International Whaling Commission

Historical Whaling Records

INCLUDING THE PROCEEDINGS
OF THE INTERNATIONAL WORKSHOP
ON HISTORICAL WHALING RECORDS

Sharon, Massachusetts
September 12–16, 1977

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Preface

This volume contains the report of the activities of the International Workshop on Historical Whaling Records held at the Kendal Whaling Museum, Sharon, Massachusetts in September 1977. We have also included seven additional papers which have been presented to various meetings of the Scientific Committee between 1980 and 1982 and which further demonstrate the value of studying historical whaling records. One of these, by Bannister, Taylor and Sutherland, has already been published by the Commission (1981, *Rep. int. Whal. Commn* 31: 821–33), but as it was written in direct response to a recommendation of the Workshop, it is included here for completeness.

Papers in the volume have been organized according to content rather than by document number. By breaking with tradition we hope to have provided a more readable and logical presentation. Papers HWR/4, HWR/2 and HWR/8 present background information on general assessment problems and models. Papers HWR/5 and HWR/11 discuss the limitations of working with logbooks and journals. Papers HWR/1, HWR/6–7 revised, HWR/10, SC/Jn80/SpW18 and SC/F82/SpS1 address sperm whale assessments. Papers HWR/3, SC/32/PS16, SC/32/PS6, and SC/33/PS7 present results of bowhead case studies. Paper SC/33/PS14 is a humpback case study while SC/32/O 8 is an area study.

Editing the report and original papers emanating from the Workshop has taken an embarrassingly long time to accomplish. We wish to thank the authors for their forbearance and endurance. The assistance of Breedlove and Co. (R. E. Stanbrough, Project Manager) in editing the original collection of papers is gratefully acknowledged. Thanks are also due to Edward Mitchell who ensured that the production of this volume was always a challenging and exciting task!

M. F. TILLMAN AND G. P. DONOVAN
April, 1983

COVER PHOTOGRAPH

Detail from 'The *Swan* and *Isabella*', a painting by John Ward (1798–1849). It was painted in about 1833 to celebrate the rescue of the Arctic explorer Sir John Ross and the crew of the *Swan* who had spent two years in the Arctic in atrocious conditions. Sir John Ross was an ex-captain of the rescuing whaler, the *Isabella*. It was not uncommon for the whalers who ventured far into the Davis Straits and Baffin Bay to be trapped in the ice and from the 1820s onwards increasing numbers of ships were forced to overwinter in the Davis Straits ice-pack. In 1830 for example, of 91 whalers in the British Fleet, 19 vessels were lost in the ice and almost all of the ships were severely damaged. *The painting is in the Town Docks Museum, Kingston upon Hull and the City of Kingston upon Hull Museums and Art Galleries are thanked for permission to use the photograph.*

Introduction

In the fall of 1977, I convened and chaired the International Workshop on Historical Whaling Records at the Kendall Whaling Museum in Sharon, Massachusetts. The objective of the Workshop was to determine if the study of early whaling records could be a viable approach to the problem of estimating initial abundance of whale stocks and of determining the effect of exploitation upon them. Being a neophyte in the scholarly realm of historical studies, I must admit to being somewhat of a skeptic prior to the Workshop. However, I came away from it enthralled by the discovery of the rich treasure of biological data which resided within old, musty whaling logbooks and journals. I now fully concur with the Workshop's conclusion that the analysis of historical whaling records is a feasible approach in determining the status of some stocks of whales.

The conclusions and recommendations of the Workshop have already had considerable effect upon the conduct of recent cetacean research. Three of six recommendations emanating from the Workshop required funding by governmental or private institutions. All three research projects have since been undertaken:

* The recommended research on the Western Arctic bowhead whale was funded by the US National Marine Fisheries Service and the US Marine Mammal Commission. This work was undertaken during 1978–80 by Dr John Bockstoce, Whaling Museum, Old Dartmouth Historical Society, New Bedford, and Dr Daniel Botkin, University of California, Santa Barbara. The results of their study are published in this volume.

* The proposed sperm whale pilot project concerning the 'Japan' and 'Coast of Japan Grounds' was funded by the UK-based People's Trust for Endangered Species. The work was undertaken by John Bannister, Director, Western Australian Museum, and its results, previously published by the International Whaling Commission (Bannister, J. L., Taylor, S. and Sutherland, H. 1981. Logbook records of 19th century sperm whaling: a report on the 12 month project, 1978–79. *Rep. int. Whal. Commn* 31: 821–33), are reprinted in this volume.

* The recommended compilation and publication of an indexed, world inventory of existing and available logbooks/journals by Professor Stuart Sherman, Brown University, was funded by the US Marine Mammal Commission in 1978 and is still under way.

During a special public session of the Workshop it was further recommended that the New York Zoological Society be requested to search for the original data and notes used by Townsend in compiling his plots of the distribution of whales taken by Yankee whalers (Townsend, C. H. 1935. The distribution of certain whales as shown by logbook records of American whaleships. *Zoologica* 19(1): 1–50). I made that request on behalf of the Workshop, and the Society undertook a search in 1978 at the library of the Osborne Laboratory of the New York Aquarium. Some of Townsend's original data were found 'in a tunnel in very poor condition, water damaged and fragile'. The Society in association with Dr Roger Payne is currently having the materials restored.

Based upon the above results, I believe the Workshop to have been one of the most successful meetings with which I have ever been associated. Furthermore, its participants proved that historians and scientists could work together and provide meaningful answers to current questions on management of whale stocks. Much of the success of the Workshop was due to the facilities and arrangements provided by Dr Kenneth Martin at the Kendall Whaling Museum. I am indebted to his help before, during, and after the Workshop.

Finally, I must say a word of thanks to Dr E. D. Mitchell who pushed and prodded me into this endeavour – it has provided some rather unique insights into a very special world.

MICHAEL F. TILLMAN (CONVENOR)
Seattle, 1983

Contents

Report on Activities of the International Workshop on Historical Whaling Records

1. VENUE

Sponsored jointly by the US National Oceanic and Atmospheric Administration (NOAA), the US Marine Mammal Commission (MMC), the International Whaling Commission (IWC), and the Kendall Whaling Museum, the International Workshop on Historical Whaling Records was held 12–16 September 1977 at the Kendall Whaling Museum in Sharon, Massachusetts. The workshop was convened and chaired by Dr Michael F. Tillman (NOAA).

2. BACKGROUND OF WORKSHOP

The IWC Scientific Committee began discussing the need for research on historical whaling records to obtain initial stock size, loss rates in the fishery, and other parameters in the early 1970s (IWC, 1973). First considering only the North Atlantic stock of sperm whales, discussion of this approach was soon amplified to the world sperm whaling records, and has recently been extended to bowhead, right, bottlenose, and other protected or presently unexploited species (IWC, 1978).

The importance of this work was recognized by S. J. Holt and J. Goodman, then of FAO, and led them to establish a Working Group on Historical Studies (Working Group 23) for the FAO Scientific Consultation on Marine Mammals held in Bergen, Norway, August–September 1976. E. Mitchell convened this Working Group. The coming together in Bergen of a number of historians, mathematicians and statisticians, curators of collections, biologists and bibliographers, led to a lengthy Working Group report (FAO, 1978) and the call for an international workshop on historical data.

The FAO welcomed this initiative to convene such an international workshop, but stated that it was not able to sponsor nor assist further in preparation for the Workshop. Various members of the FAO Scientific Consultation, especially Goodman, urged Mitchell and Martin to convene an informal steering group of a few interested and competent persons. This was done, and the Steering Group met on 9 December 1976 (Boston) and 21 March 1977 (New Bedford). Based upon the proposal, emanating from these planning sessions, the Workshop was subsequently sponsored by NOAA, MMC, IWC, and the Kendall Whaling Museum.

3. TERMS OF REFERENCE

The Steering Group established the following objectives for the Workshop:

(a) Define minimum data needs for an adequate stock assessment.
(b) Develop lists of sources and types of historical whaling records and ascertain if they contain the required minimum information.
(c) Contrast data needs and sources and determine if the study of historical whaling records is a feasible approach in determining the status of whale stocks which were subjected to early whaling.
(d) Review extant proposals or develop new proposals for research projects on stocks of whales for which this is determined to be a worthwhile approach.
(e) Limit proposal development to the two major current problem species: bowhead and sperm whales.
(f) Review extant data extraction forms or develop new ones and undertake extraction exercises to test the practicality of the proposed research.

4. ORGANIZATION

The Steering Group organized the Workshop into a series of daily sessions involving four sub-committees as outlined in the Workshop Agenda (Appendix A). An important element of the Workshop was the open plenary session on the last day during which public comment was solicited on preliminary findings.

Workshop participants are listed in Appendix B. Contributed papers, contributed data sources, and other papers circulated for background purposes are listed in Appendix C.

5. INTRODUCTION

Management of the world's whale resources by the IWC is governed by a classification of the stocks carried out by the IWC Scientific Committee based on the available evidence of their status. This policy requires estimates of the initial and current stock sizes and the stock size providing the maximum sustainable yield.

Sperm whale stocks, which are the most abundant of the great whales and a major target of the present industry, are currently assessed on the assumption that in 1946 they were effectively in an unexploited and stable condition, having fully recovered from the impact of the eighteenth- and nineteenth-century fisheries.

The western Arctic bowhead population was grossly depleted by the early fishery, and its present abundance is such that it is considered to be close to biological extinction, although its distribution and initial size are not exactly known.

The wise management of whales requires a scientific understanding of the processes that control their populations. Studying whales is difficult even when their populations are abundant. For those whale species whose numbers have been greatly decreased, e.g. bowhead whales, the possibility of direct observation is severely limited despite the amount of effort or money available. For several species, however, there is a source of extant information: the historical whaling records, including the logbooks/journals of whaling ships. These records represent the only major source of data available to scientists to derive any understanding of the changes inflicted on the population by the early fisheries, an understanding necessary for the development of wise management policies. Despite the possibilities of bias and error in these records, they remain a major source of information.

For whale populations whose numbers are now abundant, e.g. sperm whales, the usefulness of the historic records is of a somewhat different kind. Their relative utility compared to direct observation depends on the completeness of the records, the consistency of reporting within and among logbooks/journals, the relative consistency of the area where the whales were found, the size of the area and the timespan of the record.

6. MINIMUM DATA NEEDS

The Workshop considered the use of whaling logbooks/journals as a source of information about the biology of whales and the history of whaling catch effort. In its main discussion, the group took a conservative point of view, asking what could be done now using logbooks/journals and available analytical techniques. (The potential for more speculative analyses is discussed at the end of this section.)

Four basic issues were considered: the questions that might be answered, the data required, the minimum acceptable quality of the data and methods of data analysis.

The basic general questions which logbooks/journals might help resolve are: (1) the geographical distribution of a species; (2) the original population size; (3) the changes in the population over time (population size changes and, possibly, changes in size or age structure of the population and sex ratios).

Changes in population size necessarily involve a determination of the availability of the population per unit of effort and its changes over time. Given these basic questions, the group considered what data were required, both the minimum for a minimally useful analysis and the maximum desired for optimal study. These are listed in Tables 1 and 2.

The group also considered the minimum quality of the information required for any successful analyses (Table 3).

The group discussed how this information, once obtained, would be used. A summary of the total whale products returned for a species could be used with logbook/journal information to determine the number of whales killed over time. The logbook/journal information would provide an estimate of the ratio between whales killed including those lost, and products returned. The summary of total products returned could then provide an estimate of total mortality. This is primary information.

If enough logbooks/journals were accurate and consistent for a long enough time period, they could provide a variety of other information including the size distribution of populations, sex ratios and changes in relative densities of observed populations with time and location.

This approach is conservative; it asks what could be done now given available techniques. It should be noted, however, that new statistical and mathematical methods might be developed which would facilitate analysis of less complete records.

7. AVAILABILITY OF MINIMUM DATA REQUIREMENTS

The Workshop first approached its task of identifying useful historical records by addressing some of the specific questions raised about sperm and bowhead whales. The group turned to section 6 of Document 6,[1] and sought to answer the questions raised in 'Data required from historical records'. The group concluded that reasonably accurate figures for the annual production of sperm oil could be obtained for the nineteenth and twentieth centuries. The sources for these figures would be assembled from shipping lists, government records, and such specialized compilations as appear in the commercial press and those compiled by insurance underwriters such as Dennis Wood.

The group considered that a breakdown of these figures by ocean areas would not be possible without a major (and perhaps not successful) effort.

For other categories of desired information, as specified by Document 6, the group believed that most but not all questions could be answered from logbooks/journals. The least assurance was felt about age and size statistics, on the grounds that information of this kind could not be anticipated on a consistent basis.

Nor was there agreement on whether a meaningful system of measuring catch per unit effort could be devised since the sperm whaling industry may have been too complex internally to separate out the constants and variables. This question was discussed further by the Sperm Whale sub-committee (Section 9, this report).

The group then reviewed the proposal of Bockstoce and Botkin for extracting logbook/journal data for the bowheads of the western Arctic. The group believed this to be a more feasible task because this stock is confined to a limited geographic area and because of the relative completeness of bowhead records in contrast to the world-wide study that would be required of the sperm whale fishery.

The group examined the feasibility of preparing an inventory of whaling voyages, identifying ocean areas, years, masters, etc., with a view to improving the search for data (by year or whaling ground). It was agreed that this should be done and various sources for such an inventory were mentioned: the *Whalemen's Shipping List*, Starbuck (1878), the Batchelder inventory of whaling vessels (Old Dartmouth Historical Society) and the Pacific Manuscript Bureau's (PMB) inventories.

The group also agreed that in order to carry out useful, statistical research of many kinds on whaling logbooks/journals, a world inventory of surviving, available logbooks/journals should be compiled for all known whaling voyages. This should be available as an alphabetical listing by vessel, and include the minimum voyage summary data given in Appendix D. Indexes of these by port, period and ocean basin would make such a list useful far beyond simple entry to the baseline data, in showing trends in the industry.

Access to logbooks in public collections was not felt to be a problem, but it was recommended that extraction of information be performed from microfilm wherever possible. The group agreed that logbooks/journals in public collections are of sufficient quality and quantity, noting the trend of private collections passing into the

[1] All 'Documents' referred to in this report are in the HWR series given in Appendix C, Section A.

public realm, that the proposed research for bowhead and sperm whales could be undertaken.

To eliminate inaccuracies and ensure consistency of interpretation, the group believed that professional rather than voluntary personnel should be used to extract data. It was also felt that researchers might consider using computer-based technology to aid the extracting and indexing process, particularly in recording routine entries and in error checking.

8. REVIEW OF BOWHEAD WHALE PROBLEM

Information available on the bowhead whale stocks of the Western Arctic, Hudson Bay, and Okhotsk Sea fulfills the minimum criteria specified in Section 6. But information on the East Greenland stock (fished from *ca* 1610 to 1913), and the Davis Strait stock (fished from *ca* 1710 to 1913) is more limited, because there are fewer logbooks and journals extant. Nevertheless, information on these stocks includes annual catch lists. These provide data on annual reductions in East Greenland and the Davis Strait fisheries and, in some instances, on the changing size of whales taken in different periods.

Information on the western Arctic, Hudson Bay and Okhotsk Sea stocks is available from gross ship-by-ship returns for the entire industry (via shipping newspapers and other printed documents) and on individual whales taken via logbooks/journals. A combination of these could provide a variety of biological information. Daily entries of logbooks/journals can provide at least the minimum data requirements. These entries also include size data for determining population parameters. However, further need exists for a contemporary study of aging samples in order to convert size data to ages. The group recommended such an accompanying study.

The group recommended a study of the western Arctic, because ongoing research has already reached an advanced stage, and because of the concern over increased aboriginal whaling upon that endangered stock.

Ancillary studies of other bowhead stocks would be useful to document more fully (1) parameters related to technology (e.g. 'struck and lost' rate; mortality in escapement; changes in catch rate per vessel; factors affecting production efficiency; etc.); and (2) for those stocks proved to be biologically discrete, biological parameters (natural mortality; reproduction; etc.).

