *T. aduncus*, where the combined testes weight made up on average 0.64% of the total body weight in mature males. The largest combined testis weight was seen in *D. capensis*, where it constituted on average 2.01% of the total body weight (Table 4). An ANOVA showed significant differences between the three species (F -value = 158.406, $p < 0.001$).

DISCUSSION

Relative organ weights as a reflection of a species' ecology

The data on body size, group size, and distribution range indicate that *S. chinensis* is a robust delphinid that occurs in small groups and has a coastal distribution with a relatively small range (Best, 2007; Karczmarski *et al.*, 2000). Data on travel speeds for the species in South Africa have been reported to be 4.8 km hr^{-1} (Saayman and Tayler, 1979); personal observations support the notion that the species cannot be considered a fast swimmer. In contrast, *T. aduncus* is moderately smaller in body size, occurs in larger groups and has wider distribution range than *S. chinensis*, with faster travel speeds, ranging from 2.8 km/hr^{-1} to 9.9 km hr^{-1} reported for South African waters (Best, 2007; Cockcroft *et al.*, 1990; Saayman *et al.*, 1972). *D. capensis* is the smallest of the three dolphins considered, but occurs in large schools and is a fast-swimming, oceanic species with a large distribution range (Best, 2007); swimming bursts of $20.5\text{--}32\text{ km hr}^{-1}$ have been reported for the species (Rohr *et al.*, 2002). The trend in absolute organ weights observed during this investigation with smaller species, such as *D. capensis* having larger organs than the largest species, *S. chinensis*, appears counter-intuitive. Calculation of the relative organ weights in relation to body weight indicated a different trend, which can be explained by the different physiologies and ecologies of the three genera.

The significantly larger relative heart, liver, and kidneys in *D. capensis*, compared to the other two species, may reflect the higher metabolism or 'work rate' in this active, fast-swimming, oceanic species. Heart weight in cetaceans has been the subject of some investigation. Ridgway and Kohin (1995) presented relative heart weights for three genera of small odontocetes and concluded that differences in heart weight are due to differences in physiological and ecological demands. The largest relative heart weights were found in the fast-swimming, offshore species (Dall's porpoise, *Phocoenoides dalli*). The heart weight was intermediate in the slower swimming species (Pacific white-sided dolphin *Lagenorhynchus obliquidens*), and smallest in the most inshore, slowest moving species (common bottlenose dolphin *T. truncatus*) (Ridgway and Kohin, 1995). A similar trend was observed during this study with the fast swimming, offshore, *D. capensis* having the largest heart in relation to body weight. Slijper (1958) reported heart weights for a number of cetacean species and suggested that activity and swimming speed may play a role in the relative size of the heart in relation to the body weight. Bryden (1972)

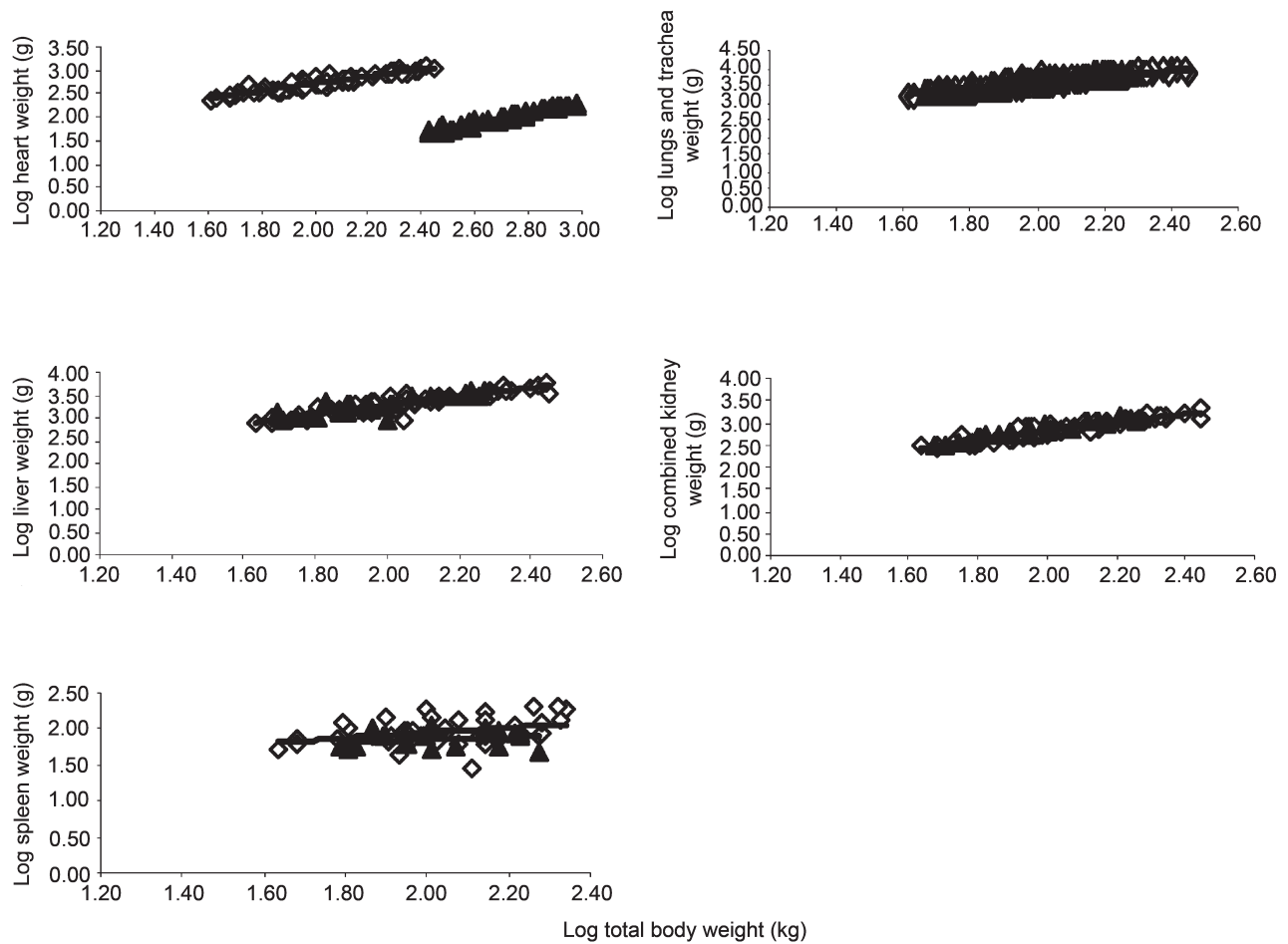


Fig. 5. Log respective organ weight (g) versus log total body weight (kg) for adult male (diamond) and female (triangle) *S. chinensis*.