Because there may be separate stocks within the western Arctic population, the extraction of data from logbooks must be done for each day from all available data. Thus the size of the extracted information requires the use of a computer-based retrieval system. The group reviewed the proposed data extraction form of Bockstoce and Botkin (Appendix E-1) and suggested possible revisions which are reflected in Appendix E-2. An extraction exercise based upon this revised form was undertaken and the format was found to be useful.

The group recommended that in addition to the extraction of daily information (on latitude and longitude, the number of whales seen, the number struck, and the size of whales taken) information should also be recorded on the number of dead whales recovered. This last category will allow one approach to a determination of mortality among those struck and lost.

The group believed that it is important to study mortality in the escapement, both through incidence of recovery of 'stinkers', and through judgment of the circumstances of escape (e.g., in the manner of Table 5 in Mitchell, 1977).

9. REVIEW OF SPERM WHALE PROBLEM

Bearing in mind the need to provide information directly useful to the IWC Scientific Committee's sperm whale stock assessments, the Workshop considered the following major questions.

(1) What was the geographical distribution of the stocks?
(2) What was the history of exploitation? Particularly
  (*a*) the size and sex composition of catches, by area and time
  (*b*) the extent of local depletion
  (*c*) the initial population size (this necessarily involves total catch estimation)
  (*d*) any other biological information, e.g., on reproductive rates, changes in school size or composition
  (*e*) the tactics used by whale boats in approaching a group of sperm whales.

It was agreed that in relation to question 1, an examination of Maury's (1852) charts (see pp. 4–5 in Kugler, 1976) would provide valuable information on stock distribution independent of modern analyses. Additionally, extracted data from which the charts were produced might provide information useful in answering some of the questions 2(*a–d*).

With regard to question 2(*e*), the group was of the opinion that no rules governed the attack other than to take the most accessible whale. Proximity rather than size was the only consideration, and the results were necessarily a random selection from the group of sperm whales being chased.

In relation to question 2, the group could not resolve easily how to obtain figures for total catches for the minimum required geographical area (i.e., ocean basin). The whaling historians should be asked to investigate how an examination of logbooks and other information and extrapolation from those data could be used to obtain total barrelage of sperm whale oil obtained from that ground or failing that, at least the number of ships operating on each ground in each year. In that investigation, it would be important to use as many logbooks as possible from countries other than the US, e.g. UK, France, Germany. Using those results and knowing the loss rate and size of whales taken, it would be possible to calculate the total kill for a given area. A plan for the compilation of individual vessel composition of a specific fishery is given in Appendix F.

The group believes, however, that it should be possible to design a pilot project to determine, for a particular stock or area, whether changes in abundance occurred over a period of years, and to include in that analysis a description of the size composition (and hence possible sex) of the catches, and any changes in them over the period. Such information would be useful in IWC stock assessments by providing information for the Allen (1977) model to allow estimation of whether the 1946 estimate of population size for the stock (or area) are in fact of initial population size or some proportion of it (see Document 4).

In detail, this pilot project should contain the following elements:

1. Definition of the stock. It is suggested that for the pilot project this could be the North Pacific 'Asian' stock, to include whales caught on the 'Japan' and 'Coast of Japan' grounds which Townsend's (1935) charts show were fished largely in the period April–September.

2. Identification of all those logbooks containing the data in element 3 below for those grounds, from as many countries as possible. Such information must be available for a series of overlapping logbooks, for 'sperm whaling' logbooks only, and where possible over a series of years for the same captain.

3. Extraction of the following data, as a minimum, for each logbook and for each day on the grounds:

Ship location, by latitude and longitude, if possible (daily position need not be recorded as long as the ship remains on the ground in question; however, checks must be made to ensure this is the case)
Number of times sperm whales sighted
Number of single and plural sightings
Number of times boats lowered
Number of whales struck
Number of whales killed including those lost and mortally wounded
Number of whales processed, plus at least the number of barrels of oil obtained, or information on dimensions or sex.

Adding together some of these records may be possible even if individual daily records are not always complete. It is assumed that weather conditions will not cause consistent bias over time, but a check should be made with independent meteorological records for the period.

Given the above information, a series of density estimates over time could be obtained, showing the percentage reduction or otherwise of that stock over the period. Estimated costs of this project are discussed in Appendix G.

A sample extraction exercise was undertaken using an American sperm whale logbook for the 'Japan Ground'. The group adopted the format given in Appendix H as a result of that exercise.

10. PUBLIC COMMENT

On the closing day of the Workshop, an open forum discussion of the basic results of the four sub-committees was held to solicit public comment and obtain immediate feedback. This open, public discussion raised the following points:

It was recommended that a useful, additional parameter to be noted in indexing logbooks/journals was a subjective judgment as to the overall usefulness, dependability or believability of the text; and that as much basic environmental, behavioural and other data as possible be extracted by hand on first reading of any logbook.

Investigators presently studying logbook/journal data for whale species other than those considered in this workshop (e.g., right, humpback whales) affirmed the comparable problems and rewards, indicating that the Workshop's findings have general application to such studies.

The first useful lead to the long search (W. E. Schevill's efforts; and Document 10) for the original logbook data copies and compilations used for Townsend's (1935) plots was reported by H. E. Winn, who has located about 400 pages of whale encounter entries (at 20–30 entries per page) from logbooks prepared for Townsend, in the Osborn Library of the New York Zoological Society. There was a recommendation that the institution be urged to undertake an exhaustive search for the remaining data and compilations and to make these available in suitable format for rapid dissemination to scholars. It was further recommended that the Workshop chairperson write to the New York Zoological Society and inform them of the above needs.

11. PUBLICATION OF REPORT AND PAPERS

The Workshop agreed that the report of its activities and the contributed papers (Appendix C) should be published together as a single issue in a report series of the major funding agency, NOAA. If this were not possible, it was noted that IWC was also interested in publishing this material as a special issue of its report series. The chairperson was charged with making necessary arrangements for publication, including editing of documents.

In view of the great need for an inventory of whaling logbooks/journals, the group agreed that Sherman (Brown University) should coordinate as appropriate with authors and institutions in an effort to publish the contributed data sources (Appendix C) in a suitable format.

Mitchell specifically proposed that in view of his earlier efforts (e.g. Sherman, 1965) in this area, Sherman should undertake to compile, edit, oversee publication, and author a scholarly volume comprised of separately authored chapters where necessary, giving a world census of existing and available whaling logbooks/journals, and further requested that it be indexed by, at a minimum, ports, target species and ocean basins; that computer format might be desirable; and that completion was desirable within approximately two to three years. The group endorsed this proposal and suggested that reports on the progress of this work be forthcoming in timely fashion.

12. CONCLUSIONS AND RECOMMENDATIONS

From its deliberations, the Workshop concluded that the analysis of historical whaling records is a feasible approach in determining the status of some stocks of whales through studies of initial stock size and trends in abundance. It therefore recommended the following:

(a) Since sufficient historical records apparently exist as an adequate sample documenting the fishing throughout its history, that a comprehensive study of the western Arctic bowhead whale be undertaken.
(b) Since sperm whale historical records are not available separated by stock area, that a pilot project be undertaken on the North Pacific 'Asian' sperm whale stock (to include 'Japan Grounds' and 'Coast of Japan Grounds'). This should include identification of an adequate sample of existing logbooks/journals, extraction of minimum data (Appendix H) and analysis to obtain a series of density estimates over time showing the percentage reduction or otherwise of the stock.
(c) That institutions holding logbooks/journals carry out an inventory of holdings and make this available; and further that such institutions, when (internally) reading/indexing logbooks and jour-

nals, attempt to index the minimum data requirements in the Voyage Summary Data, Appendix D.

(d) That institutions and investigators carrying out biological research on whale populations involving data extraction from logbooks/journals, consider recording at least the 'minimum desired' data indicated in Table 1 (Section 6).

(e) That Professor Stuart Sherman (Brown University) undertake the compilation and publication of an indexed, world inventory of existing and available whaling logbooks/journals, in collaboration with other scholars and institutions, to be completed as soon as possible.

(f) That Workshop participants and other interested investigators submit to the National Marine Fisheries Service annual progress reports on their research activities for compilation as part of the US progress report which is submitted annually to, and published by, the International Whaling Commission.

13. REFERENCES

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Appendix A
WORKSHOP AGENDA

The Workshop will be held September 12–16. Preliminary organizational, steering group and sub-committee meetings will occur one day before, and follow-up meetings will also be held one day after to complete draft reports and extraction exercises. The business of the workshop will be conducted in daily sessions having the following sub-committee structure and tasks:

Sep. 11 (Sun.) Concurrent meetings starting at 1 p.m.
- (i) Mathematicians' sub-committee meets to define assessment methods and parameters (Beddington)
- (ii) Steering group and sub-committee chairpersons meet with Workshop chairperson (Tillman)

Sep. 12 (Mon.) Workshop begins
- 8–10 a.m. *Registration and coordination*
- 10–12 a.m. *Introductory Plenary Session*
  - (i) Welcome by host (Martin)
  - (ii) Nature and scope of workshop (Tillman)
  - (iii) Outstanding current assessment problems (Gambell)
- 2–4 p.m. *Reconvene Plenary Session*
  - (iv) Methods and data required for whale stock assessment (Beddington)
  - (v) Nature, possibilities, and limitations of Manuscript Whaling Records (Sherman)
  - (iv) Methods and data required for whale stock assessment etc.

Sep. 13 (Tue.) *Logistics of Using Historical Records*
- 9–12 a.m. Two sub-committees meet in morning sessions
  - (i) Biologists' and Mathematicians' sub-committee (Botkin) defines assessment questions and develops parameter list
  - (ii) Historians and Scholars sub-committee (Kugler) develops lists of historical records by type, indicating source, content, accessibility
- 1–5 p.m. Plenary discusses feasibility of approach.

Sep. 14 (Wed.) *Definition of Species Problems*
Two sub-committees comprised of a mixture of biologists/mathematicians and historians/scholars exchange materials on 'what we need' and 'what we have'. On-going studies are reviewed and decision made as to worth of extracting data for assessment purposes. Parameter lists and extraction formats are put in final form. Costs are estimated in terms of time and resources. Example extraction exercises are undertaken.
- (i) Sperm Whale sub-committee (Bannister)
- (ii) Bowhead Whale sub-committee (Bockstoce)

Sep. 15 (Thurs.) *Development of Proposals and Recommendations*
- 9–12 a.m. Species sub-committees complete proposals
- 2–5 p.m. Plenary consideration of proposals and recommendations.

Sep. 16 (Fri.) *Summary Plenary Session (Open Session)*
- 10–12 a.m. Public presentation of workshop results
  - (i) Chairperson's review of workshop goals
  - (ii) Reports of sub-committee chairpersons
    - Biologists/Mathematicians
    - Historians/Scholars
    - Bowhead Whale Problem
    - Sperm Whale Problem
  - (iii) Question and answer open forum
- 1.30–3.00 p.m. Presentations
  - Right whales and humpback whales in Australian Waters (Dawbin).
  - The hunt of the Greenland whale (DeJong).
- 3–5 p.m. Final Working Session (Closed)

Appendix B
PARTICIPANTS

Mrs Virginia Adams
Providence Public Library
Mr John Bannister
Western Australian Museum
Mr Bruce Barnes
New Bedford Free Public Library
Dr John Beddington
University of York
England (now IIED, London)
Dr Peter Best
Sea Fisheries Branch
South Africa

Dr John Bockstoce
Old Dartmouth Historical Society
Professor Daniel Botkin
Marine Biological Laboratory
Woods Hole
Mr Jeffrey Breiwick
University of Washington (now NMFS, Seattle)
Mr Sydney Brown
Whale Research Unit
England (now Sea Mammal Research Unit, Cambridge)
Dr Cornelis DeJong
University of South Africa

Dr Ray Gambell
International Whaling Commission
Dr David Henderson
California State University
Mr Richard Kugler
Old Dartmouth Historical Society
Dr Kenneth Martin
The Kendall Whaling Museum
Dr James Mead
National Museum of Natural History
Dr Edward Mitchell
Arctic Biological Station
Canada
Mr Kenneth Nesheim
Beinecke Rare Book Library
Dr Seiji Ohsumi
Far Seas Fisheries Research Laboratory
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Professor Stuart Sherman
Brown University Library
Mrs Ann Savours (Shirley)
National Maritime Museum
England
Mr George Shuster
Providence, Rhode Island
Mr Philip Chadwick Foster Smith
The Peabody Museum
Mr Edouard Stackpole
The Peter Fougler Museum
Dr Michael Tillman
National Marine Fisheries Service (NOAA)
Miss Helen Winslow
Elgin, Illinois
George Nichols (guest)
Ocean Research and Education Society, Inc.
Ms Pamela Miller
Pennsylvania State University
Ms Sandra Shaw Martin
Kendall Whaling Museum
Gerald Scott (guest)
University of Rhode Island
Ms Ruth Stanbrough
Kendall Whaling Museum
Ms Nancy LeBlanc
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Dr William Dawbin
University of Sydney, Australia
Ms Rebecca L. Jackson
Kendall Whaling Museum
Mr Robert Ellis
Kendall Whaling Museum
Mr John Sheldon
Kendall Whaling Museum
Mr Frederick P. Schmitt
The Whaling Museum
Cold Spring Harbor
Mr Kenneth C. Balcomb (guest)
Moclips Cetological Society

Appendix C
DISTRIBUTED PAPERS

A. Contributed Papers

Document number

*HWR/1 Best, P. B.; Sperm Whale Stock Assessments and the Relevance of Historical Whaling Records.

*HWR/2 Breiwick, J. M.; Methods and Data Required for Whale Stock Assessments.

*HWR/3 deJong, C.; The Hunt of the Greenland Whale: A Short History and Statistical Sources.

*HWR/4 Gambell, R.; Outstanding Whale Assessment Problems Requiring Analysis of Historical Data.

*HWR/5 Jackson, R. L.; Interpreting Historic Logbooks and Journals: A Survey.

*HWR/6 Mitchell, E.; Draft Example of Sperm Whale Log Book Data; and Suggestions for Use.[1]

*HWR/7 Mitchell, E.; Importance of Whaling Logbook Data in Quantifying Aspects of Model of Sperm Whale Social Structure.[1]

*HWR/8 Ohsumi, S.; Parameters in Sperm Whale Population Models Needed from Historical Whaling Record and their Sensibility.

*HWR/9 Shuster, G. W.; The Galapagos Islands: A Preliminary Study of the Effects of Sperm Whaling on a Specific Whaling Ground.

*HWR/10 Shuster, G. W.; Proposed Methodology for Abstracting Sperm Whale Data from Logbooks.

*HWR/11 Sherman, S. C.; The Nature, Possibilities, and Limitations of Whaling Logbook Data.

HWR/12 Dawbin, W. H.; Seasonal migration of Southern Right Whales in the South Pacific Ocean based on Whale Logbook Data.[2]

* Revised and published in this volume.
[1] HWR/6 and 7 have been combined.
[2] Not intended for publication, background data only.

B. Contributed Data Sources[3]

1. *Authored*

Savours, A. and Brown, S. G.; A List of Collections of Logbooks and Journals Relating to Voyages of British Whaling Vessels in the Northern and Southern Whale Fisheries.

Langdon, R. A. and Bannister, J. L.; Whaling Logbooks in Australia.

Sherman, S. C.; Preliminary Directory of Whaling Records.

Van Meter, E.; Whaling Logbooks and Journals in the Kendall Whaling Museum.

[3] Draft manuscripts and documents; not to be quoted without prior reference to the author.

Winslow, H.; A List of Nineteenth Century Sperm Whaling Voyages by Vessels Registered in Nantucket, Massachusetts Contained in Logbooks Held by the Nantucket Historical Association.

Kugler, R.; Checklist of Logbooks in the Collection of the Old Dartmouth Historical Society and Whaling Museum.[4]

2. *By Institution*

Free Public Library, New Bedford, Massachusetts; Melville Whaling Room.[4]

Peabody Museum of Salem, Salem, Massachusetts; A Listing of Whaling Logs or Journals Held by the Peabody Museum.[4]

Providence Public Library, Providence, Rhode Island; Guide to Nicholson Whaling Collection Microfilm.

U.S. National Museum, Washington, D.C.; Whaling Logbooks in the Collections of the U.S. National Museum.

Yale University Library; Whaling and Sealing Logs.[4]

[4] Compiled for distribution prior to the International Workshop on Historical Whaling Records.

C. Other Papers Circulated

Bockstoce, J. R. and Botkin, D. B.; Proposal for Research on Historical Whale Populations of the Western Arctic. (Unpublished Grant Proposal.)[3]

Anon. 1976. Research-historical studies (Report of WG 23). Paper ACMRR/MM/SC/WG23.1, FAO Scientific Consultation on Marine Mammals, Bergen. (Published in 1978, *FAO Fish. Ser. No. 5* [Mammals in the Seas] 1: 181–4).

International Marine Archives, The; *The Compilation and Addenda of Marine Microfilm Holdings.*

Kugler, R. C. 1976. The historical records of American sperm whaling: what they tell us and what they don't. Paper/ACMRR/MM/SC/105, FAO Scientific Consultation on Marine Mammals, Bergen. (Published in 1981, *FAO Fish. Ser. No. 5* [Mammals in the Seas] 3: 321–6).

Mitchell, E. 1977. Initial population size of bowhead whale (*Balaena mysticetus*) stocks: cumulative catch estimates. Paper SC/29/Doc 33, IWC Scientific Committee Meeting, Canberra (unpublished).[3]

Ross, W. G. 1974. Distribution, migration and depletion of bowhead whales in Hudson Bay, 1860 to 1915. *Arctic and Alpine Res.* 6(1): 85–98.

Appendix D

VOYAGE SUMMARY DATA FOR WHALING LOGBOOKS AND JOURNALS

Standardized format for identification of whaling records held by libraries and museums adopted by the International Workshop on Historical Whaling Records (1977). Items marked with an asterisk are considered basic information; the others are desirable.

- * Name of vessel
- * Rig
- * Port of departure
- * Name of master
- * Inclusive dates of logbook or journal
- * Logbook or private journal[1]
- Complete or partial record; daily or intermittent entries
- Number of pages of text
- Name of keeper of logbook or journal
- * Main Species sought
- * Areas visited:

North Atlantic	Antarctic Ocean
South Atlantic	Eastern Indian Ocean
Northwest Pacific	Western Indian Ocean
Northeast Pacific	Western Arctic including
Southwest Pacific	Bering Sea
Southeast Pacific	Greenland Sea
	Davis Strait (W. Greenland)

- Yield in pounds of bone and barrels of oil by type
- Other special features: whale stamps, sketches, illustrations, accounts, verse, remedies, etc.

[1] See *The Voice of the Whaleman* (1965) by Sherman for characteristics of logbooks and private journals.

Appendix E-1
BOWHEAD EXTRACTION FORMAT

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PRELIMINARY

Encounter					Position					Conditions											Fauna								
Date			Vessel		Lat.		Long.			Temp.	Barom.		Wind		Weather		Sea		Curr.		Description					Yield			
Day	Month	Year	Code letter	Code number	Degree	Minute	Degree	Minute	West or East	+ Degrees [Fahr.]	Inches	Decimal	Direction	Velocity	Conditions	Visibility	Height	Ice	Direction	Velocity	Species	Number seen	Activity	Where going	Number struck	Number taken	Barrels	Lbs.	Special information
1–2	3–4	5–6	7–8	9–10	11–12	13–14	15–16	17–18	19	20–21	22–23	24–25	26	27	28	29–30	31	32	33	34	35–36	37–39	40–41	42	43–45	46–48	49–51	52–54	55

Appendix E-2
REVISED BOWHEAD EXTRACTION FORMAT

Vessel name————————————

Vessel type————————————

Port————————————

Captain————————————

Recorder————————————

Date					Position				Weather							Encounter data					Encounter data					Encounter data				
Year	Month	Day	Vessel	Document	Lat.	N/S.	Long.	E/W.	Wind direction	Sea state (Beaufort no.)	Visibility	Ice	Total no. encounters	No. struck	No. taken	Species	No. sighted in encounter	Capture[1]	Barrels oil	Lbs. bone	Species	No. sighted in encounter	Capture[1]	Barrels oil	Lbs. bone	Species	No. sighted in encounter	Capture[1]	Barrels oil	Lbs. bone

[1] Where: 1 = Struck, processed; 2 = Struck, lost, no judgment; 3 = Struck, lost, moribund; 4 = Struck, lost, survived; 5 = Not struck, 'stinker' found, processed; 6 = Struck, sank.

Appendix F

A PLAN FOR COMPILATION OF INDIVIDUAL VESSEL COMPOSITION OF A SPECIFIC FISHERY

(Compiled by J. G. Mead)

(1) Compilation of list of voyages to a general ocean area, e.g. North Pacific, for a given time period, from major listing sources (Starbuck, PMB, shipping lists). This constitutes a geographic search resulting in a relatively large, but incomplete list of voyages probably on a given ground (i.e., Japan Ground) (= A).

(2) Compilation of list of voyages to a specific ground (e.g. Japan Ground) from detailed compilations (Maury/Wood abstracts). This constitutes a specific geographic search resulting in a relatively small number of voyages known to have been on a given ground (= B).

(3) Compare the above, deleting from the list of probable voyages (A) those known to have been on the ground (B), arriving at a smaller list (C = A − B) of probable voyages.

(4) Check this list of voyages (C) against the detailed compilations (Maury/Wood), deleting those voyages found to have not visited the grounds in question. This constitutes a search by vessel of these compilations and is quite different from Step 2. It results in a list of voyages (D) for which the data in the major listing sources (Starbuck, PMB, shipping lists) are erroneous, which is useful as an index of the accuracy of these sources. It also results in a further reduced list (F = C − D) of voyages probably visiting those grounds.

(5) Examine listings of logbook holdings for the voyages known to have visited the grounds (B), plus the voyages probably visiting those grounds (F), determining that a portion of these are in fact available for examination.

(6) Compile the required data from this available sample of logs, including vessels seen or spoke on the grounds. This independently derived list of vessels known to have visited the grounds (Z) should then be compared to the residual list of probable vessels (F), which will confirm the presence of some of these, which can then be added to the known list, (B).

We would then have a list of vessels known to have been on the ground on the basis of direct examination of their logs; indication of their presence in another log, or indication of their presence on that ground from a specific compilation source (Maury/Wood; and/or a few specific entries where grounds visited were recorded in other compilations). We would also have a much reduced list of vessels possibly visiting the grounds, but whose specific whereabouts could not be determined (G). This will be essentially those vessels listed in Starbuck (which is relatively complete for US vessels) for which there are no logs, no listing in Maury/Wood, no specific ground listing in other compilations, and which were not seen or spoke by any vessels whose logs were examined. This should be a very small number of voyages. We will be completely missing only those voyages which were not extracted from Starbuck on the first examination for major ocean area (either because they were not listed or were listed erroneously) and which were not seen by any of the vessels whose logs were examined. This should be a very small number, comparable to the number of vessels in the residual probable list (G) which did not actually visit the grounds. It is then probably safe to treat G as a sample actually visiting the grounds, assuming these small scale errors will balance one another.

This approach will yield virtually all of the US vessels, plus a large number of foreign vessels (from Z, the list of vessels seen or spoke). One can then decide whether to proceed and extrapolate data based on the US fishery alone, or whether to attempt to subsample the list of known foreign vessels.

It is also important to note that the element requiring the greatest effort (compilation of Z from actual log examination) is merely a small portion of the effort necessary to examine this sample of logs for extraction of the biological data, and for this relatively small amount of effort will yield a relatively complete vessel census for the fishery.

Appendix G

PROJECT PROPOSAL

Analysis of Changes in Abundance in the Sperm Whale Stock on the 'Japan' and 'Coast of Japan Grounds' in the nineteenth century

The pilot project should comprise the following:

(i) search of existing logbook collections for those relevant to the sperm whale fishing on the 'Japan' and 'Coast of Japan Grounds';

(ii) selection of logs suitable for the analysis;

(iii) extraction of information from that sample;

(iv) derivation of availability index;

(v) comparison of results with Allen model findings.

The sub-committee estimates that possibly 500 logbooks may exist containing data for the reputive grounds. Of those only a percentage (possibly 50%) would be suitable for the analysis. On the assumption that the fishery lasted 40 years (from 1820), a minimum requirement could be 5 data points for every 2 years through the fishery, i.e., requiring 100 'good' logbooks.

It would probably be possible to include extractions to justify the 'total barrelage' problem (see Appendix F) in the course of the above project.

Table 1

Data needed from each logbook/journal daily

What to measure	Information: Maximum desired	Minimum required
I. Catch effort		
1. Meteorological	Winds, sea, clouds, fog, rain, ice, snow	Is whaling possible and intended?
2. Is it an intended whaling day?	—	In transit; on the grounds; in port; ship full; at work; at other tasks
3. Distance travelled	Corrected for day length	None
4. Ship location	Latitude–longitude or distance and position from a shore point	Whaling ground or ocean
5. Ship activity	Number of boats lowered and number of lowerings	Were boats lowered? Yes/No
6. Techniques	Gear used	—
II. Biological		
1. Whale sightings	Number of individuals by groups, size and species	Number of sightings (Yes/No)
2. Whales chased	Number of individuals by groups, size and species	—
3. Whales struck	Number of individuals by groups, size and species	Number
4. Killed	1. Sunk[1] 2. Escaped mortally wounded[1]	—
5. Processed	(A) Barrels of oil[1] (B) Pounds of baleen[1] (C) Physical dimensions[1] (D) Sex[1]	Number processed

[1] But must be recorded where available; for a discussion of 'mortally wounded' see Mitchell (1977).

Estimated costs for such an exercise would be:

Salary, for a graduate assistant for 12 months	$10,000 Aus.
Overheads (leave loading etc.)	1,000
Provision of 100 microfilms at $11 each	1,100
Provision of microfilm reader	400
Travel and living allowance	800
Administration expenses	500
	$13,800

The above are estimated at current Australian costs. The assumption is made that it would be more convenient to select the logbook sample at an institution possessing the PMB microfilm collection (e.g., in Canberra, Honolulu, or Washington), and for copies of the sample microfilm then to be made available to the investigator at his own research centre. Travel costs above have been calculated on the basis that this might be Perth, western Australia. If the work were to be carried out in the United States, approximately 20 per cent should be added to the cost estimate. It seems unlikely that the work would easily be carried out in the United Kingdom because of restrictions on use of PMB microfilm.

Table 2

Data needed from industry records[1]

Category	Maximum desired	Minimum required
Ship information	Name, Rigging, Tonnage, Port of Registry, Captain, Logbook Author, Port of Origin of Voyage, Number of Boats, Crew, Date Returned, Oil Landed in Total (including transhipment) (sperm and whale oil reported separately), Total pounds of baleen	Name
Industry information (by year, for all nations)	Total barrels of oil, total pounds of baleen, by category of vessel, whaling ground and number of vessels returning	Total barrels of oil, total pounds of baleen returned by ocean

[1] This information is needed for as early as possible in the entire whaling history, particularly from those dates after which whaling was clearly a significant source of mortality.

Table 3

Minimum quality of information required for any successful analysis

Criteria
1. Original stock geographic distribution (as from Maury, 1852)
2. A series of overlapping logbooks
3. History of total catch (the minimum industry information listed before)
4. Reasonable consistency among and within logbooks, as revealed by a test of consistency (for example five or ten logbooks for each year for a decade)

Appendix H

SPERM WHALE EXTRACTION FORMAT

Vessel Name——————— Type——— Port————— Captain——————————— Ground—————— Year————

Extractor—————— Date——————

Date	Lat. Long. [Probably not required as long as ground remains the same]	No. of encounters		No. of times boats lowered	No. of Whales:				Individual barrel yield				Comments (dimensions etc) whale found dead
		Single	Plural		Struck	Killed Esc.	Killed Sank	Tried out		Sex		Sex	

HWR/4

Outstanding Whale Assessment Problems Requiring Analysis of Historical Data

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INTRODUCTION

In 1975 the International Whaling Commission (IWC) implemented a new policy for managing the world's whale resources. This is based on the concept of the Maximum Sustainable Yield (MSY).

All whale stocks have a natural capacity for increase and a natural rate of mortality. At their initial level these two factors balance one another so that the stocks remain more or less in equilibrium. As the stock is reduced in size, the pregnancy rate increases, the age at which the whales start to reproduce falls, and the total recruitment increases. At some particular stock level the surplus of recruits over natural deaths reaches a maximum (the MSY) which can be safely harvested without reducing the stock size. At stock sizes below this level, the surplus of recruits over natural deaths declines until another equilibrium is reached at very small stock levels.

The IWC, on the advice of its Scientific Committee, now identifies and classifies all species of large whales in management stocks which broadly correspond to the unit populations of the whales. The classification is revised annually and the size of the catch which may be taken from the stocks is then determined by more or less automatic rules. A stock which is more than 10% below the MSY level is given total protection from commercial fishing. This does not mean that it is endangered but merely that it is slightly below its most productive level. Stocks which are much larger than the MSY level are allowed to be harvested under quotas designed to reduce them in a controlled fashion towards this most productive level. For stocks which are already near the MSY level, the quotas are set with the intention of maintaining them at about this size. An allowance is made for uncertainties and the possibility of error in determining catch limits, so that no more than 90% of the estimated MSY may be taken from any stock.

There are supplementary rules for determining the allowable catches when there is insufficient knowledge to assess the status of the stock completely. This is especially true when exploitation has only just begun on a stock, and also when a stock has been exploited for many years at a sustainable level.

Management of the world's whale resources therefore hinges on the classification carried out by the Scientific Committee of the IWC, which in turn requires an estimate of the initial stock size before exploitation, the current stock size and the stock size supporting the MSY.

Two species of whales are of particular relevance in this classification procedure. These are the sperm whale, which is the most abundant of the great whales and represents the major target for the whaling industry, and the right whales, which were the early target of whalers before the modern era and which have been severely depleted to the point where, despite total protection from commercial whaling by the IWC, some stocks are feared to be in danger of extinction.

SPERM WHALES

Current analyses made by the IWC Scientific Committee of the sperm whale stocks in both the Southern Hemisphere and the North Pacific involve an assumption that the immediate post-war (1946) stock levels were effectively in an unexploited and stable condition, having equal rates of recruitment and mortality. They further assume that this situation had continued for at least as many years as would allow the incoming recruits, that is whales aged 15 to 20 years, to be as numerous as would be found in a population that had never undergone exploitation. If this is not a valid assumption it could make a difference to the classification of the sperm whale stocks for management purposes.

Sperm whales have been exploited to varying degrees in different parts of the world by European and American whalers in earlier years, particularly in the nineteenth century. Although this fishery had effectively stopped for several decades before significant catches were made by modern commercial whalers, particularly following the Second World War, the expected recovery rate of the sperm whale population is not very fast. The normal reproduction rate is one calf every four or five years. Thus a stock reduced by whaling to half its unexploited size in terms of the number of females would, after whaling ceased, take a century or more to regain a level of 90% of its original size. The intensity and impact of the nineteenth century whaling could be very important in this basic assumption of current sperm whale stock estimates.

A particularly important question concerns the sex and size composition of the early catches. There appear to be conflicting views on this matter. Some figures for the yield of oil per whale, sizes of teeth and other data, suggest that the large males were the focus of attention. Alternatively, it has been suggested that whole groups of animals were taken whenever the possibility occurred, which would include many females, so that the female proportion in those early catches would be much higher than in modern whaling.

The impact of the early catches could be variable in either direction in terms of current assessments. If the harem masters, which are not easily replaced during the breeding season, had been reduced sufficiently in numbers by selection, this could significantly affect the reproduction of the population as a whole and hence the number of both males and females in the following generations. Females, as well as males, could have been reduced so that again the recruitment rates would have been directly affected. A third possibility is that the males could have been reduced significantly without affecting the reproductive potential of the stock and their numbers were simply restored through the operation of normal reproduction. The consequences of all these possibilities need to be explored in detail. It is also important to try to determine which, if any of them, was the true state of affairs in the early fishery.