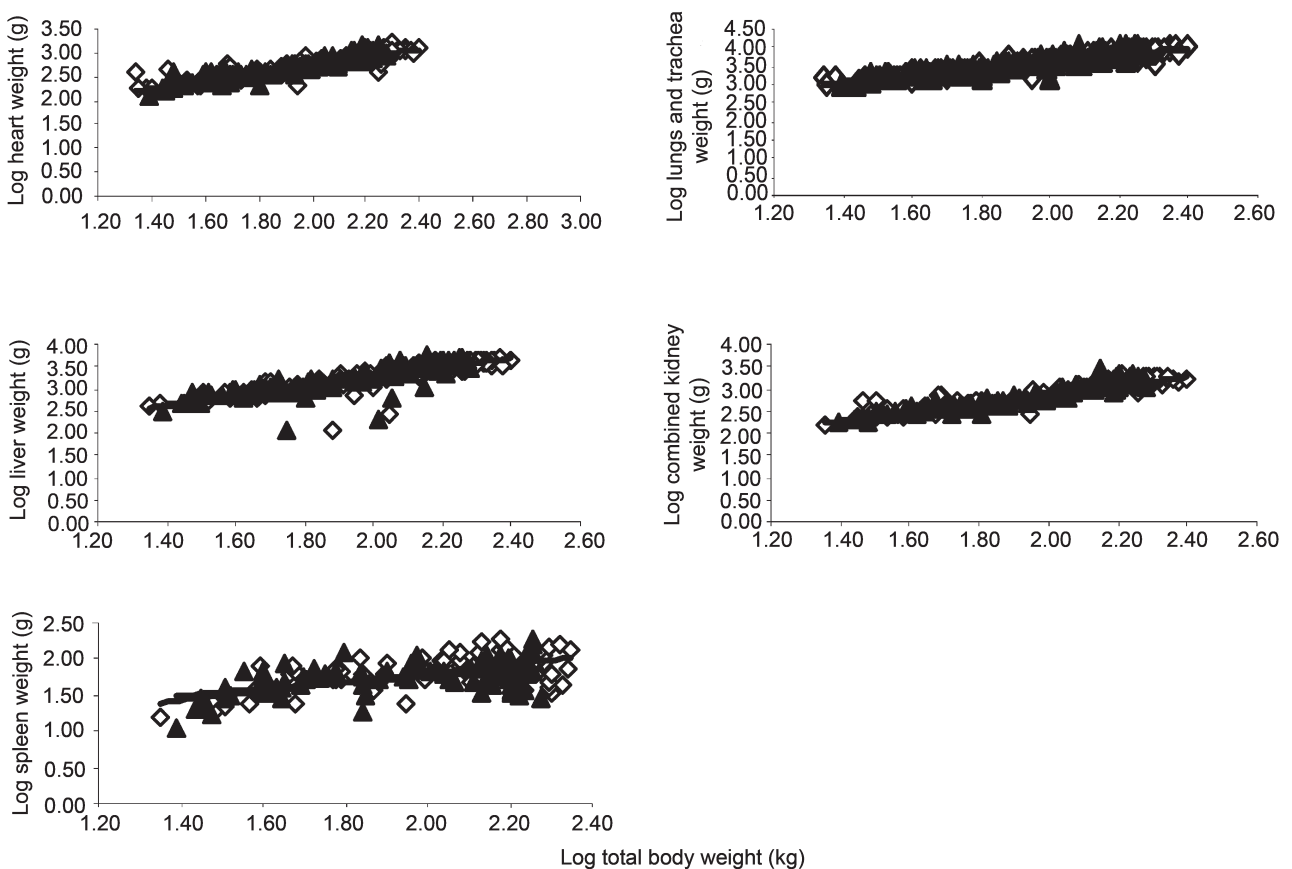


Fig. 6. Log respective organ weight (g) versus log total body weight (kg) for adult male (diamond) and female (triangle) *T. aduncus*.

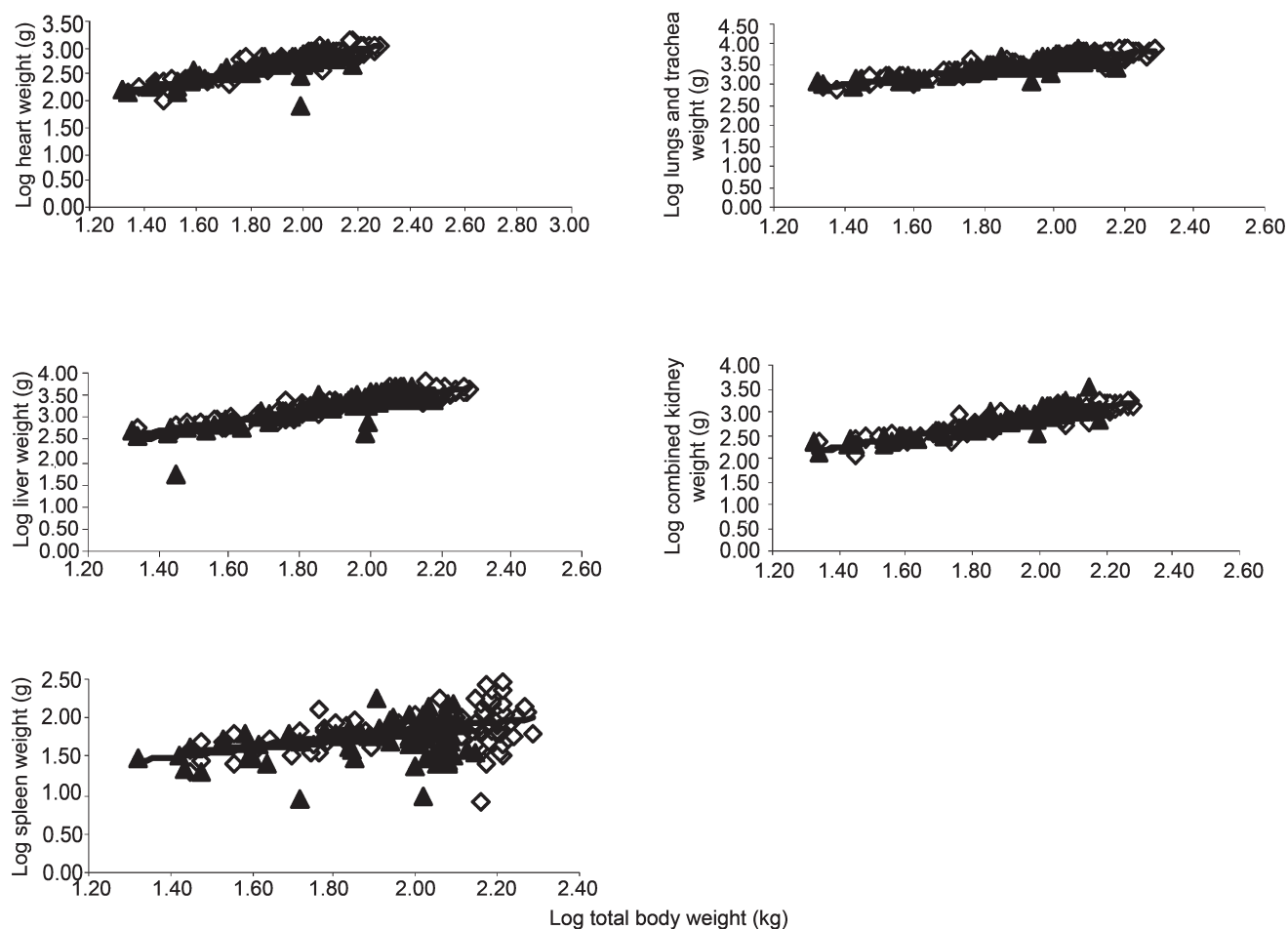


Fig. 7. Log respective organ weight (g) versus log total body weight (kg) for adult male (diamond) and female (triangle) *D. capensis*.

concluded that the relative heart size within different groups of mammals is probably as closely related to activity, speed and other physiological factors as it is to body weight (Bryden, 1972). Greater relative heart weights in pinnipeds have also been explained using increased activity, for example in Ross seals (*Ommatophoca rossi*) as compared to crabeater seals (*Lobodon carcinophagus*; Bryden and Erickson, 1976), and Cape fur seals (*Arctocephalus pusillus*) in comparison to Antarctic fur seals (*A. gazella*) (Stewardson *et al.*, 1999), with the two former species having to dive deeper and feeding on faster prey than the latter.