A recent analysis carried out by Allen and Kirkwood (1976) has attempted to explore the possible effects of nineteenth century whaling on the current assessment model used by the Scientific Committee. Using the Cohort form of the model (Allen, 1977), the response of sperm whale populations to known catches has been simulated to determine the age distribution of the population during the following years. During the initial 30-year period the population was subjected to sufficient fishing pressure to substantially reduce the exploitable population levels at the end of that time. This is the minimum time sufficient to ensure that all future recruits are derived from the reduced parent stock. Following this initial period, the population was allowed to recover for 100 years with the age distribution monitored throughout the period. Two alternative strategies were tested concerning the age of recruitment. These assumed that the early catches were concentrated mainly on the large bulls in or near the breeding grounds, and alternatively, that all available whales were taken so that many more females were captured.

If the smaller whales were taken (a length at first capture of 29 feet), it was found that a population which had been reduced to 50% of the unexploited levels recovered to 80% after 70 years and 85% after 100 years. If the exploited population was reduced to 20% of the initial level, the average recovery reached 65% in 100 years.

If only larger whales were taken (a length at first capture of 36 feet), the recovery was much improved. The average recovery of males after an initial reduction to 50% reached 95% in 70 years and 97% in 100 years. The females were less reduced initially and recovered to an average level of 94% after 45 years. When the initial reduction of the males was set at 24% then the recovery for both sexes was 87% and 90%, after 70 and 100 years respectively.

It seems unlikely that the reduction in sperm whale stocks in the nineteenth century proceeded to an extent comparable with that experienced by the bowhead or right whales or more recently the blue and humpback whales. Because of this, it seems more reasonable to assume that the populations may have been reduced to 50% of their original levels rather than something half that size. If this is the case then the catching strategy during the early fishery has very considerable importance. For a fishery concentrated on the larger animals, recovery by 1946 would have been virtually complete. If however, smaller animals were taken in significant numbers, there would still be a strong residual effect apparent in the stocks available in 1946.

There is also uncertainty as to the size and areas of operation of the early sperm whale fishery. In some areas, the North Atlantic for example, early whaling was intense and clearly affected the stock dramatically. Elsewhere catches seem to have been smaller, but it is puzzling that the early whalers moved from one location to another and travelled large distances. This suggests that they may have experienced local depletion of stocks. Basic information on the geographical distribution of catches could be very useful in confirming or modifying the present thinking on the stock identification of sperm whales. As a subsidiary to this, the history of exploitation of the various presumed stocks could yield valuable information for current assessment purposes.

RIGHT WHALES

The problems posed in the case of right whales are different from those of the sperm whales. Right whales were the early target of whaling in the open boat and hand harpoon days. Because they were slow swimming and relatively easy to catch, their numbers were depleted to extremely low levels before the controls introduced by the international agreements which preceded the formulation of the International Convention for the Regulation of Whaling in 1946. Right whales have been effectively protected throughout the world from the middle 1930s.

The major need for all species of right whales is the basic data necessary for the calculation of initial population sizes from the catch data recorded in log books and other sources. Without this initial population estimate we cannot know the relative size of the present populations and our observations can have little significance other than the overall impression that stocks are extremely low indeed.

BOWHEAD WHALES

Bowhead whales were severely overexploited in the eighteenth and nineteenth centuries following the decline of the northern right whale stocks. There are very few estimates of current stock sizes available, apart from a recent review based on cumulative catches by Mitchell (1977). It is largely on the basis of this documentation that the IWC decided in June 1977 to prohibit the catching of all bowhead whales, even by native peoples who were previously given an exemption to the commercial whaling ban imposed by the IWC.

Of particular concern is the Bering Sea stock hunted by the Alaskan Eskimos. There has been a recent trend for an increase in catching effort and an unknown, but presumed large number of whales killed or struck but lost. In this situation it is very important that reasonable estimates of the initial size of the stock should be made for comparison with the present condition. The point being that recent catches, although numerically rather small, may have been sufficient to prevent the recovery of a population reduced to the point where its very survival is in question. An increase in catches might indeed lead to the total extinction of this particular stock.

The IWC Scientific Committee (IWC, 1978) has noted that a particularly serious consequence of the present high rate of exploitation of a small stock is the attendant instability of the system in the face of environmental perturbations. These problems are worsened when the stock is at a low level relative to its initial size. The available information points strongly to the bowhead stocks being in such a state. With the current environmental modifications caused by continental shelf exploration, the situation is seen to be extremely serious. Any taking of bowhead whales could adversely affect the stock and contribute to preventing its eventual recovery, if in fact such recovery is still possible. No bowhead whale stocks have shown any discernible increase since protection began 40 years ago.

It is somewhat ironic that a species which has been given the maximum protection possible by current international regulations is the one now thought to be in the gravest danger of biological extinction. The need for a thorough examination of the initial population sizes through examination of the catch records during the height of the bowhead fishery is clearly of great significance in determining the best policy for the management and conservation of the species.

CONCLUSION

Present whale management policy for both the major target of the modern whale fishery – sperm whales, and for a protected species which has been grossly depleted in the past – the bowhead, could benefit greatly from rigorous analysis of early whaling records. In both cases, estimates of original population sizes would be invaluable in determining the best policy for current management strategies. It is fortunate that such records still exist and while the effort of extracting the necessary data may be laborious and expensive, the end results for the future of whales could be very significant and therefore extremely worthwhile.

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Methods and Data Required for Whale Stock Assessments

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INTRODUCTION

The International Whaling Commission (IWC) held its first meeting in 1949 and established a Scientific Committee. This committee proceeded to warn the IWC that the stocks of fin, blue and humpback whales were being overfished. Although a quota was established for the whole Antarctic, it appears to have been based more on the capacity of the industry than on any biological basis. In 1960 the IWC formed the 'Special Committee of Three' made up of scientists who had expertise in population dynamics and were from non-whaling countries. Their subsequent analyses have resulted in a more rigorous study of the population dynamics of whales than ever before. This paper will describe some of the more common types of analyses that have been used in assessing whale stocks and the data required for such assessments.

SUSTAINABLE YIELD

Most whale stock assessments have as their goal the estimation of the (maximum) sustainable yield (MSY). A stock in its natural, unexploited state is usually in a more or less stationary condition – neither increasing nor decreasing but relatively constant in size and having a stable age distribution. A stable age distribution implies that any given age class will be a fixed proportion of the total numbers. A stationary population has a stable age distribution and exhibits no change in numbers over time. A population which is stationary is sometimes referred to as being in equilibrium or in an equilibrium state. An equilibrium may be either stable or unstable. For example, a pendulum on a pivot is in a stable equilibrium (with respect to motion) in the downward position but in an unstable equilibrium in the balanced, upright position – a slight perturbation will cause it to swing downward.

Whales in a stock of a particular size and composition will have a certain capacity for reproduction and a certain mortality rate. The excess of reproduction and subsequent recruitment to the exploited stock over the natural deaths is a measure of the 'surplus' production. If this surplus is harvested, it will maintain the population at the same level. Hence, it is referred to as the sustainable yield (net reproduction). The fishing mortality rate that will give a particular sustainable yield is called the sustainable yield rate for that stock size. In an unexploited stock (assumed to be stationary) the recruits balance the natural deaths. As a stock is decreased by whaling, the rate of recruitment, r (ratio of recruits to stock size), increases or the natural mortality rate, M, decreases, or both. This results in an excess of recruitment over natural mortality. This rate of population increase, $r-M$, is usually maximum at about half the unexploited stock size. For baleen whales it is thought to be maximum at about 60% or more of the unexploited stock size. In order to obtain the curve relating sustainable yield to stock size, we must know (1) the largest size achieved by the stock; this is usually the level found at its unexploited or initial size, (2) the stock size giving the maximum sustainable yield (MSY), and (3) the MSY; the highest point on the yield curve (see Fig. 1). In order to obtain the largest yield, it is desirable to reduce the stock if it is much above the stock level producing MSY. If a stock is much below the MSY level, the fastest way to allow it to regain this level is to cease whaling until it does.

At present most assessments involve estimating the current and initial stock sizes. This is in accordance with the 'new management procedure' of the IWC which classifies stocks into three categories according to the ratio of current to initial stock size. Initial Management Stock – current population size is more than 20% above the stock size giving MSY (permitted catch is 90% of MSY). Sustained Management Stock – current population size is between 10% below and 20% above the stock size giving MSY (permitted catch is 90% of MSY if stock size is above MSY stock level and rises linearly from 0 at the lower limit to 90% MSY at the MSY stock level). Protection Stock – current population is below the lower limit of a sustained management stock (no allowable catch).

STOCK ASSESSMENT AND WHALE BIOLOGY

Several aspects about the biology of whales distinguish their management from that of most fishes. The very large random fluctuations in the year classes of most fishes are less evident in whale stocks while the reproductive rate of whales is rather low in comparison to fishes (Chapman, 1975). Assuming that a whale is born every other year, the gross addition to the stock will be no more than 25% of the number of adults, since the sex ratio is about even at birth (Gulland, 1974). The low reproductive rate implies a rather low natural mortality rate and M is typically in the range 0.04–0.10. The age at maturity can be high (8–10 years for sei whales) and, depending on the species, the age at maturity can be less than (southern sei whales) or greater than (southern fin whales) the age at recruitment to the fishery.

CATCH AND EFFORT DATA

A basic equation used in fisheries population analyses is

$$C_t = qf_t\bar{N}_t \quad (1)$$

which can also be written as

$$C_t = (F_t/Z_t)(1-\exp(Z_t))N_t \quad (2)$$

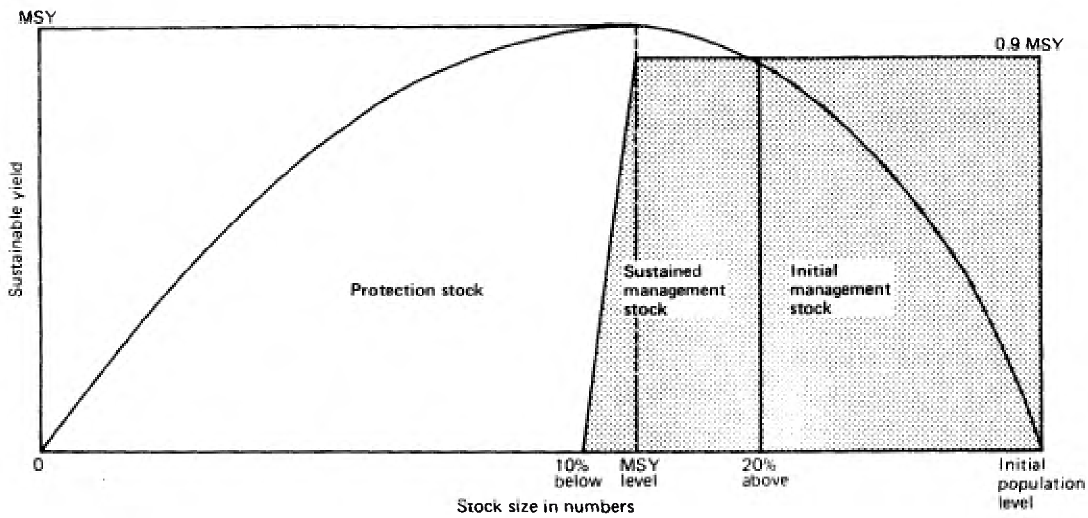

Fig. 1. Diagram showing stock classification categories, sustainable yield and allowable catch limits under 'new management procedure'.

where C_t = catch during interval $(t, t+1)$
q = constant of proportionality (catchability coefficient)
f_t = effort expended in $(t, t+1)$
$F_t = qf_t$ = fishing mortality rate
$Z_t = F_t + M$ (M = natural mortality rate)
N_t = stock size at time t
$\bar{N}_t$ = average stock size during $(t, t+1)$

Thus we have the basic assumption $(C/f)_t = q\bar{N}_t$. That is, one assumes that C/f, the catch per unit effort (CPUE), is directly proportional to the average stock size N. The ratio $(C/f)_t/(C/f)_{t+1}$ should equal the ratio $\bar{N}_t/\bar{N}_{t+1}$ if q is constant (a sometimes doubtful assumption). CPUE is used as an index of the abundance of the stock size. The decline in CPUE of the exploited stock is indicative of a decline in the exploited stock itself. This method can also be used with age-class data. The equation assumes that catch is proportional to effort and population size at all levels of both. If estimates of q and M are available, then an estimate of the stock size at the start of a season can be derived from (2). The natural mortality rate can be derived from the ratio of two successive, fully recruited age groups in the catch of an unexploited or lightly exploited population. (If M is assumed to be constant, then values obtained from successive ratios can be averaged.) In an exploited stock q and M may be simultaneously estimated by plotting total mortality rate against effort by season. The regression equation, $Z_t = qf_t + M$, can be solved using standard least-squares techniques.

Most of the analyses performed by the Committee of Three (later Four) relied heavily upon catch per unit effort data. These early analyses were based upon an examination of age-length keys, the decline in CPUE (DeLury model, etc.) and the estimation of the surplus stock for each season (Schaefer method). In addition there were data available from the marking of fin and blue whales.

In the case of whales, catch per catcher day's work (CDW) is used as an index of abundance – the catch divided by the sum for all expeditions of days spent on the whaling grounds by all catchers operating (Holt and Gulland, 1964). Catch per unit effort data typically exhibit large variations between Areas, seasons and expeditions. There has been a change over the years in catcher efficiency due to increased power, speed, navigational aids, increasing technological experience of the personnel, capacity of factory ships, fluctuations in demand for whale oil and meat and changes in regulations (Doi, 1962). To correct for the increasing efficiency of catchers, the increase has been taken to be proportional to the increase in average gross tonnage of the catchers. Gross tonnage has been found to be more closely correlated with fishing power than horsepower (Chapman, Allen and Holt, 1964). The average tonnage increased from a little over 300 tons in 1946 to about 750 tons during the early seventies (Gulland, 1974). Variations in whale catches are due not only to fluctuations in the effort expended in any month and subarea, but also to highly variable weather conditions. In addition, the migration of whales by time and place is variable.

As with many pelagic fisheries, there is often a mixed-species, mixed-effort problem. That is, effort is often given for several species and not broken down by species so that it is difficult to determine the true effort expended in catching a given species. One simple, though not wholly satisfactory adjustment is to use only CPUE data for subareas in which the catch and effort has been directed toward a single species.

DELURY MODEL

The DeLury model (DeLury, 1947) has been widely used in whale stock assessments (Chapman, Allen and Holt, 1964; Chapman, 1974). If the population is closed (to natural mortality and recruitment) except for catch, then,

$$N_t = N_0 - K_{t-1},$$

where K_{t-1} is the cumulative catch up to and including season $t-1$. The average stock size during the season is then,

$$\bar{N}_t = N_0 - K_{t-1} - C_t/2.$$

Allen and Chapman (1977) rewrite this as,

$$(C/f)_t = q(N_0 - (K_{t-1} + K_t)/2). \qquad (3)$$

This can only be used in the above form if removals due to catching are large in relation to population changes due to natural mortality and recruitment. The usual assumption that q remains constant through time must also be made. The above equation then lends itself to analysis by least-squares regression techniques.

Since the catching season is typically short (three to four months in the Antarctic) and the natural mortality rate is low, the following difference equation due to Allen (1966) can be written:

$$N_{t+1} = (N_t - C_t)s + R_t \tag{4}$$

where the survival rate $s = \exp(-M)$ and R_t is the number of recruits added to the stock during the interval $(t, t+1)$. If M is known and estimates of the R_t are available, then given a starting N_t, successive population sizes can be calculated.

If it is further possible to derive the expected catches and relate these to an initial N_t, say N_0, then the following equation can be minimized with respect to q, M, and N_0:

$$S = \Sigma(C_t - \hat{C}_t)^2, \tag{5}$$

where $\hat{C}_t$ is the expected catch in season t. Chapman (1974) utilized (4) to obtain estimates of sei whale stock sizes at the onset of exploitation by Area. He assumed that during the time period of interest, recruits came from an equilibrium stock. Thus $r - M = 0$, $r = M$, and approximately, $R_t = MN_0$. This model minimizes $(C/f)_t$ instead of C_t in (5) above. Chapman's model has been used extensively for analysing stocks which have only experienced several years of exploitation. The assumption that recruitment is constant will only be valid as long as the time between the start of exploitation and the ending period is less than the age of recruitment. It should be noted that Allen (1966) developed a technique for estimating the proportion of new recruits in the catches which does not depend on the estimates of other parameters.

MODELLING

Modelling can be a useful technique for gaining insight into population processes and is made practical with an electronic computer. Equation (4) has been employed as a simple model by specifying several functional forms for R_t, eg., $R_t = g(N_{t-K})$. That is, R_t is a function of the stock size $t-K$ seasons ago.

In most modelling applied to whale stocks, a function relating some density-dependent parameter (pregnancy rate, recruitment rate, etc.) and stock size must be specified. Doi and Ohsumi (1970) postulated a relationship between reproductive rate and number of mature whales. This became the driving function in their model which utilized various relationships among parameters in a stable population. The output, sustainable yield at different stock levels, depends on the values of the other parameters and especially upon the hypothesized relationship between reproductive rate and mature stock size.

If models such as these are properly calibrated, they can yield useful results, but more often than not there is a paucity of data with which to ascertain the density-dependent relationships. A model may not give reliable numerical results and yet still be useful in discovering the sensitivity of the results to various parameter values and functional forms.

MARKING DATA

Data obtained from marking experiments can be used to determine the distribution of whales as well as their abundance and related parameters. The proportion of marks recaptured is an estimate of the exploitation rate (catch divided by the stock size at the start of the catching period). If certain assumptions can be made, then F, the fishing mortality rate, and Z, the total mortality rate, can be estimated. Mark-recapture data are also useful in obtaining estimates of stock size (Chapman, 1972), although this is becoming more difficult due to the low numbers of recaptures.

The simplest procedure is the Petersen single-census method. M marked whales are released into the population and R marks are recaptured at a later date (to allow for dispersion) out of a total catch of C. Assuming that the proportion of the catch with marks is the same as the proportion of marks in the total population (N), we have

$$\frac{M}{N} = \frac{R}{C} \quad \text{and then} \quad N = \frac{MC}{R}$$

is the estimate of the population size. This method requires a number of assumptions in order to be valid. The Jolly–Seber Method (Seber, 1973) uses information obtained from recoveries over several years and such parameters as annual mortality rate and recruitment can be estimated.

Marking whales is difficult and costly, and relatively few have been marked in the seasons since the war. Another difficulty is that a high proportion of marks are not detected by the whaling ships (Allen and Chapman, 1977).

SIGHTING DATA

Whale sighting information is used in determining distribution of whales and may also serve as an index of abundance. Sighting models have been developed which take into account the probability of sighting a whale present in the scouting zone, speed of boat, whale's dive direction, and direction and distance of whale from observer, etc. (Doi, 1974). In obtaining population estimates from sighting data, essentially an estimate of the density in the scouting area is first obtained and this is expanded to the total area. However, there are many problems associated with sighting data: the question as to whether all the whales are seen, the problem of species identification, the varying proportion seen at different distances and under different weather conditions, and how to define the area the whales inhabit (Mackintosh and Brown, 1956).

The most common method used to analyse sighting data is the line transect method. This involves searching along a transect and observing whales and estimating their distance from the ship's track. The effective searching width is then estimated as twice the average distance of a sighted whale from the ship. Thus if n is the number of whales seen, L is the transect length, d is the average distance and A is the total area, we have

$$N = \frac{An}{2Ld}.$$

This is simply the estimated density times the total area. This method can be refined (Seber, 1973) by using a model that specifies the probability of sighting a whale at a given distance from the observer. Seber (1973) lists seven basic assumptions underlying the various methods employed. Among them are: (1) the animals are randomly and independently distributed over the population area; (2) the sighting of one animal is independent of the sighting of another; and (3) no animal is counted more than once.

AVAILABLE DATA AND SOURCES

The Bureau of International Whaling Statistics (BIWS) in Norway has records of Antarctic whaling data going back to at least the early 1930s. Most of the data is coded on punch cards and includes the species, sex, length, date, location (noon position of factory ship to nearest degree of latitude and longitude), and data on foetus, if present, for each whale caught. The BIWS also has effort data on separate cards. Data for the North Pacific are not so extensive, but Japanese and Soviet scientists distribute catch and effort data. Data for other whaling operations throughout the world are less available.

The BIWS data are summarized below:

(1) Catch data (numbers)
- (*a*) species
- (*b*) country (expedition)
- (*c*) statistical area (latitude and longitude)
- (*d*) date (day/month/year)

(2) Effort data (catcher day's work)
- (*a*) species (may be several species for given CDW)
- (*b*) country (expedition)
- (*c*) statistical area
- (*d*) date (day/month/year)

(3) Biological data
- (*a*) sex
- (*b*) length
- (*c*) number of foetuses
- (*d*) sex and length of foetuses

Auxiliary data are often available from the following:
- (*a*) special cruises and surveys
- (*b*) sighting observations
- (*c*) mark-recapture experiments

From the basic data above there are a number of biological parameters that can be estimated. Among the most important are:
- (*a*) pregnancy rate
- (*b*) sex ratio at birth
- (*c*) age and size at sexual maturity
- (*d*) age and size at recruitment to the fishery
- (*e*) recruitment rate
- (*f*) age at length (age-length key)
- (*g*) harem size, number of females per harem bull, age and size at social maturity (males) for sperm whales

It should be noted that while much of the above data and biological parameters are known for the period 1930–1970, with the decline in the total catch of the larger whales and reduction in the number of factory ships operating, there are fewer and fewer data with which to make adequate assessments. Two possibilities are to (1) more closely examine the historical data during the last 40 years, using refined methods, etc., and (2) attempt to obtain historical data on whaling activity in the nineteenth and early twentieth centuries in order to relate stock sizes and catches in this period to more recent assessments.

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HWR/8

Parameters in Sperm Whale Population Models, Needed from Historical Whaling Record, and their Sensitivity

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INTRODUCTION

Work to accurately assess whale stocks has been rapidly developing since the establishment of the Committee of Three by the International Whaling Commission (IWC) in 1960. The IWC Scientific Committee has since introduced and developed various descriptive and analytic population models.

Of all the cetaceans, the sperm whale is the most polygamous and has a most complex social organization. These remarkable characteristics make the population assessment and management of this species more complex and difficult than that of the baleen whales. Therefore, although complex population models have improved the study of sperm whale populations, correct input data of many kinds of population parameters are still needed and knowledge of these parameters is not yet satisfactory.

The author is not familiar with historical whaling records, but believes that population models will become more feasible if the historical whaling records provide new and additional knowledge of the population parameters. For example, the observations by Beale (1839) on board a whaling ship suggests that a review of some biological parameters as well as other aspects of sperm whale ecology is necessary.

Population models of the sperm whale and their parameters will be introduced in this document as material for discussion to acquire knowledge from historical records concerning these parameters, though there has already been a good review of this subject by Best (1976).

DEVELOPMENT OF POPULATION MODELS FOR THE SPERM WHALE

Biological knowledge of population parameters had been gradually accumulating for the sperm whale, but population assessment studies remained at an elementary stage until the beginning of the 1960s. The Committee of Three was nominated by the IWC in 1960 (comprising three scientists: experts on the population dynamics of fisheries resources) to assess major baleen whales in the Antarctic. Its work also affected the development of population assessment of the sperm whale.

The North Pacific Working Group was established in the Scientific Committee of the IWC in 1961. This group worked to establish a catch data exchange system among four countries (Canada, Japan, USA and USSR) of the North Pacific, and to assess whale populations. It had several meetings by 1968, and population studies including studies of sperm whale stocks developed rapidly in this area.

A sperm whale sub-committee was also established in the Scientific Committee in 1962. The sub-committee has had six special meetings (Seattle, 1963; Honolulu, 1966; Rome, 1968; Honolulu, 1970; Parksville, 1972; and La Jolla, 1976). In addition, the Scientific Committee has met annually to formulate population studies of the sperm whale. The development of a population model is largely associated with the accumulation of biological data, and more complex population models have been improved by the ecological studies of the sperm whale by the sub-committee.

The Committee of Three applied the Schaefer (1954) model, which was developed from logistic equations describing the change in numbers of human populations and extended it to blue and fin whales (Chapman, 1964). However, the model has never been used for the sperm whale. The Committee also modified the DeLury (1947) method to estimate population sizes of baleen whales (Chapman, 1964). This modified DeLury method was criticized by Allen (1966), after which he developed a technique known as the Natural Mortality and Reproduction method. Chapman (1974) further developed the modified DeLury method, and subsequently his method has been used in evaluating many species of whales. Tillman and Breiwick (1977) applied this method to estimate initial population sizes of the male sperm whale stocks in the North Pacific.

Allen (1966) used the 'least squares' or 'comparison of actual and expected catches' method to estimate population size of whales. His model has been developed into a computer program named 'CHPOP' (Allen and Kirkwood, 1977a). This method has been applied to estimate initial population sizes of male sperm whales in the Special Meetings in Parksville and La Jolla (IWC, 1973; 1977).

The Russell (1931) equation was modified and applied to whale populations by Doi, Ohsumi, Nasu and Shimadzu (1970). This method is useful in estimating trends in population size. Ohsumi and Fukuda (1972) applied this method to the North Pacific sperm whale. Allen (1973) and Allen and Kirkwood (1977b) developed a dynamic pool model (SPDYN) which enabled them to simulate the change in a population over a series of years. Allen and Kirkwood (1977c) further developed this model into the POPDYN computer model.

The 'cohort' or 'virtual population' analysis technique has also been applied to sperm whales to estimate population size. Borodin (1976) used it to estimate the 1946 population size of the male sperm whale in the North Pacific. Allen and Kirkwood (1977c; 1977d) developed a computer model of cohort analysis (SPCOH and its modification), while Holt (1977) attempted a similar type of analysis using observed changes in the size composition of male sperm whale populations.

The first trial using a population model based on age structure and population parameters was provided by Doi, Nemoto and Ohsumi (1967). They calculated sustainable yield (SY) exploitation rates under several conditions of values of the population parameters in the models for males and females, respectively. This kind of approach to estimate SY was examined and adopted by the IWC–FAO Working Group on Sperm Whale Stock Assessment, Rome, 1968 (IWC, 1969).

Ohsumi (1970) improved this kind of population model and estimated the maximum sustainable yield (MSY) as well as the population level giving MSY (MSYL) of female sperm whales, assuming the change in biological parameters with the mature female population level. Ohsumi and Fukuda (1972) further developed a population model for the male sperm whale, and examined the MSY exploitation rate and MSYL of females and males combined. Allen (1973) later modified Ohsumi and Fukuda's (1972) model and made a computer program, and further (Allen, 1977b) developed a more complex population model in the La Jolla meeting of 1976. This program was named SPVAP.

Smith (1977) developed a matrix model for sperm whale populations based ultimately on the work of Leslie (1945).

POPULATION MODELS AND THEIR PARAMETERS

Several population models for the sperm whale have been introduced here. A brief explanation of these models and their population parameters is noted as follows.

Modified DeLury method

The DeLury method (1947) estimates an initial population size from the change in CPUE and the accumulated catches under the assumption that natural mortality and recruitment are negligible. The Committee of Three (1964) modified the method to include the effects of these factors during the period under consideration. Thus the natural mortality coefficient (M), age at recruitment and recruitment rate for the parent stock (r_I) are needed as population parameters in this model. Chapman (1974) further developed the modified DeLury method. In his model, r is regarded as equal to M in the initial years until the point at which recruitment is affected by the exploitation. Therefore, only one parameter is needed in this model.

Least squares method

This method was developed by Allen (1966) and estimates population sizes by minimizing the sum of the squares of the differences between actual and expected catches from the population. It proceeds using M and recruitment rates for the exploited population (r_{II}) which are calculated from age composition data. Then, if catch, effort and age composition data are available, M is the only needed parameter in this model. The CPOP computer program (Allen, 1977a) was developed to calculate r_{II} from age composition data, and the CHPOP program was also incorporated by Allen and Kirkwood (1977a) for the least squares method.

Modified Russell equation

Russell (1931) formulated an analytic model:

$$P_2 = P_1 + (R+G) - (F+M)$$

where P_1 is the stock in the first year, and P_2 in the second. R is the annual increment in recruitment, G is the annual increment in growth, F is the annual sum of deaths due to fishing and M is the annual sum of deaths due to natural causes.

The Russell equation was modified by Doi *et al.* (1970) for whale population analysis:

$$N_{t+1} = (N_t - C_t)e^{-M} + R_{t+1}$$

where N_t is the population size in a year, N_{t+1} is that in the next year, C is the catch, M is the natural mortality coefficient, and R is recruitment. R_{t+1} can be estimated from r_I or r_{II} and population size. Thus, the parameters required in this model are M and r_I (in this case age at recruitment t_r, is also needed), or r_{II}.

Chapman's (1974) version of the modified DeLury method can also be considered as another modified Russell equation.

The SPDYN computer model developed by Allen and Kirkwood (1977b) simulates any desired population by applying a time series of catches to a population of a selected initial size and having a given combination of parameters. This is also regarded as a modified Russell equation. The following parameters are needed in this model: juvenile mortality rate (M_j), natural mortality rate after juvenile stage (M), pregnancy rate (p), harem size (h), duration of juvenile mortality rate (t_j), female age at maturity (t_{mf}), age of social maturity of males (t_{mm}), female age at recruitment (t_{rf}) and male age at recruitment (t_{rm}).

Cohort analysis

The study of the estimation of a virtual population, or sum of catches throughout the life of year classes, has a long history. If age compositions of catches in a series of years are available, cohort analysis can be applied giving an estimated value of fishing rate (E) in a year and of M.

Population model based on age structure

A mathematical model was examined by Doi *et al.* (1967) to estimate SY in a stable condition of population thus strictly determining the age structure of the population. In this model, the following parameters are needed: age at sexual maturity of females (t_{mf}), age of social maturity of males (t_{mm}), pregnancy rate (p), harem size (h), ages at recruitment of females and males (t_{rf} and t_{rm}), natural mortality coefficient (M), and the estimated SY exploitation rate in several combinations of parameters.

Population models in Rome meeting, 1968

Some mathematical population models were discussed in the IWC–FAO Working Group on Sperm Whale Stock Assessment to estimate the SY of female and male sperm whales. These models are essentially the same as the models by Doi *et al.* (1967). The surplus of recruits over natural deaths, ie. potential catches, are calculated for given parameters of the females. Pregnancy rate (p), age at maturity (t_{mf}), natural mortality coefficient (M) and age at recruitment (t_{rf}) are used for the female population model as parameters.

In the males, stability is achieved if the number of males reaching potential social maturity each year is equal to the annual replacement required. Thus a model was made to estimate the SY of males. The needed parameters in this model are the natural mortality coefficient of males before social maturity (M_1), natural mortality coefficient after social maturity (M_2), age at recruitment (t_{rm}), age at social maturity (t_{mm}), harem size (h) and pregnancy rate (p).

Population model by Ohsumi and Fukuda (1972)

The above population models only dealt with a stable population, and they were not designed to estimate MSYL and MSY. Along with the accumulation of biological knowledge of the parameters of whale populations, it has been understood that some of the parameters are density dependent. Ohsumi (1970) developed a population model for female sperm whales by applying density dependent parameters. Ohsumi and Fukuda (1972) advanced the population model of males and females combined. They established the age composition, and the natural mortality coefficient in the immature stage was calculated to be balanced at the unexploited population level by using assumed population parameters at that level. Then they assumed that several parameters are changed with the mature population level of females. Thus, SYs were calculated in each mature population level for females and males, respectively, and then the MSYL and MSY of males and females combined were estimated. The following parameters are needed in this model: pregnancy rate (p), age at sexual maturity of females (t_{mf}), age at recruitment of females and males (t_{rf} and t_{rm}), age at social maturity of males (t_{mm}), natural mortality coefficient in sexually mature whales (M), natural mortality coefficient in the immature stage (M'), and harem size (h). These parameters, except for h, were assumed to change linearly with mature female population levels.