Relative liver weights previously reported for cetaceans reflect an inverse relationship between body size and relative liver weight, which was also apparent during the present study. Slijper (1958) reported an average weight of liver of 3.22% of body weight for the harbour porpoise *Phocoena phocoena*, 2.20% of body weight for a number of dolphin

species, and 1.20% of body weight for the sperm whale *Physeter macrocephalus*. Perrin and Roberts (1972) reported an average liver weight equivalent to 2.53% body weight for the spotted dolphin (*Stenella graffmani* = *attenuata*) and 1.90% of body weight for the spinner dolphin *S. longirostris*. Prothero (1982) examining liver weights over a large range of mammalian taxa, both aquatic and terrestrial, concluded that there were no differences in relative liver weights between aquatic and terrestrial mammals or between males and females, although he observed that the proportion of the liver tissue contributed to the overall body weight decreases with increasing body weight.

Slijper (1962) commented that the relative weight of the kidneys in small cetaceans in general is exceptionally large, reporting relative weights 0.84% of total body weight for several porpoises, 1.10% of body weight for *T. truncatus*, and 0.93% for *L. obliquidens*. *S. attenuata* show average relative kidney weights of 0.98% and *S. longirostris* of 0.65% (Perrin and Roberts, 1972). An inverse relationship between relative kidney weight to body weight as seen in three species examined in the present study has not been reported previously.

Although a trend in relative heart, liver and kidney weights was observed between the three species examined, surprisingly no significant difference was found in the relative lung and trachea weights. Previous studies on lung mass in cetaceans suggest that the lungs of delphinids and phocoenids are larger than those of similar sized terrestrial

Table 4

Combined testis weight as a percentage of total body weight for mature male animals.

Species	<i>Sousa chinensis</i>	<i>Tursiops aduncus</i>	<i>Delphinus capensis</i>
<i>n</i>	26	90	172
Minimum weight (%)	0.16	0.20	0.07
Maximum weight (%)	0.7	1.12	4.19
Mean % weight ($\pm$ SD)	0.43 ($\pm$ 0.12)	0.64 ($\pm$ 0.20)	2.01 ($\pm$ 0.88)

mammals (Bryden, 1972; Kooyman, 1973; Kooyman and Sinnett, 1979; Piscitelli *et al.*, 2010), while the relative lung mass of deeper diving odontocetes (kogiids, physeterids, and ziphiids) is similar to that of similar sized terrestrial mammals (Piscitelli *et al.*, 2010). Dive depths for the three species off South Africa examined here are non-existent, but available data on stomach content analyses indicate that *S. chinensis* feeds in shallow, inshore, often estuarine habitats (Barros and Cockcroft, 1991; 1999), while *T. aduncus* feeds mainly on coastal reef fishes (Cockcroft and Ross, 1990b) and *D. capensis* on epipelagic shoaling fish (Young and Cockcroft, 1994). As all three delphinids examined can be considered relatively shallow divers, which are 'fast' breathing (meaning high ventilation rate, short ventilation/dive times, and high lung volume exchanged per breath) (Kooyman, 1973; Piscitelli *et al.*, 2010), and thus no differences in lung weight would be expected between the three species. In comparison, the lungs of *S. attenuata* and *S. longirostris* are very similar in size, making up 3.2% of the body weight and 3.3%, respectively (Perrin and Roberts, 1972). In *P. phocoena* the lungs make up 3.5%, in *T. truncatus* 2.87% and 3.59% in *L. obliquidens* (Slijper, 1958).

The significantly smaller spleen found in *T. aduncus* in the present study, compared to that of *D. capensis* and *S. chinensis*, is intriguing, particularly in conjunction with the weak allometric relationship of this organ with body weight found for all three species examined. As the function of the spleen is the creation, storage and filtration of red blood cells as well as involvement in active immune response, no obvious explanation is to date at hand for this observation. Bryden (1972) remarked that the spleen in cetaceans is very small (0.02%) in comparison with that of most terrestrial mammals, where it constitutes around 0.3% of the body weight. Relative spleen weights reported for other odontocetes support this, with average values *S. attenuata* and *S. longirostris* being 0.06% and 0.04%, respectively (Perrin and Roberts, 1972). Interestingly, sexual dimorphism in spleen weights has also been reported for *S. longirostris*. For *P. phocoena* and *T. truncatus*, the spleen constitutes 0.02% and 0.09% of the total body weight (Slijper, 1958). Thus the relative weights of 0.09%, 0.07% and 0.08% of total body weight found for *S. chinensis*, *T. aduncus* and *D. capensis*, respectively, during this investigation are in accordance with relative spleen weights for small cetaceans published previously.

Testis weight and mating system

Cockcroft (1993) hypothesised previously that the combined testis size of these three delphinids in relation to group size and sexual dimorphism within the individual species may give indications as to the mating system. He reported an average relative testes weight of 0.7% for *S. chinensis*, 1% for *T. aduncus*, and 4.2% for *D. capensis* (Cockcroft, 1993). Although the trend of smallest values for average relative testis weight in *S. chinensis* (present study: 0.4%), followed by somewhat larger testes in *T. aduncus* (0.6% of total by weight), with the biggest testes found in *D. capensis* (2%) is also seen in the present study, the values are somewhat lower than those reported by Cockcroft (1993). However, interestingly the maximum values seen in the present study concur with the average values presented by Cockcroft

(1993). Plön and Bernard (2007), in reviewing available data for combined testis sizes in relation to proposed mating systems for cetaceans, concluded that relatively small testes in relation to body weight indicate a monogamous or extreme polygynous mating system. Conversely, relatively large testes are indicative of frequent copulations and sperm competition. In this sense the data from the present study indicate that the small relative testis weight in association with sexual dimorphism and small group sizes seen in *S. chinensis* is representative of a mating system in which a single male has access to a number of females. The somewhat larger testes, reduced sexual dimorphism, and larger group size in *T. aduncus* is indicative of more frequent copulations by males (Connor *et al.*, 2000; Plön and Bernard, 2007). The relatively large testes seen in *D. capensis*, with no sexual dimorphism and large group sizes prevalent in this species are representative of sperm competition (Cockcroft, 1993; Connor *et al.*, 2000; Plön and Bernard, 2007).

SUMMARY

In summary, the results of the present study suggest that the relative size of the major organs in the three genera examined here are a reflection of the differing life histories and ecologies of the species. Absolute organ weight has been shown to have little biological meaning and organ weights need to be considered in relation to body weight. While the above organ weights are in accordance with similar studies carried out previously on other cetacean genera, recent findings on *P. phocoena* suggest that on average 27% of the total body weight in adult animals is made up of blubber (McLellan *et al.*, 2002). The contribution of blubber to the total weight is even higher in juvenile animals (Lockyer, 1993; McLellan *et al.*, 2002; Miyazaki *et al.*, 1981). Unfortunately, contributions of blubber weight to the total body weight could not be taken into account during this study as these measurements were not available for the majority of the carcasses. Thus it is unclear whether this would skew the data in any way, particularly as the contribution of blubber weight to the total body weight appears to vary between species as well between seasons (Lockyer, 1993). However, future studies should aim to account for contributions of blubber weight to total body weight to elucidate these issues.

The baseline data on organ weights in the three genera established in the present study will form the basis of more detailed pathological and health examinations of the carcasses in the future and hopefully contribute to identification of what presents 'normal' organ weights in the three species. These will then be available for comparison with data from strandings or heavily diseased animals.

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A note on observations of cetaceans in the Indian Ocean Sanctuary, Australia to Israel, April 1995

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ABSTRACT

A forty-day voyage from Hobart (Australia) to Haifa (Israel) included a visual and acoustic census for cetaceans in the Indian Ocean Sanctuary. One hundred and sixty-three sightings were made, 156 occurring within the Sanctuary. Twelve species were identified. Sperm whales (*Physeter macrocephalus*) were encountered most frequently (51% of identified encounters), whilst spinner dolphins (*Stenella longirostris*) were numerically dominant. Other species identified included bottlenose dolphins (*Tursiops* spp.), short-beaked common dolphin (*Delphinus delphis*), pan-tropical spotted dolphin (*Stenella attenuata*), rough-toothed dolphin (*Steno bredanensis*), Risso's dolphin (*Grampus griseus*), killer whale (*Orcinus orca*), short-finned pilot whale (*Globicephala macrorhynchus*), false killer whale (*Pseudorca crassidens*), Bryde's whale (*Balaenoptera edeni*) and Cuvier's beaked whale (*Ziphius cavirostris*). The most sightings occurred WNW of the Seychelles, east of Somalia, and in the Gulf of Aden and Red Sea. Half of the sperm whale sightings were to the east of Ras Hafun (Somalia), and included adults, subadults and at least one calf. Thirteen hours were spent listening for cetaceans using a towed array whilst the ship was underway. Cetaceans were detected at 78% of the listening stations, with a possible four species recorded (sperm whale, spinner dolphin, pilot whale, bottlenose dolphin). The survey shows the value of platforms of opportunity for studying the pelagic communities of cetaceans in the Indian Ocean Sanctuary. It highlights the need for further research in the northwestern sector where anthropogenic threats are varied and increasing.

KEYWORDS: INDIAN OCEAN; SPERM WHALE; SPINNER DOLPHIN; PAN-TROPICAL SPOTTED DOLPHIN; BOTTLENOSE DOLPHIN; ROUGH-TOOTHED DOLPHIN; BRYDE'S WHALE; RISSO'S DOLPHIN; COMMON DOLPHIN; PILOT WHALE; KILLER WHALE; CUVIER'S BEAKED WHALE; FALSE KILLER WHALE; SURVEY-ACOUSTIC; SURVEY-VESSEL

INTRODUCTION

Cetacean studies within the IWC's Indian Ocean Sanctuary (IOS) have largely been carried out in coastal waters (including Australia, Sri Lanka, Oman, South Africa and India). Fewer studies have been undertaken offshore, although Mörzer-Bruyns (1971), Keller *et al.*, (1982), Kasuya and Wada (1991), Eyre (1995), Ballance and Pitman (1998), de Boer (2000a) and the Ocean Alliance Odyssey voyage (Ocean Alliance, 2009; Wise *et al.*, 2009) have contributed to our current knowledge of the pelagic cetacean fauna. Acoustic studies of cetaceans to supplement visual observations have been primarily used for sperm whales (Godard *et al.*, 2003; Gordon, 1987; Khan *et al.*, 1993; Whitehead and Gordon, 1986).

The non-government environmental organisation Greenpeace International makes regular oceanic transits with its vessels. Cetacean surveys in the IOS have been undertaken using these vessels in 1993 (Eyre, 1995), 1995 (Eyre, 1997), 1998/99 (De Boer *et al.*, 1999), 1999 (De Boer, 2000a), 1999/2000 (De Boer, 2000b; De Boer *et al.*, 2003) and 2000 (Eyre, 2000).

This paper reports on results obtained during a transit of the Sanctuary during the austral autumn of 1995, originally presented as an unpublished report to the IWC (Eyre, 1997). Subsequent research conducted by other organisations in the locations covered here are briefly mentioned.

METHODS

The survey vessel was the *MV Greenpeace*, a 58m deep-sea salvage tug which averaged 9.9 knots during the transit. A

Furuno GP-500 Navigator provided vessel position, and navigational charts were used for approximate depth in addition to the ship's depth sounder in shallow water. Water temperature was taken from the ship's engine cooling system at a depth of approximately 2.5m, and sea and wind conditions were estimated using the Beaufort scales.

The vessel left Hobart, Australia on 25 March 1995 and entered the IOS on 29 March. The course continued northwest to the northeastern waters of Africa and into the Red Sea, arriving at Haifa, Israel on 3 May 1995. Fig. 1 shows the vessel's cruise track.

Although the principle purpose of the transit was one of vessel delivery, the course or speed was altered to close in on large cetaceans for data collection or to survey areas of interest. An area WNW of the Seychelles which was covered in the 1993 survey (Eyre, 1995) was transited, and the vessel also detoured off Ras Hafun (Somalia) for a day when large numbers of sperm whales were encountered.

Visual survey

Visual observations were conducted during daylight hours and in sea conditions below Beaufort 6 (Fig. 2). Most observations were carried out from a platform 12m above sea level. Searching also occurred from the crow's nest (20m), wheel-house roof (10m) and bridge (8m) depending on environmental conditions.

Two observers were usually present, each searching 180° on each side, with most effort concentrated 90° forward. From 26 April to 3 May, only one observer was present, concentrating search effort 180° forward. The crew on watch

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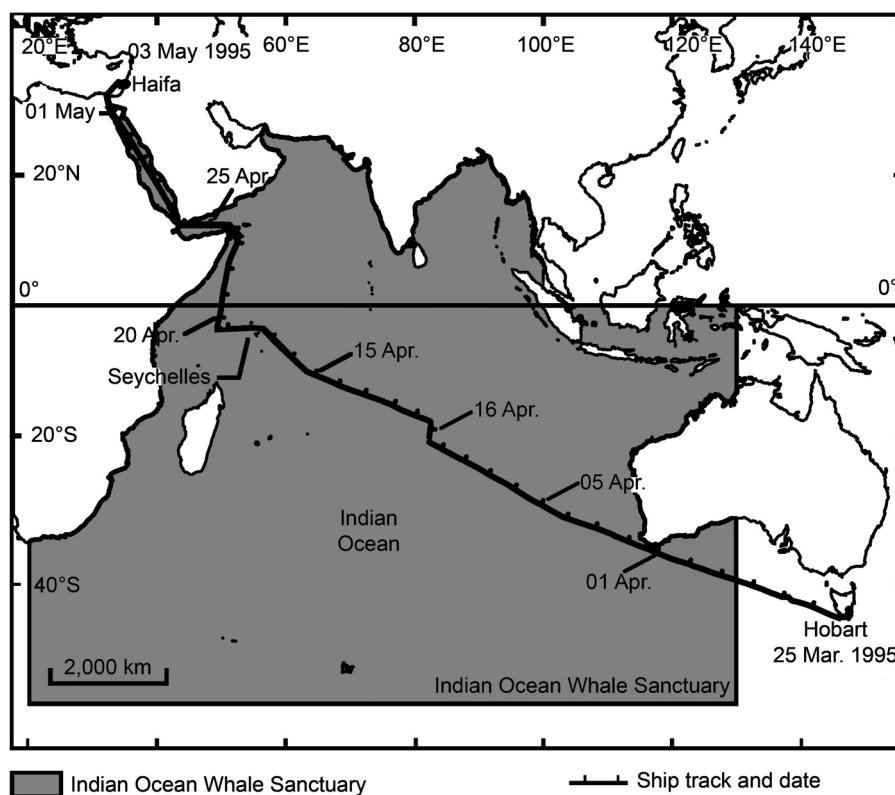


Fig. 1. Vessel cruise track and associated dates.

also assisted during this time. On-effort watchers scanned with the naked eye and used Steiner 7×50 field glasses to search from the vessel out to the horizon.

Effort, ship's course and speed and environmental data were collected hourly or when a sighting was made. School sizes were estimated using low/high/best estimation of numbers of individuals. Photographs were obtained where possible using Pentax and Canon SLR cameras with 50–200mm lenses.

The term 'sighting' refers to cetaceans separated spatially or temporally. It is recognised that sperm whale sightings are likely to be sub-groups of larger aggregations. The methods do not allow abundance to be estimated.