SPVAP model

Allen (1973) modified the population model by Ohsumi and Fukuda (1972) and developed a computer program. The parameters which were used in this model were the same as those used by Ohsumi and Fukuda (1972). Allen (1977b) developed the SPVAP computer program. This model becomes more complicated and in addition, uses the following parameters: reserve per harem male (g), density dependent exponent (d) and the growth parameters of males and females (W_∞, K, T_0). MSYL and MSY by weight can be estimated from this model. Allen and Kirkwood (1977d) introduced two further new parameters to SPVAP, in SPCOH. One is the proportion of calves killed, and another is that the pregnancy rate is assumed to decrease proportionally with the number of socially mature males, when this is less than sufficient to provide fully for harem-masters and reserves.

Matrix model

Smith's (1977) matrix model allows the consideration of the state of the population as it moves toward a new equilibrium. It also allows one to determine better the effect on age of specific changes in reproductive and mortality rates on the equilibrium points using the following coefficients: natural mortality in mature stages (M), natural mortality in immature stages (M', computed to ensure equilibrium), pregnancy rate (p), age at maturity of females (t_{mf}) and a parameter in an equation in the model.

Table 1 summarises these population models and the kinds of population parameters in them. The values of parameters are either constant, variable or density dependent according to the model used.

POPULATION PARAMETERS AND THEIR SENSITIVITY

Many population parameters have been used in sperm whale population models as shown in Table 1. The polygamous behaviour of the sperm whale makes the population model more complex and means that many population parameters are needed. The sensitivity of the parameters in the population models have been tested by some authors (Doi *et al.*, 1967; IWC, 1969; Allen, 1972; Ohsumi and Fukuda, 1972; IWC, 1977; Allen and

Table 1

Population models of the sperm whale and their population parameters (up to 1977)

Models	Population parameters														Authors
	M	M_j	t_{mf}	t_{mm}	t_{rf}	t_{rm}	t_j	r_I	r_{II}	p	h	g	d	*	
Modified De Lury	C				C	C		C							Chapman (1964)
Modified-modified De Lury	C														Chapman (1974)
Least squares method	C								V						Allen (1966)
CHPOP	C								V						Allen and Kirkwood (1977a)
Modified Russell equation	C							V or	V						Doi *et al.* (1970)
Cohort analysis	C														
Population model in Rome	V	V	V	V	V	V				V	V				IWC (1969)
Ohsumi and Fukuda model	D	D	D	D	D	D				D	V				Ohsumi and Fukuda (1972)
SPVAP	D	D	D	C	C	C	C			D	V	V	V	C	Allen (1973)
SPDYN	D	V	D	C	C	C	C			D	C	C	C		Allen and Kirkwood (1977b)
Matrix model	D	D	D	D	V	V				D	V				Smith (1977)

Remarks: M, natural mortality coefficient after juvenile stage; M_j, natural mortality coefficient in juvenile stage; t_{mf}, age at sexual maturity or first parturition; t_{mm}, age at social maturity of males; t_j, duration of juvenile mortality; r_I, recruitment rate for parent population; r_{II}, recruitment rate for exploitable population; p, pregnancy rate; h, harem size; g, reserve per harem male; d, density-dependent exponent; *, growth parameters. C, Constant; V, Variable; D, Density-dependent.

Kirkwood, 1977c). The following is a brief explanation of the parameters and their sensitivity.

Natural mortality coefficient of mature animals (M)

This parameter is fundamental, and is used in every population model. There are several methods used to estimate the parameter, but it is rather difficult to get an accurate figure. This parameter is usually estimated from the gradient of the age distribution of unexploited or lightly exploited populations of the whales. However, there are many factors to be examined in order to differentiate the real rate from the apparent rate. Ohsumi (1966) examined the age distribution of the male sperm whale and compared those in the higher latitudes with those in the middle latitudes. It was found that the segregation coefficient should be considered for the middle latitudinal age distribution. When emigration according to age occurs, the apparent gradient is higher than the real one. Alternatively, when immigration according to age occurs, the apparent figure is lower than the true one. If the population has been growing in size, the apparent rate which is calculated from the gradient of age distribution is higher than the real rate. This may have been the case for sperm whale populations, which, if they had been depleted during the 'Yankee' whaling era, may have been increasing at the onset of modern whaling.

The second problem concerning this parameter is whether it is density-dependent, though changes in natural mortality rates appear to have only minor effects on MSY and MSYL (except for the mature female population level giving MSY, Allen and Kirkwood, 1977c). The difficulty in estimating the true figure of M makes it difficult to examine this problem. From the theoretical point of view in animal ecology, M should change with population level, for the intake of food per capita (and hence the general level of 'health' of the population) increases with the decline of population size resulting in a lower M value. If some information on natural mortality is available from the historical whaling record, it will serve as valuable information for the solution to this problem. Although it may be difficult to obtain the age distribution of the sperm whales directly from the historical whaling record, the record of the finding of old harpoons from whales will be useful, for the maximum life span is related to the figure of M. The age, determined from teeth which were collected in the old whaling era, will also be useful. Therefore, historical whaling materials and records may be profitably examined.

Estimates of yield and population size are sensitive to the value of M used. The former increases as M decreases and the latter is particularly sensitive if estimated using cohort analysis.

Values of M have been regarded as constant at least in the mature population, and most population models have incorporated this assumption although a thorough examination has not yet been reported. Most population models are also made under the assumption that the value of M is the same for both males and females.[1] There are some papers in which M is calculated for males and females separately. These problems should be examined thoroughly in the future to make more realistic population models.

[1] This is no longer the case and M values for males and females separately are now incorporated, e.g. IWC, 1980.

Natural mortality coefficient of juveniles (M' *or* M_j)

It is impossible to estimate this parameter directly from the age distribution, for legal size limits have been established for the taking of sperm whales since the formation of the IWC. Therefore, this parameter is estimated from other biological parameters in the unexploited population level by balancing the population at the same level. This parameter is largely concerned with the estimation of recruitment rate in a population model rather than the estimation of SY exploitation rate.

If small sperm whales were caught in the old whaling era and sufficient body lengths were recorded in historical whaling records, then this parameter may be roughly estimated from the age distribution, obtained from the length and age–length key.

One problem of M' is whether it is density-dependent or not and if it is density-dependent, whether it increases or decreases with the decline in population level. One parameter of this problem is the incidental mortality of calves dependent on their mother if the mother should be killed. This parameter is incorporated into the SPVAP population model, though it has only relatively minor effects (Allen and Kirkwood, 1977c). It will be useful to try to locate whaling record descriptions of observations addressing these problems.

Age at sexual maturity or first parturition of female (t_{mf})

This parameter is concerned with the size of mature females, a fundamental measurement in population assessment. The yield of females is set almost exclusively by the extent of the pregnancy rate change predicted by the model, its density-dependent exponent, and any reduction in age at first parturition.

The fact that this parameter is density-dependent has been known from the fin and sei whale, but this kind of evidence is not clear in the sperm whale, for the females in those populations examined, have not generally been heavily reduced. Although it may be difficult to estimate this parameter from historical whaling records, data on this parameter from the old whaling era will be useful if they are available.

Age at social maturity of males (t_{mm})

The sustainable yield of males is almost entirely dependent on the value of this parameter. It increases significantly if the parameter is taken to decline with population level. However, MSYL is not significantly affected by any changes in this parameter.

It may be difficult to estimate this parameter from historical whaling records directly, but if records of the body length of harem bulls are available, then changes in this parameter may be examined.

Age at recruitment (t_{rf} *or* t_{rm})

The population level giving MSY is affected by the value of this parameter. The lower this value is, the higher the MSYL becomes. However, MSYL is not significantly affected by the changes in this parameter with population level.

As this parameter is concerned with the legal size limit or segregated distribution of whales, the values from the old whaling era may be different from the recent figures. However, it is still important to obtain information on this parameter for the old whaling era (e.g. from body length data where recorded) to examine the recovery rates of the populations (see Gambell, 1983).

Duration of juvenile mortality rate (t_j)

This parameter is only needed to calculate M' or M_j, and is not concerned with the sensitivity of models. For this parameter, the weaning age of sexually immature whales has been used.

Recruitment rates (r_I *or* r_{II})

This parameter is needed in some population models, but it is calculated with other parameters in other models. A computer program, CPOP, was developed by Allen (1977a) to calculate this parameter from age distribution data.

Pregnancy rate (p)

This parameter is one of the most vital population parameters in terms of producing a SY. The yield varies significantly if this parameter and its density-dependent exponent change extremely. The population level giving combined MSY by weight is most affected by the extent of this parameter change and its density-dependent exponent.

However, the present question is how much this parameter changes in heavily exploited populations. Although some features of this parameter change with population level, most female populations are considered to remain stable at the higher level. Here again, data on this parameter from old whaling records will be useful.

The present method of estimating the true pregnancy rate from ovaries, the finding of foetuses, and the body length of the foetus, may not be applicable to the historical whaling record analysis. It may be possible to obtain estimates, however, through an analysis of the observation of newborn calves and the number and length records of other sperm whales seen in each school, which are available from historical whaling records.

Recently, pregnancy rate has been assumed to decrease proportionally with the number of socially mature males. This is less than sufficient to account accurately for harem masters and reserves. More analysis will be needed to confirm this assumption.

Harem size (h)

This parameter is a vital one in terms of producing SYs as well as the number of reserve males. Male SY is almost entirely dependent on the value of this parameter.

This parameter is calculated from the number of mature females in a harem school and from observations of the numbers of large males seen in the school. These data may be noted in the historical whaling records and will be most useful in confirming this parameter.

Number of reserve males (g)

Although this parameter was neglected in the earliest population models, it has become important to consider that it might be more realistic to assume that some sort of harem reserve is needed (IWC, 1977). This parameter does largely affect the SY of males. Therefore, it is important to get biological evidence on this parameter. If some descriptions on the matter were recorded in the historical data, they will serve as important information in the solution to this problem.

Density-dependence exponent (d)

All density-dependent data should be considered for this parameter, but to date it has only been considered for the pregnancy rate.

The larger this parameter, the lower the mature female population level, given the MSY of males. The MSYL of females is only significantly affected by changes in this parameter. When it is zero, MYSL is 50% of the initial. But, as this parameter increases, MSYL moves closer to the initial level.

It is difficult to examine the nature of this parameter, however. Historical trends in pregnancy rate may be useful in examining this question.

Bertalanffy parameters (W_∞, K, t_0)

When MSY by weight of both sexes combined is examined, these parameters are needed.

If there are measurement data on body weight and body length of whales caught in the old whaling era, they will be useful to check the parameters in the modern whaling age.

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HWR/5

A Note on Interpreting Historic Logbooks and Journals

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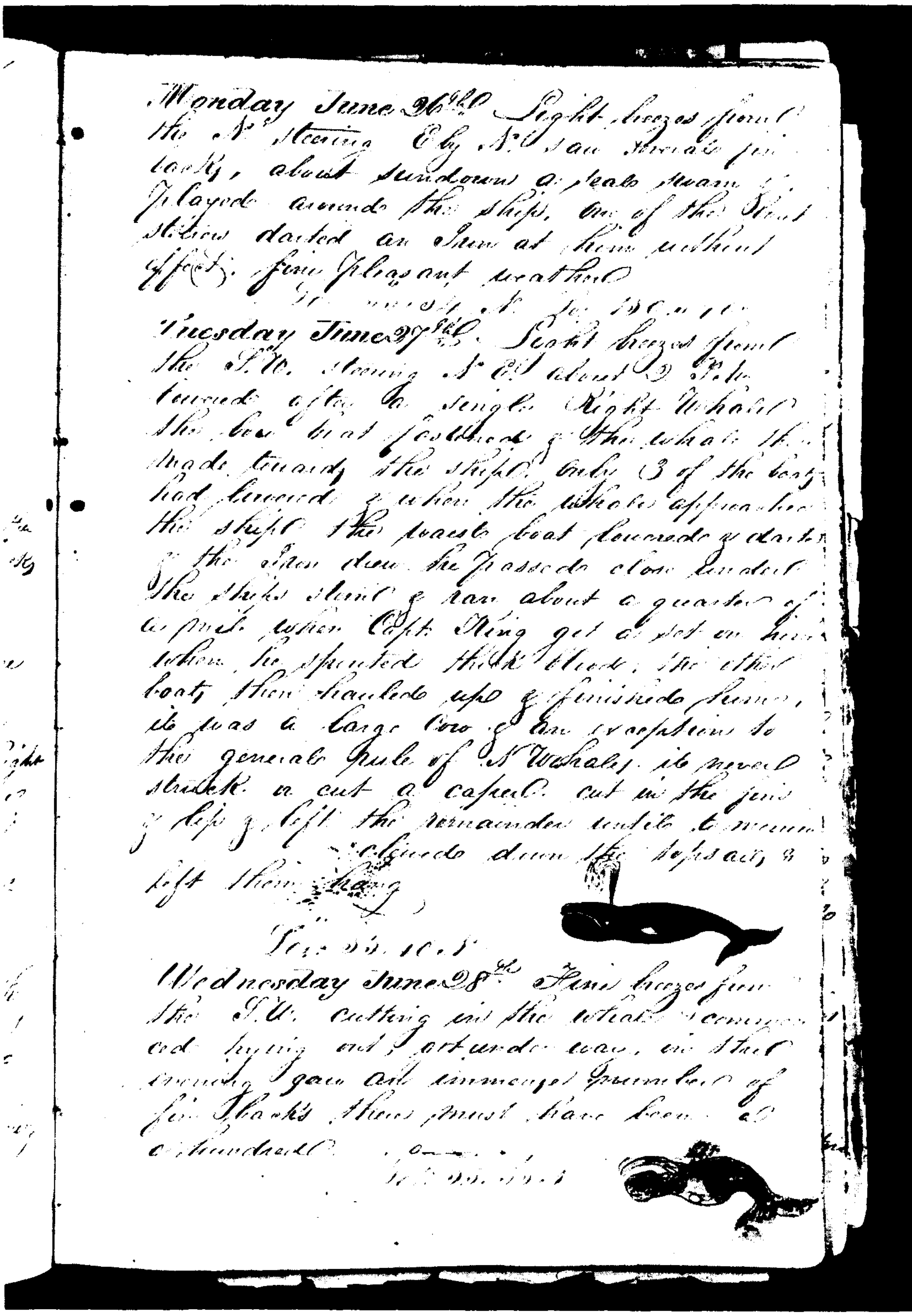
The following samples illustrate the difficulties and rewards of data extraction from journals and logbooks. As the whale fishery aged, details became sketchier and always depended upon the temperament of the journalist. Legibility and consistency of notations, as well as information included, determine each manuscript's codification potential. Information about whale encounters (species, number of individuals, travel direction, behaviour, escapement or oil yield, and other species sighted) sometimes complement navigational and meteorological data.

The first sample page (Fig. 1) is from the journal of John F. Martin, kept on board the ship *Lucy Ann* of Wilmington, Henry King, master, 28 November 1841 – 14 June 1844. Information on this encounter with a right whale includes sex, direction of travel, and behaviour during encounter. The oil yield is noted on the journal's next page (not shown). Sightings of other species are detailed. Latitude, longitude, and weather are also included. Extraction of information from this journal is simplified by Martin's consistent entries and ink drawings. His journal is also rich in watercolours and sketches of many aspects of a whaling voyage which are of major sociological interest.

The journal of J. H. Cather, kept on board the ship *Roman 2nd* of New Bedford, Seth M. Blackmer, master, provides a striking contrast (Fig. 2). Cather's journal (18 August 1854–27 October 1855) includes no latitude and longitude notations. His record of a right whale encounter reveals nothing about the size, sex, or activity of the whale. There is no information on other right whales in the area, or on sightings of other species, and unlike Martin's whale symbols which provide information at a glance, whale encounter data are difficult to spot in Cather's stampless account.