Acoustic survey

Two hydrophone systems were used. One was a single element hydrophone with 12m of cable deployed from a

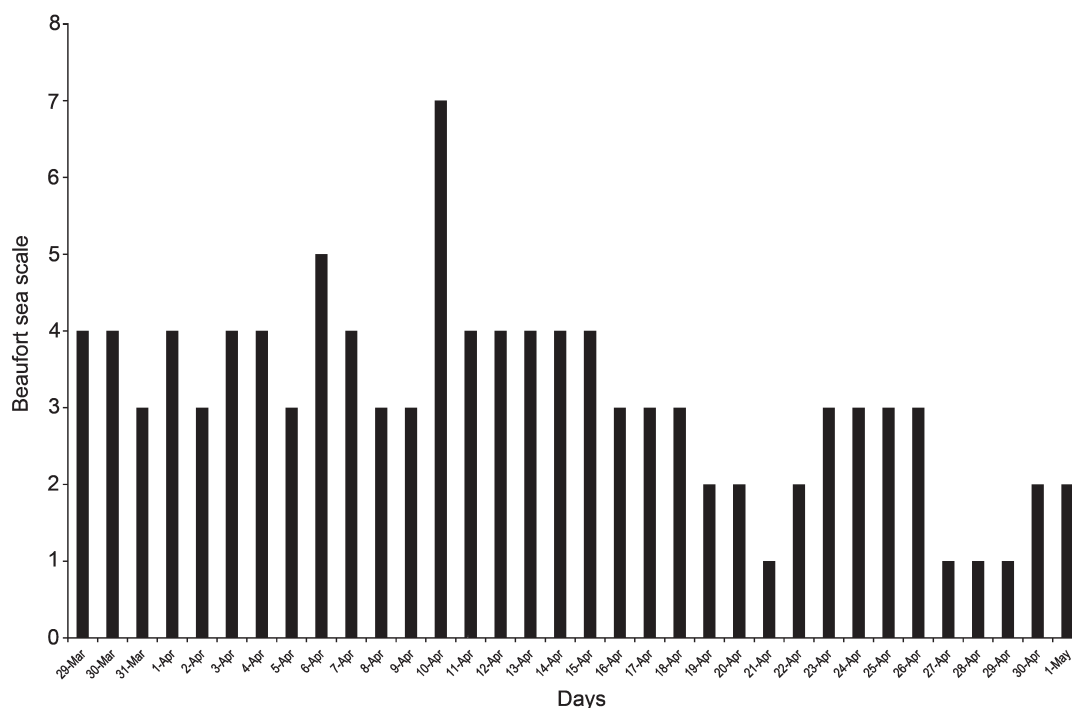


Fig. 2. Average Beaufort sea state during on-effort watching whilst in the Sanctuary (29 March–1 April 1995).

rigid-hulled inflatable. A preamplifier with a range of 20–60dB covering a bandwidth of 50Hz–20kHz was connected to a *Panasonic* SV-250 portable DAT recorder.

The second system was a two element towed array, consisting of 90m of strengthened cable towed approximately 78m behind the vessel and with a rope tail for stability. The array contained two *Benthos* AQ-4 elements with 30dB gain preamplifiers and a frequency response of 200Hz–35 kHz, mounted in a 10m long reinforced polyurethane tube filled with deodorised paraffin oil. The array was connected to a *Sony Pro TCD-D10* DAT recorder. The hydrophone array was developed by the International Fund for Animal Welfare, based on equipment used by Leaper *et al.*, (1992) and had been used by Pierpoint *et al.*, (1997) prior to this survey.

Routine tows were conducted from 17–26 April, between 08:30–09:30 hours. Three evening tows were also conducted during this period (Fig. 3). The ship slowed to 6.5 knots, and the visual survey was maintained during daylight tows. During one hour of listening, recording was done at alternate 10 minute intervals (total 30 minutes recorded). Non-routine tows occurred when cetaceans were in the vicinity and ship schedule allowed.

Recordings were aurally analysed for presence/absence and identification of cetacean sounds and were then sent to the Cetacean Group at the University of Oxford for sperm whale abundance analysis using the ‘Cartwheels’ program (Conservation Research Group, 1989) but unfortunately the quality of the recordings precluded estimates being developed.

RESULTS

Visual

A total 16,688km was covered from Hobart to Haifa, with 14,563km (87.2%) within the IOS. There were 378 hours of effort in total of which 332 hours (87.8%) were in the IOS, giving an average of 9.5hrs per day. Of the 163 sightings made (on 22 of the 40 days) 156 sightings (95.7%) were within the IOS. All but 4 sightings were on effort. On-effort encounter rate was 1.05 sightings/100km within the IOS.

An estimated 2,560 individual cetaceans were sighted, and twelve species identified. Sightings are summarised in Table 1 and locations given in Figs. 3 and 4.

The most individuals sighted were of spinner dolphins ($n = 1,059$) and the most sightings were of sperm whales ($n = 69$).

Four sightings were of mixed species associations. These included pilot whales and bottlenose dolphins (two occasions), Risso’s and rough-toothed dolphins, and spinner and pan-tropical spotted dolphins. Oceanographic conditions within the IOS predictably shifted from cool to warm as the vessel headed northwest (Table 1), with calmer conditions within the Red Sea. Fig. 2 shows the average daily Beaufort sea state whilst on-effort within the IOS. On April 10 the weather intensified and watching conditions deteriorated due to the proximity of Cyclone ‘*Marlene*’.

Acoustic

A total of 14h 14min were spent listening at nineteen stations (Fig. 3), with 8h 47s recorded. Almost 11 hours were

scheduled tows, which covered 134.3km. Non-routine tows occurred on five occasions after cetaceans had been sighted, totalling 2h 3min of listening. On two occasions the single-element hydrophone was used from an inflatable. This included 23 minutes recorded on 23 April in the company of a widely dispersed sperm whale group. No cetacean sounds were heard on the other occasion.

Cetaceans were heard at 78% of the stations. These sounds included sperm whale clicks, as well as odontocete whistles. Whistles could be detected on 50% of recordings, and whilst it was not possible to positively assign whistle series to a species, spinner dolphins were in the vicinity on at least three occasions and a mixed aggregation of pilot whales and bottlenose dolphins were in the area on one occasion. Sperm whales were heard but not seen on two occasions.

SPECIES ACCOUNTS

Short-beaked common dolphin (*Delphinus delphis*)

Two confirmed sightings of this species were made (Table 1, Fig. 2) The first sighting was of a large, widely dispersed group accompanied by seabirds (Australasian gannets, *Morus serrator*), assumed to be engaged in feeding. The animals were in shallow coastal water off Tasmania. The second sighting occurred 4 days later when several large animals bowrode for approximately 11min. No calves were observed.

Spinner dolphin (*Stenella longirostris*)

Spinner dolphins were encountered in several locations and conditions (Figs 3 and 4) and in small and large aggregations (Table 1). In mid-ocean, the species was often observed travelling slowly or milling amongst sea birds, presumably feeding. Aerial activity was always seen. Sightings occurred during all daylight hours, with a slight peak near midday. A mother and calf was seen on 28 April in the Red Sea and smaller individuals within pods were seen northwest of the Seychelles and in the northern Red Sea.

Bowriding was only observed in the Red Sea, including a mixed pod with pan-tropical spotted dolphins (Fig. 3).

There was some variation in size and colour pattern amongst the Red Sea animals. A tripartite pattern was common in all animals, but many were dark grey dorsally and on the pectoral fins with a band of the same colour separating the lateral and ventral fields, originating from and enclosing the eye and terminating parallel to the genitals. This band varied in width and shade for individuals (possibly an indication of age) and on larger animals was a very pronounced stripe. Other groups of animals were uniformly smaller and lighter in colour; the flippers were similar in shade to the lateral field; the rostrum was shorter and the dark lateral band was absent.