John F. Akins' journal, kept on board the ship *Virginia* of New Bedford, Joseph Chase, master, 7 November 1843–5 June 1847, is an example of a good record of a sperm whaling voyage (Fig. 3). Whale stamps make data accessible on species and oil yield of individuals taken, as well as notations of escapements. The sex, behaviour, and location within the bay of the sperm whales is recorded, and vessels sighted on the grounds are noted, as is the weather. Latitude and longitude are replaced by a location heading: 'Bouka Bay, Solomons Isles'. Like Martin, Akins filled his journal with detailed sketches and watercolours, some of historic value.

The fourth sample page (Fig. 4) is from an anonymous account of a voyage on the schooner *C. W. Morse* of New Bedford, Frank C. Morris, master, 10 May 1887–4 July 1890. It illustrates the dearth of information common to relatively late whaling records. Latitude, longitude, and weather are noted. But this sperm whale encounter is described in terms of the activity of the whalemen, not the whales. Sex, size, and number of individuals are not recorded, and there are no observations of other species. These barely legible, unadorned entries are obvious handicaps to data extraction.


Monday June 26th Light breezes from the N. steering E by N. saw [illegible] about sundown a [illegible] played around the ship, one of the boat steerers darted an Iron at him without effect. fine pleasant weather

[illegible]

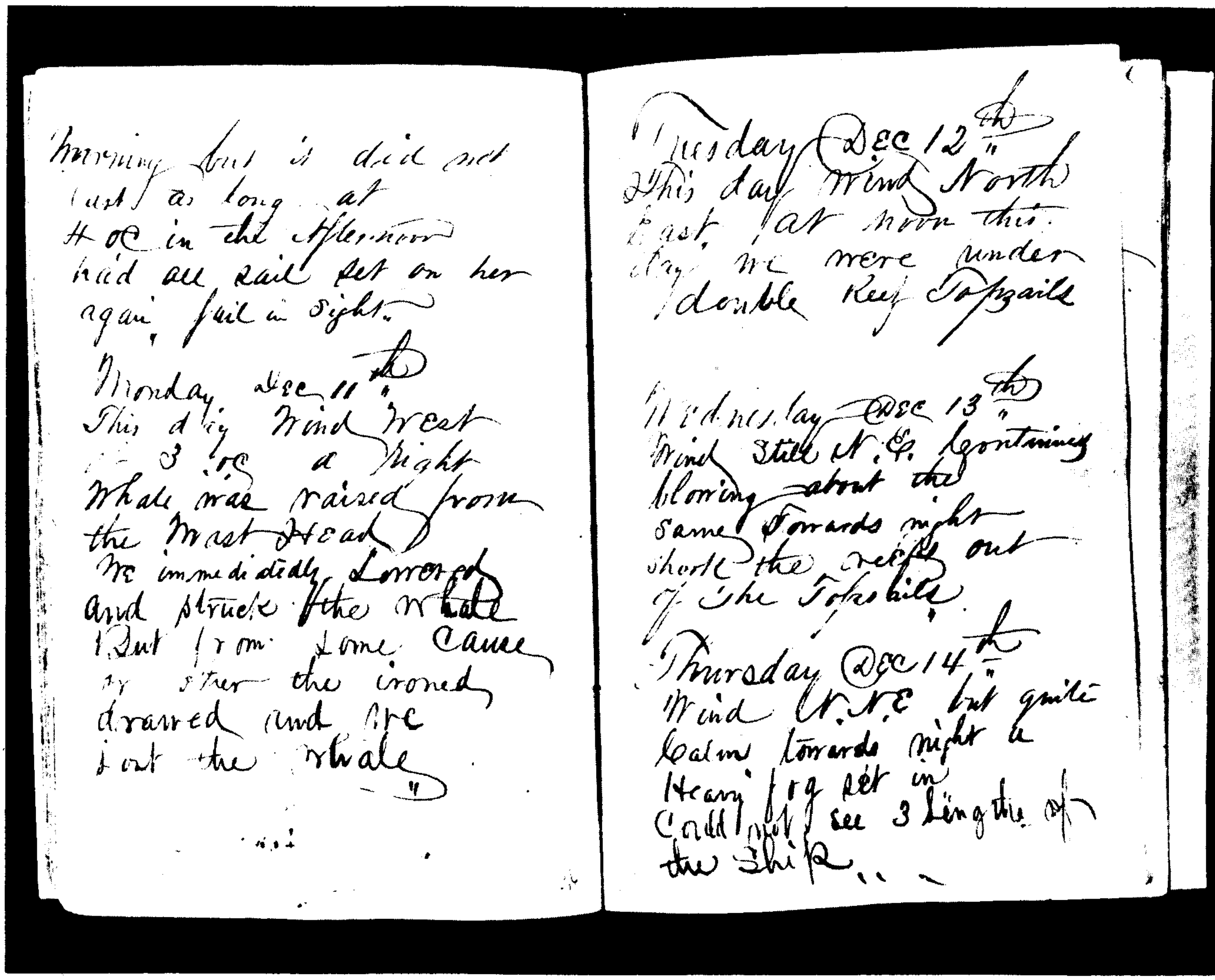
Tuesday June 27th Light breezes from the S.W. steering N.E. about 9 A.M. lowered after a single Right Whale the [illegible] boat fastened & the whale then made toward the ship, only 3 of the boats had lowered & when the whale approached the ship the waist boat lowered & darted & the Iron drew he passed close under the ships stern & ran about a quarter of a mile when Capt. King got a set on him when he spouted thick blood, the other boats then hauled up & finished him, it was a large Cow & an exception to the general rule of N.W. whales it never struck [illegible] cut a [illegible] cut in the [illegible] & left the remainder [illegible] clewed down the topsails & left them [illegible]

[illegible]

Wednesday June 28th Fine breezes from the S.W. cutting in the whale commenced trying out [illegible] in the evening I saw an immense number of fin backs there must have been a hundred

[illegible]

Fig. 1. John F. Martin, journal kept on board ship *Lucy Ann* of Wilmington, 1841–4.



morning but it did not
last as long at
4 OC in the Afternoon
had all sail set on her
again sail in sight.
Monday Dec 11th
This day Wind West
at 3 OC a Right
Whale was raised from
the Mast Head
We immediately Lowered
and struck the Whale
But from some cause
or other the irons
drawed and we
lost the whale

Tuesday Dec 12th
This day Wind North
East at noon this
day we were under
double Reef Topsails

Wednesday Dec 13th
Wind Still N.E. Continuing
blowing about the
same Towards night
shook the reefs out
of the Topsails

Thursday Dec 14th
Wind N.E but quite
Calm towards night a
Heavy fog set in
Could not see 3 Lengths of
the Ship

Fig. 2. J. H. Cather, journal kept on board ship *Roman 2nd* of New Bedford, 1854–5.

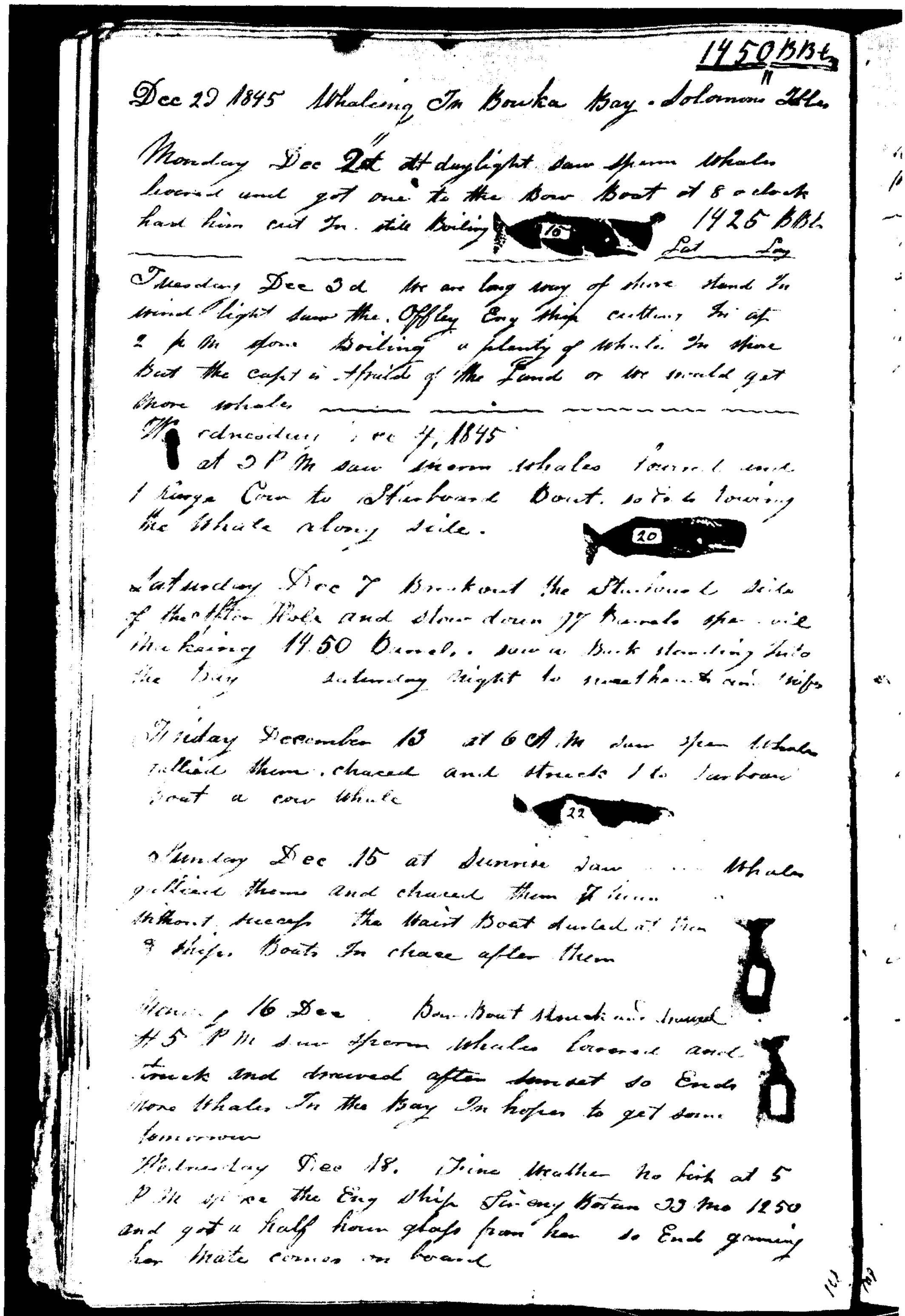
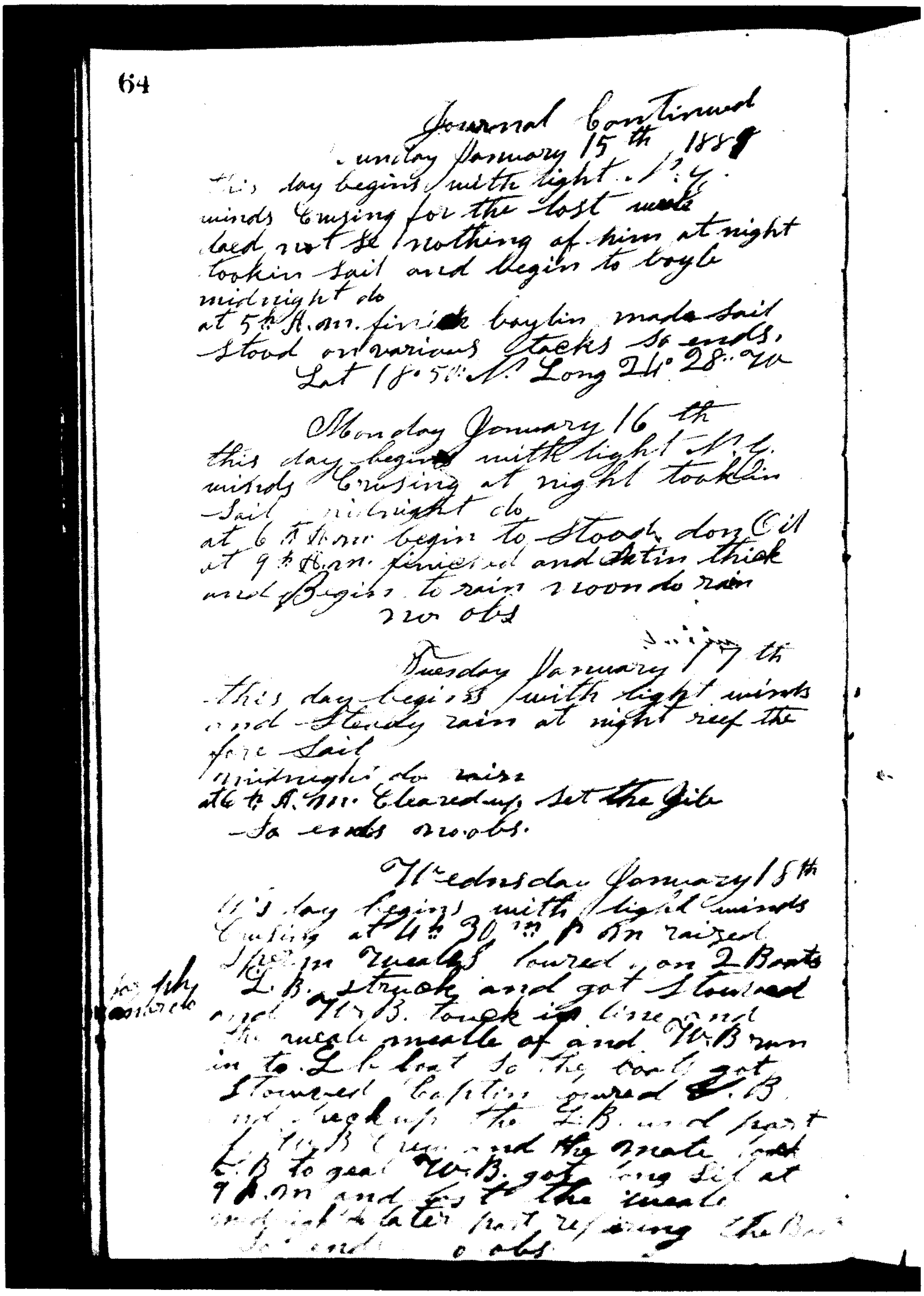


Fig. 3. John F. Akins, journal kept on board ship *Virginia* of New Bedford, 1843–7.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Journal Continued

Sunday January 15th 1888

This day begins with light N.E. winds Cruising for the lost whale but did not see nothing of him at night took in sail and begin to boyle midnight do at 5th A.M. finish boylin made sail Stood on various tacks So ends, Lat 18°50' N Long 24°28' W

Monday January 16th

this day begins with light N.E. winds Cruising at night took in sail midnight do at 6th A.M. begin to stow down Oil at 9th A.M. finished and Getting thick and Begins to rain noon do rain no obs

Tuesday January 17th

This day begins with light winds and Steady rain at night reef the fore sail midnight do rain at 6th A.M. Cleared up, set the Jib So ends no obs.

Wednesday January 18th

this day begins with light winds Cruising at 4h 30m P.M. raised Sperm whales lowered, on 2 Boats L.B. struck and got Stoved and W.B. took in line and the whale [illegible] and W.B. run in to L.B. boat [illegible] got Stoved [illegible] L.B. [illegible] the L.B. [illegible] W.B. [illegible] and the mate [illegible] L.B. to [illegible] W.B. got [illegible] at 9 P.M. and [illegible] the whale [illegible] later part repairing the Boat So ends no obs.

Fig. 4. Journal kept on board schooner *C. W. Morse* of New Bedford, 1887–90.

The Nature, Possibilities and Limitations of Whaling Logbook Data

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It is ironic that the very records that bear witness to the taking of thousands of whales may serve as an important source in the effort to preserve them from extinction. The most valuable sources of information about the whaling industry are manuscript logbooks and private journals kept on whaling vessels. Despite certain limitations, they are an untapped resource offering a wide range of information useful to anthropologists, astronomers, cetologists, economists, geographers, historians, meteorologists, oceanographers and zoologists.

This paper attempts to analyse the information relating to whales, weather conditions, and the size of the whaling fleet, which can be found in the logbook of an American whaling voyage for bowhead whales in the Western Arctic Ocean. The purposes of the study are as follows:

(1) To determine whether historical whaling records can provide the data needed for making whale population assessments.