Pan-tropical spotted dolphin (*Stenella attenuata*)

Spotted dolphins were positively identified in the Red Sea (Fig. 3), but were likely to account for some of the ‘unidentified delphinids’ encountered throughout the survey. Most (70%) of the sightings involved bowriding, including the mixed group with spinner dolphins. Group sizes ranged from 9–70 individuals. Calves were seen in the southern Red Sea.

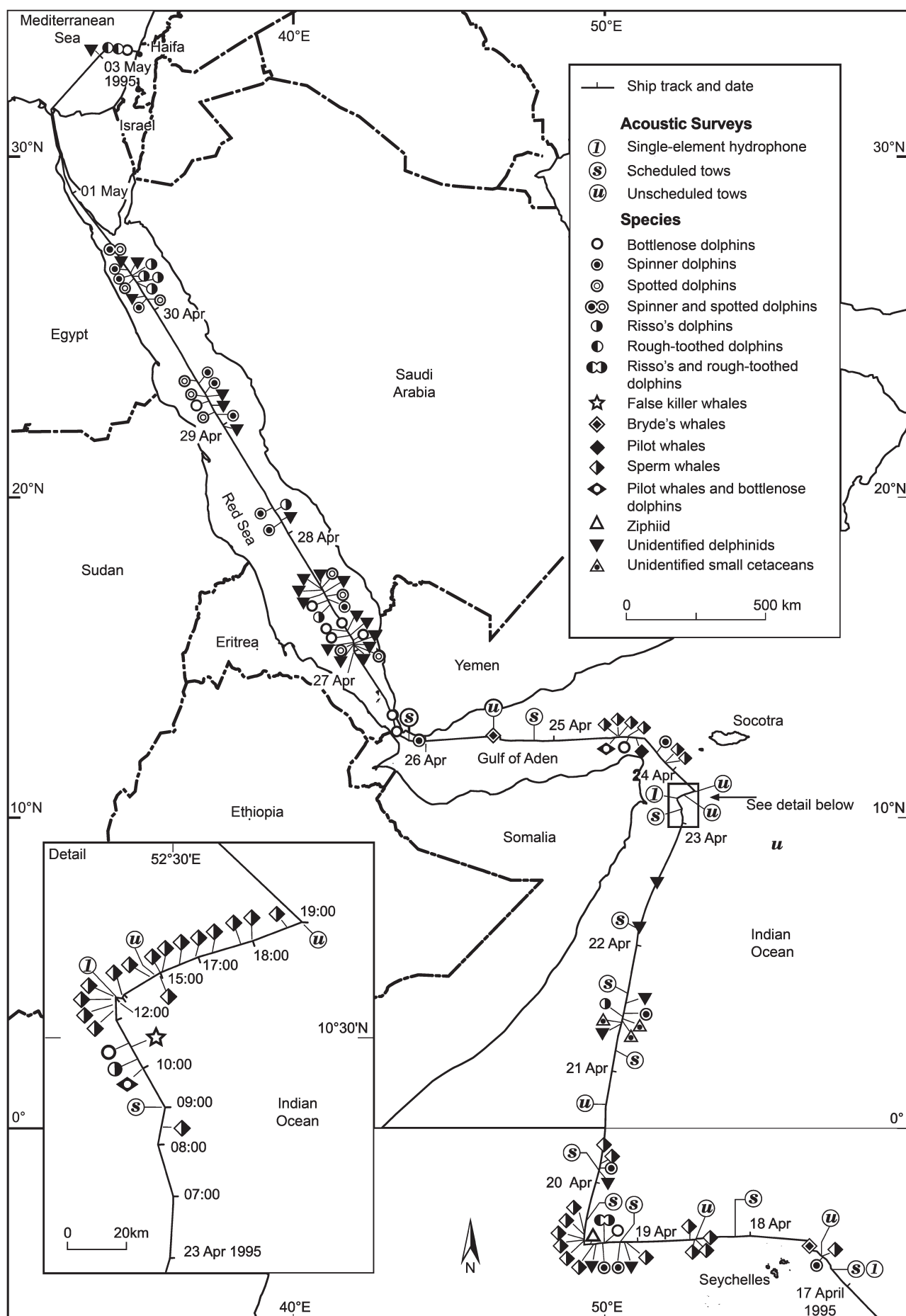


Fig. 3. Vessel cruise track, sightings positions and listening stations throughout the western sector of the Indian Ocean Sanctuary and Mediterranean. Some symbols are for multiple sightings of the same species.

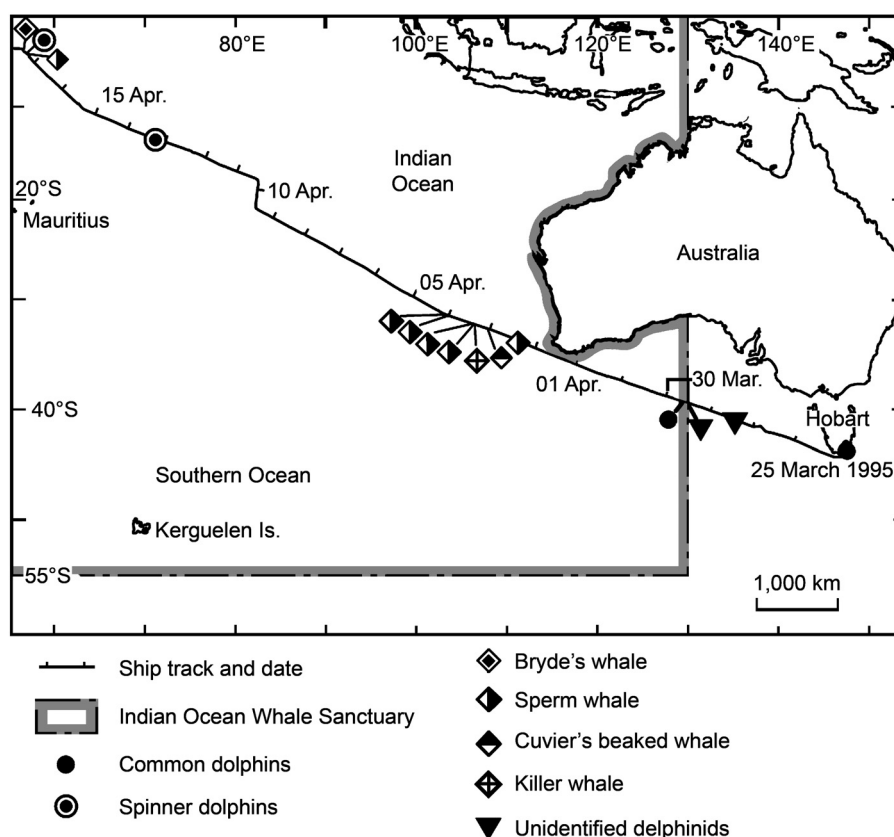


Fig. 4. Vessel cruise track and sightings positions for the eastern sector of the Indian Ocean Sanctuary. Some symbols are for multiple sightings of the same species.

The white rostral tip and dark cape was common to all groups observed, with some groups having distinctive white lips. Larger animals had dark flecks below the cape. Three groups contained a large number of individuals with a dark band extending from the gape, continuing beyond eye patch and ending above the trailing edge of the pectoral fin. Their size was comparable to other individuals without a band.

Bottlenose dolphin (*Tursiops* spp.)

Bottlenose dolphins were seen in different environmental conditions, including clear, deep oceanic waters and shallow, murky coastal waters on the approach to Haifa port (Table 1). The genus was only positively identified in the western part of the Sanctuary, including the Gulf of Aden and Red Sea (Figs 3 and 4).

The largest groups of animals ($n = 60$ and 40) were seen in the company of pilot whales. Most (79%) of sightings involved bowriding, including those associated with pilot whales.

Most of the animals encountered were quite large, robust and with short, blunt rostrums. Colour varied from dark grey (except for the ventral surface), to grey gradation along the flanks. Only three sightings were of lighter and smaller animals identified as Indo-Pacific bottlenose dolphins, *Tursiops aduncus*. One was mid-Red Sea (29 April, Fig. 3) and the other two were off the Horn of Africa (24 April, separate and with pilot whales, Fig. 3).

A mother and calf bowrode on two separate occasions in the Red Sea and the multi-species group in the Gulf of Aden had smaller animals present.

Rough-toothed dolphin (*Steno bredanensis*)

This species was seen on three occasions: once mid-ocean in deep, warm water and twice in the Mediterranean in deep, relatively cool water of 18°C (Table 1, Fig. 3). In the IOS the species was associated with Risso's dolphins and were broken up into units containing 1–4 animals which appeared boat-shy. All animals in the Mediterranean bowrode for an average of four minutes, including one juvenile.

The animals surfaced in synchrony when closely grouped and had a peculiar 'space shuttle' appearance when bowriding by holding their large pectoral fins at right angles to their body.

Risso's dolphin (*Grampus griseus*)

Risso's dolphins were encountered mid-ocean and in the Red Sea (Fig. 3). The largest group ($n = 25$) was associated with rough-toothed dolphins and consisted of young and old animals dispersed throughout the *Steno* groups. This was the only time the species approached to within 10m of the vessel. Group sizes varied from 1–5 animals for other encounters. Smaller animals were seen on three occasions in the Red Sea.

They were often (78%) seen 'sailing', with their flukes held vertically above the water or resting motionless at the surface on days of warm sea and air temperatures ($\geq 24^\circ\text{C}$ and $\geq 25^\circ\text{C}$ respectively).

Killer whale (*Orcinus orca*)

One group (about 10 animals of mixed age and sex) was encountered in cool, deep water in the eastern sector of the

Table 1
Group sizes of identified species, including water depth and temperature.

Total sightings	Total individuals ('best')	Mean group size (SD; range)	Approx depth, m (SD; range)	SST, °C (SD; range)
Pan-tropical spotted dolphin				
10	361	36 (24; 9–70)	657 (378; 178–1,302)	27 (3; 24–30)
Bottlenose dolphin spp.				
14	151	11 (17; 1–60)	912 (1,396; 14–5,000)	29 (3; 19–32)
Risso's dolphin				
9	53	6 (7; 1–25)	1,744 (1,605; 509–5,000)	28 (4; 24–32)
Sperm whale				
69	100	1 (1; 1–4)	2,461 (1,624; 1,000–5,000)	30 (3; 20–32)
Spinner dolphin				
19	1,059	56 (54; 4–250)	2,016 (1,929; 64–5,000)	28 (3; 24–32)
False killer whale				
1	2	2 (0; 2–2)	1,251 (0; 1,251–1,251)	30 (0; 30–30)
Short-beaked common dolphin				
2	310	155 (205; 10–300)	2,684 (3,768; 20–5,349)	15 (0; 15–15)
Bryde's whale				
2	2	1 (0; 1–1)	2,250 (1,768; 1,000–3,500)	30 (1; 30–31)
Killer whale				
1	10	10 (0; 10–10)	3,934 (0; 3,934–3,934)	20 (0; 20–20)
Pilot whale				
3	66	22 (14; 6–30)	1,938 (597; 1,251–2,328)	30 (0.3; 30–30)
Rough-toothed dolphin				
3	31	10 (13; 2–25)	2,708 (1,990; 1,425–5,000)	23 (8; 18–32)
Ziphiids				
2	3	2 (1; 1–2)	4,950 (71; 4,900–5,000)	26 (8; 21–32)

IOS (Table 1, Fig. 4). The animals were travelling fast, and blows were clearly visible 1km away in Beaufort sea state 4. They had a brown rather than black appearance and the saddle patch was faint.

Pilot whale (*Globicephala* spp.)

Pilot whales were encountered in the Somali Basin and the Gulf of Aden (Fig. 3). They were probably short-finned pilot whales (*G. macrorhynchus*) given their position (Leatherwood *et al.*, 1991). Pilot whales were associated with bottlenose dolphins on two occasions, and were noticeable even at a distance by their blows. Large animals appeared in all groups and no calves were seen. Six animals were observed surfing in sea state 4 with a 1.5m swell.

False killer whale (*Pseudorca crassidens*)

One sighting of two animals occurred in an area east of Somalia where a high number of other species were encountered, notably sperm whales (Fig. 3). They appeared disturbed by the vessel's presence, altering course away from the ship and spending little time at the surface,

Ziphiids

Two Cuvier's beaked whales (*Ziphius cavirostris*) were seen in the east of the IOS. Both were brownish grey dorsally, however one was cream-coloured anterior to the dorsal fin in a well-defined demarcation. The skin around the eye was dark and noticeable against the light background, and scarring was not evident on either animal. The whales had sloping melons with short rostrums and the dorsals were large and falcate, positioned well back. The trailing edge of the dorsals were grey. The animals had been

slowly milling at the surface and sounded as the vessel approached.

An unidentified single whale (Fig. 4) was seen in deep water (SST 32°C). It was medium-sized and resting motionless at the surface. A small triangular dorsal fin was positioned over half way along the body. The animal submerged as the vessel approached.

Bryde's whale (*Balaenoptera edeni*)

Two sightings of single animals were made in warm deep water (Table 1, Fig. 3). A large individual was sighted near Mahé (Seychelles). It had a variable swim pattern and submergence times from 1–9 minutes. The ship's course was slowed and altered without causing obvious disturbance to the whale.

The second sighting was in the Gulf of Aden. The whale was only seen briefly and no sounds were detected.

Sperm whale (*Physeter macrocephalus*)

This was the most frequently encountered cetacean species (Table 1). Sightings occurred throughout the IOS (Figs 3 and 4) with the exception of the Red Sea. Concentrations of animals occurred WNW of the Seychelles Group, south east of the Horn of Africa and in the Gulf of Aden.

Group numbers and estimated size of individuals showed a latitudinal pattern, with large, lone individuals (presumably adult males) seen in the south east IOS, in temperate (20–22°C), deep (3,934–5000m) water. Small groups, primarily thought to be subadults, were seen WNW of the Seychelles and south of the Equator, in warm (32°C), deep (2,000–5000m) water. Large, dispersed groups of adults, subadults and at least one occurrence of a calf were observed 10° north

of the Equator, west of Ras Hafun (SST 30.5–31°C, depth 1,200–2,000m). In the Gulf of Aden most animals were adults, either alone or in pairs (SST 30°C, depth 1,000–1,500m).

The highest number of sightings and individuals occurred on 23 April, when the vessel deviated 69km off course, 98km from Ras Hafun (Fig. 3). Sightings were divided roughly into four groups as the track progressed east throughout the day. The first group was of three sightings, totalling five adults encountered early in the morning. The second group consisted of adults, subadults and at least one calf (estimated 5m long) dispersed in subgroups of 1–3 animals, either resting at the surface or diving. Photographs were taken, and 23 minutes of recordings were made using the single element hydrophone deployed from an inflatable boat. Despite considerable surface noise, multiple clicks could be heard. Fifteen minutes prior to joining this group, two noticeably large, lone animals were seen. The group was observed from late morning to early afternoon.

An hour after leaving these whales and continuing east, the next group was encountered. This consisted of mostly large animals, either singly or in pairs. Whilst some rested at the surface, others were active. One pair was observed to roll together whilst swimming underwater, and a single animal with a dorsal fin callus was also seen swimming upside down just below the surface. Another pair of large whales was engaged in lob tailing. The array was towed whilst the vessel slowly circled in the area. At one stage all animals had sounded, but many animals could be clearly heard. One and a half hours were spent with this group mid-afternoon before course and speed were resumed. In the late afternoon, the final group was observed, with whales alone and at the surface.

Of a total 19 listening stations, sperm whales could be heard on five occasions, including three when animals were in view. Sperm whales are most often silent when at the surface (Whitehead and Gordon, 1986), making it probable that more animals were in the area than were seen.

Dorsal fin calluses were seen on 70% of individuals photographed. Dorsal fin calluses are associated with female sperm whales (Arnbom and Whitehead, 1989; Kasuya and Ohsumi, 1966).

Unidentified delphinids and small cetaceans

Some 17% of sightings were animals of dolphin-like appearance for which no species could be assigned. Lack of closure on sightings other than large whales made identification difficult unless animals approached or showed distinctive features or behaviour. Reduced visibility due to sea conditions contributed to unconfirmed identification, as did elusive behaviour. Some sightings made by the crew could not be positively identified.

On 21 April off the east coast of Somalia, five of the seven sightings were of small animals which could not be assigned to species (Fig. 3). This was on a warm, still day. Despite these good sighting conditions where animals could be detected resting at the surface from considerable distance, on approach they would sink below the surface until the vessel passed. It is possible that at least two of these sightings were of *Kogia* sp.

In the Red Sea, 37% of sightings were of indeterminate

species. Many of these sightings were at distances greater than 800m and the behaviour exhibited was either slowly travelling or resting at the surface. Vessel speed had increased and there was only one dedicated watcher present.

DISCUSSION

The Indian Ocean is characterised by monsoon-driven upwelling north of the Equator. The southwest monsoon current flows from late April to October, producing upwelling and nutrient-rich waters off the Somali east coast (Small and Small, 1991; Wyrki, 1973). As a result of this upwelling, influx of nutrients and increased phytoplankton biomass during the southwest monsoon, the NW Indian Ocean is considered a significantly productive ocean basin (Veldhuis *et al.*, 1997). Ballance and Pitman (1998) reported that the southwest monsoon began in late May in 1995, and April is often referred to as an inter-monsoon period. The northward flowing Somali Current commences near 10°S, where a large number of sightings were recorded and many species seen (Fig. 3). Upwelling is significant between 5° and 11°N (Small and Small, 1991), where the highest number of sightings were recorded. The mouth of the Gulf of Aden, where the Somali Current converges with the waters of the Gulf was also associated with a high number of sightings (Fig. 3); Small and Small (1991) present similar data on species, area and time of year for offshore sightings.

Our results confirm the conclusions of previous cruises, Balance and Pitman (1998) and Eyre (1995), that spinner dolphins and sperm whales are probably the most abundant cetacean species in the IOS.

As noted, it is likely that some of the unidentified sightings were spotted dolphins. This species appears to be an important part of the deep water fauna of the Red Sea. Beadon (1991) found that spotted dolphins were the most frequently encountered cetacean species off the southern tip of the Sinai Peninsula, but did not record spinner dolphins in the area. Gilpatrick *et al.*, (1987) and Eyre (1995) note a similar distribution for spinner and spotted dolphins in the Red Sea.

Risso's dolphins and bottlenose dolphins occurred throughout the Red Sea and western portion of the Indian Ocean. Kruse *et al.* (1991) refers to the frequency and distribution of Risso's dolphin sightings in the IOS from a review of available information and Beadon (1991) noted that they were the second most commonly encountered species in the Gulfs of Aquaba and Suez. The tail-up behaviour of Risso's dolphins observed on many of the encounters may be related to thermoregulation and has been observed in the Maldives (Anderson, 2005), Oman (Baldwin, 2003), Indonesia (B. Kahn, pers. comm.) and Papua New Guinea (Mörzer-Bruyns, 1971).

The two reported types of bottlenose dolphin would appear to be consistent with other reports (e.g. Beadon, 1991; Leatherwood, 1986; Mörzer-Bruyns, 1971). The association between *Tursiops* sp. and short-finned pilot whales is not uncommon (e.g. Anderson, 2005; Ballance and Pitman, 1998; Small and Small, 1991).

Pilot whales may have a seasonal distribution in the Gulf of Aden and east of Somalia. Small and Small (1991) recorded sightings from February–May and November and Ballance *et al.*, (1996) recorded them in May. Leatherwood

(1986) and Leatherwood *et al.* (1991) reported sightings in similar months in this area. Eyre (1995) transited this in June/July 1993 and reported no sightings of pilot whales. The lack of reported sightings from May–October may be related to the monsoon periods and associated weather patterns.

The single sighting of killer whales in the southeastern portion of the IOS may have been of Antarctic migrants; the brownish colouration may be attributed to diatoms (R. Pitman, pers. comm.). Unfortunately no photographs were obtained.

Although rough-toothed dolphins have been observed with other cetaceans (Perrin and Walker, 1975), this appears to be the first record of the species associating with Risso's dolphins. The two sightings of *Steno* in the eastern Mediterranean were not aberrant. A specimen was previously collected from Haifa (Watkins *et al.*, 1987) and the species is now considered to be a permanent part of the Mediterranean fauna (Miyazaki and Perrin, 1994). Sightings and strandings have been recorded off Israel and Palestine in March and April 1997, 1998 and 2005 (Goffman *et al.*, 2009; Khalaf, 2008).

The Seychelles is an important cetacean area (e.g. Ballance *et al.*, 1996; Claro and Hergueta, 2002; Eyre, 1995; Hermans and Pistorius, 2008; Kasuya and Wada, 1991; Keller *et al.*, 1982). Survey and whaling records suggest that the Seychelles area is an important region for sperm whales in all seasons (e.g. Wray and Martin, 1983). Townsend's (1935) charts show the Mahé Banks were an important whaling ground. Robineau (1991) notes that sperm whales were the most frequently encountered species around the Seychelles, but does not elaborate on whether the seasonal decline for balaenopterid sightings during April extends to sperm whales.

The only one other reference to large concentrations of sperm whales near the area off Ras Hafun is that of Ballance *et al.* (1996), who recorded over 20 sightings of sperm whales from 7–10 May 1995, in an area slightly east of the present study. No mention was made of group composition. Leatherwood (1986) reported two records of single animals from this region on 24 April 1977. Townsend (1935) and Kasuya and Wada (1991) show concentrations of animals SE of this area during April. The presence of sperm whales in this area is probably seasonal (Berzin, 1971) and related to a breeding and calving season that includes March and April (Klinowska, 1991). The presence of a calf amongst an assumed nursery group and the presence of adult animals engaged in close contact suggests that east of Ras Hafun may be a breeding and nursery site. The Gulf of Aden supports large numbers of sperm whales and 'young' sperm whales were recorded from the area in March and May (Small and Small, 1991). Yukhov (1969) noted females and 'small' whales in the later months of the year.

While there has been increased research effort in some parts of the IOS in recent years (e.g. Feingold and Kerem, 2008; Marsden *et al.*, 2004; Notabartolo di Sciara *et al.*, 2007; Notabartolo di Sciara *et al.*, 2009; Reijnders, 2001; 2002; Wise *et al.*, 2009) it is clear that long-term, year-round dedicated studies are required to obtain necessary information on abundance, distribution, seasonal patterns and behaviour of cetaceans within the IOS to address potential anthropogenic threats. However, this study has

shown that increased use of platforms of opportunity could provide valuable information for relatively little cost.

The identification of areas with high abundance and species diversity supports the implementation of more intense efforts in these areas, ideally combining visual and acoustic techniques. Unfortunately the northwestern sector of the IOS has in recent years become affected by war and piracy, making it difficult to conduct vessel-based research. The apparent dependence of some cetacean populations on areas of high primary productivity within the IOS implies that future management of these regions should be considered with respect to fisheries, pollution and climate change.

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