(2) To extract information regarding the number of bowhead whales struck and lost; struck and saved; the sex, size, and species of whales taken; and the number of whales taken by other vessels. (Starbuck provides the yield in barrels, but we need to know the yield in numbers of whales.)

(3) To estimate the loss rate, ie. the number of whales taken compared to the number of attempted strikes.

(4) To note the affect of weather and ice conditions on whaling activities and the number of days when whaling was impossible.

(5) To determine the size of the whaling fleet working on a particular whaling ground.

The voyage examined is that of the bark *Pioneer* (231 tons) of New Bedford, Frederick R. Billings, master, from 24 June 1851 to 8 April 1854. This voyage was selected because it was representative of a typical three-and-one-half year voyage at the height of the industry. It occurred shortly after 1848, when Captain Royce, in the whaleship *Superior* of Sag Harbour, first entered the Arctic Ocean where he found bowhead whales in abundance. The voyage is represented by a complete logbook in the Brown University Library. The paper evolved from a Group Independent Study Project for which the author served as a faculty advisor for two seniors at Brown University.

The *Pioneer* left New Bedford for the Azores utilizing the beneficial effects of the Gulf Stream. Arriving at Fayal on 26 July, it picked up experienced harpooners and crew and fresh supplies. After two or three days, the *Pioneer* began the long passage to Cape Horn, arriving at Staten Island 7 December 1851. Between New Bedford and the Horn two blackfish and one sperm whale were taken, and three blackfish, four sperm, one humpback, and one right whale were struck but lost alive.

After rounding Cape Horn the *Pioneer* arrived 8 January at Talcahuano where the crew spent a day or two. The vessel then reached the Sandwich Islands on 1 March, and remained there for a month while the vessel was refitted for a season in the Arctic. Only two blackfish were taken on the passage north from the Horn, while a finback cow and calf were lowered for but lost.

THE NATURE OF WHALING LOGBOOKS

The logbook is the official record of a whaling voyage kept by the mate. It was a report to the owners of a business venture in which a large sum was invested. Three entries were made each day to record the working of the vessel and events on board early in the morning, at mid-day, and in the latter part of the day.

The characteristics of logbooks and private journals have been described in *The Voice of the Whaleman* (Sherman, 1965), but the information to be found in logbooks which is pertinent to this paper includes weather and ice conditions which may have had an effect on whaling opportunities; whales sighted, lowered for, struck and saved, or struck and lost, whales taken or lost by other vessels observed in the vicinity, the latitude and longitude and date on which whales were sighted, captured or lost, the size, sex, and species of whales; and the yield in oil and bone.

LIMITATION OF LOGBOOK INFORMATION

One of the characteristics of whaling logbooks is the fragmentary nature of the entries. Private journals, in contrast, tend to provide more information, and, especially, subjective responses to the day's activities on board ship. If the logkeeper gave as much attention to the habits of whales, their sex and species, the size of the pods, ice and current conditions, and details of the chase and capture, as he did to the changing of the sails three times a day, logbooks would be far more useful.

What are some of these limitations? The limited education of the logkeeper, phonetic spelling and illegible entries are characteristic.

The size, sex and age of whales captured is almost never mentioned. The species is not regularly mentioned. (In the Western Arctic, however, it may be assumed that the whales involved are bowheads unless otherwise mentioned.)

Air and water temperature is rarely recorded. Weather terminology varies somewhat from logbook to logbook.

If the mate changed vessels during the course of the voyage, one must get used to varying terminology, legibility, and terseness of entries. Partial logbooks of a voyage are, naturally, less desirable than complete logbooks, but they should not be overlooked, because they may offer the only information we have about a vessel and its yield.

Sightings of whales are not always recorded. Lowerings, however, tend to be accurately recorded. If, therefore, one is reading a logbook for a total record of whales sighted, a lowering must be tallied when a sighting is not separately recorded, since a lowering must, of course, be preceded by a sighting.

Another related limitation is the failure to note the number of whales sighted. The entry will usually note: 'lowered the boats for whales', 'lowered without success', or 'lowered for whales and took one to the starboard boat'. One rarely knows whether it was one whale or a pod which was sighted.

The entry 'lowered without success' fails to reveal whether a whale was actually struck and lost or simply that the boats failed to be deployed so as to strike. Such an omission is of concern in population studies.

The logbook rarely distinguishes between 'lost alive' and 'lost dead' after striking a whale. Only once in the logbook of the *Pioneer* was it recorded that a bowhead was struck and 'lost dead'.

The sighting of other vessels is usually noted in the logbook despite occasional vague references to 'several' or 'fifteen or twenty'. If, however, a vessel becomes involved in cutting and boiling, or sends its boats ashore for wood and water, or gets caught in the ice or a contrary current without wind, then it becomes so involved with its own problem that it may fail to note the activity of other vessels.

Despite these and other limitations, logbooks provide a primary, virtually untapped valuable resource to scholars in various disciplines.

One final limitation of this source of information should be noted. Of 13,927 voyages known to have been made by American vessels, only about 4,000 logbooks are believed to have survived (Sherman, 1965).

VESSELS SIGHTED

Vessels sighted by the bark *Pioneer* offer another record of whaling activity. Such records should, however, be used with caution. One must not accept such records as an indication of the size of the Arctic whaling fleet since it represents only vessels observed by the bark *Pioneer* on a given day. Furthermore, these records often contain repeated sightings on successive days, as will be shown. The dependability of those particular records is, therefore, in question. Careful interpretation by persons familiar with the whaling industry and its records is essential.

The difficulty of obtaining accurate figures, and the need to interpret logbook entries are revealed by the following logbook entries:

1 June 1852 10 ships in sight
2 June 1852 12 ships in sight
3 June 1852 13 ships in sight

It will be apparent to those familiar with the habits of whalemen that these vessels were whaling 'in company' and that they often remained together for several days. If approximately the same number of vessels were sighted on several successive days, they are assumed to be the same. The records above were very likely the same vessels each day, so a maximum of 13 is recorded for the three days. Another example shows:

14 June 10–12 ships in sight
15 June 15–20 ships in sight, 2 of them boiling

A conservative figure of 18 vessels sighted for the two days, with two whales taken was therefore recorded.

'Several' is interpreted as three, for the reason that if two had been sighted, then two, not several, would have been recorded.

On one day, 'sighted several ships' was written in the logbook for the mid-day entry. Then, 'sighted seven ships' was recorded for the latter part of the same day. Because of possible duplication, seven sightings were recorded.

'Several sail in sight' is repeated in the entries for 17–19 July 1851. They are interpreted as being the same vessels. Three, therefore, are recorded only once.

Logbooks do not consistently distinguish between whaling, merchant, and naval vessels when recording the sighting of a sail. Therefore, the entry 'sighted a sail' can be considered accurate only if the sighting occurred during the whaling season in the Arctic or on a whaling ground. It makes a difference where the count is made.

One more example demonstrates the problem:

1 August 1852 sighted 15 sail
2 August 1852 sighted 5 sail
4 August 1852 sighted 9 sail
5 August 1852 sighted 9 or 10 sail
6 August 1852 sighted 15 sail
7 August 1852 sighted 27 sail,
10 boiling, 2 cutting

That there were duplicate sightings on successive days appears obvious. There is little to be gained by trying to sort out duplicate sightings. Therefore, 27, which is the greatest number seen on one day, is recorded.

WEATHER AND ICE CONDITIONS

It is difficult to state precisely the number of days on which whaling could not be undertaken. Use of terms which describe the weather was not always uniform. Furthermore, vessels were not consistent about lowering in bad weather. On one day, a whale was sighted but the mate made the entry, 'Too heavy to lower'; at another time they lowered in a gale. Possibly sea conditions were not bad enought to deter them; or if a long period had elapsed without taking a whale, they might have taken a chance.

For the period 1–7 May 1852 the *Pioneer* ran into bad weather for seven days. She was south of the Aleutian Islands between 47° and 51° N. Entries in the logbook read: 'high sea', 'ship under double-reefs', 'fresh SW gale and thick', 'lay to on starboard tack', and 'strong gale from E. and thick snow storm'. No sightings of whales occurred during this period, and thus, no lowerings. But it is doubtful that whaling could have been performed safely under these conditions. Seven no-whaling days were, therefore, recorded.

On 9 May 1852 the logbook recorded 'thick snow squall latter part', but most of the day was 'light breeze and clear', so that was recorded as a whaling day.

On 30 May the rigging was so heavy with ice at 61° N 'as to make it difficult working ship'. Yet a boat was lowered for whales. On 28–30 June whales were sighted each day and logbook entries reveal uneven lowering experience during bad weather, as shown in the following:

4–6 June: At anchor closed in by ice and fog.

28 June: Strong gales and clear. 'Plenty of whales but too rough to lower.'

29 June: Strong gale and clear. Reefed. Squalls of snow. 'Plenty of whales but too rough to lower.'

30 June: Strong gales with squalls of snow and rain, but lowered, struck and drew.

A considerable amount of fog occurs in the Arctic during the summer. This was an almost constant hazard, and it placed severe limitations on sightings and lowerings. The following table shows that June and July were the foggiest months during the 1852 season:

May 1852	Fog reported only on 3 days
June	20 days of fog for all or parts of the day
July	17 days of fog for all or parts of the day
August	12 days of fog for all or parts of the day
September	11 days of fog for all or parts of the day

If fog lasted all day, it was recorded as a non-whaling day.

During the 1853 Arctic season weather and ice conditions reported by the *Pioneer* were essentially like those in 1852. There were nine days between 1 May and 31 August when whaling was judged impossible. On those days (1, 2, 8, 9 May; 21 June; 30 July; and 11, 14, 17 August) the logbook reported variously: 'thick snow storm and rough sea'; 'strong gale... thick weather and snow' with damage to the ship; 'sea too rough to lower'; and 'strong gales, thick rough sea'.

There were, in addition, about 17 other days when conditions would have made whaling difficult, if not precarious, including five days when a 4–5 knot current kept the bark at anchor most of that time. Fog was again a constant hazard and on 31 July the entry closes: 'So ends this month in thick fog; it commenced with thick fog.'

Ice was another deterrent to whaling, though not as prevalent as fog, at least according to the logbook. Despite the report of heavy ice on 25 May, boats were lowered three times. Plenty of ice was reported on 18 June with the bark hanging about the ice trying to find whales; and on 19 June the mate reported, 'Made our way through the ice with 20 other ships.'

POTENTIAL WHALING DAYS

The duration of the bark *Pioneer's* voyage, from its New Bedford departure on 24 June 1851 to its return on 8 April 1854, was 1,020 days. However, the business of whaling could not be carried on every day while at sea. Four days had to be cancelled on the way out when the *Pioneer* stopped at Fayal and Flores for recruits and supplies. About four weeks had to be excluded from whaling on the passage around the Horn. The vessel then spent 146 days at anchor in the Sandwich Islands taking on supplies and refitting for the two seasons in the Arctic. After making some educated guesses, 63 additional days must be subtracted for weather or ice conditions which made lowering impossible. Another six days must be excluded, for the period after the try-works were cast over toward the end of the voyage. In summary, then, the non-whaling days appear as follows:

Lying off and on Fayal July 1851	4 days
Rounding Cape Horn twice	28 days
At Talcahuano January 1852	2 days
At anchor in the Sandwich Islands	149 days
Bad weather in 1852 Arctic season	32 days
Bad weather in 1853 Arctic season	31 days
Try-works cast over 2 April 1854	6 days
	252 days

Thus, there were only 768 days of the 1,020-day voyage when whaling could be considered.

THE ARCTIC WHALING SEASON OF 1852

The bark *Pioneer* left Maui on 2 April for the Arctic Ocean. On 3 May boat crew watches were set which indicate that they commenced looking for bowheads. This was the probable date of the beginning of the season at 51° N, south of the Aleutians.

On 19 May in latitude 56° N and longitude 170° E the *Pioneer* 'spoke' the *Gladiator* which had sighted a bowhead that morning. Boat crew watches were again set, and on the same day lowered for a right whale without success. Two days later the *James Edward* was seen with a whale (species not identified) alongside. The *Pioneer* lowered for her first bowhead on the 22nd, but it sank after being struck.

It is estimated that the Arctic season ended on 6 September when, at 66° N near the Diomedes, the vessel began working south. Between 3 May and 6 September there were 127 days. Subtracting 32 non-whaling days left 95 working days. During that time boats were lowered for whales 52 times, or about one lowering every two days. Six bowheads were struck and lost. One sank with three lines, four irons, and two lances; another was spouting blood before stoving a boat and had to be cut loose; two were struck and drew; two were struck and lost with a line and two irons.

The total catch for the *Pioneer* for the 1852 season was seven bowheads. This was an average of 7.4 lowerings for each whale taken.

The logbook provides a clue to additional whaling by vessels 'gammed' or sighted by the *Pioneer* in the process of chasing, cutting or boiling:

Alexander	9 whales on 26 August
Alfred Gibbs	5 whales on 27 July
Baltic	3 whales on 17 July
Bartholomew Gosnold	10 whales on 2 August
Benjamin Tucker	5 whales on 23 July
Bramin	2 whales on 27 July
Cambria	9 whales on 4 August
General Scott	12 whales on 1 September
George Washington	5 whales on 23 July
Good Return	6 whales on 1 July
James Edward	1 whale on 21 May
John Howland	5 whales on 25 August
Liverpool	7 whales on 7 July
Lydia	8 whales on 20 July
Magnolia	1 whale on 21 June
Nimrod	10 whales on 20 July
Olympia	11 whales on 29 August
Triton	1 whale on 20 July
William Henry	8 whales on 20 July
Unnamed English bark	1 whale on 2 July
Unnamed vessel	1 whale on 1 July

This is an average of 5.7 whales per vessel, so the *Pioneer*, with seven whales, had a slightly better than average season among this group.

In addition to the above, the *Dover* was recorded with 1,200 barrels on 9 September; the *Herald* was seen with boats fast on 16 June, and the *Kutusoff* was seen boiling on 28 May.

It should be emphasized that this record includes only those vessels that were gammed or sighted by the *Pioneer*. They may have taken other whales after the above were recorded.

THE ARCTIC WHALING SEASON OF 1853

The 1853 season in the Arctic for the *Pioneer* was one of limited success, at least in comparison with the previous season. Only three bowheads and one gray (45 bbls.) were taken.

The commencement of the whaling season occurred about 16 May at 59° N when they lowered and struck a bowhead but were obliged to cut the line because the whale 'run in amongst thick ice', and it was left spouting blood. Seven vessels were in sight, one boiling and one cutting. They spoke the *Niger* of New Bedford boiling a humpback. Humpbacks and plenty of finbacks were also sighted the same day.

During the season, bowheads were sighted or heard at night 28 times. Boats were lowered 26 times, only four of which were successful. On 2 June one boat struck but the whale took two lines. On three days boats were lowered three times; on two other days boats were lowered but were obliged to return to the ship because of thick fog. Whales were reported frequently as very shy. There were periods in June and July when no whales were sighted for as many as 13 successive days, and up to 10 in August.

Finbacks were sighted more often this season, on nine days, the number estimated as 'several', 'four', 'plenty' or 'a number'. A right whale was sighted once. On 11 July a number of graybacks were sighted and on the following day two were struck but one iron drew and another line parted. On 15 July, though, they picked up a grayback (probably a 'stinker'). Graybacks were sighted again on 19 August, and a school of killers was seen on 28 August.

The *Pioneer* reached farthest north at 64° 57′ N on 12 July and the season ended when she began working south about 4 September.

From 30 October 1853 when the *Pioneer* left the Sandwich Islands for home there were sightings of finbacks and blackfish, and boats were lowered only twice for sperm whales, each time successfully. With those two exceptions, there were 158 days without lowerings on the passage home. They cannot be considered as non-whaling days because the weather would have permitted whaling.

OTHER WHALING ACTIVITIES OBSERVED BY THE *PIONEER*

In addition to the whales taken by other vessels which spoke or gammed with the *Pioneer* as previously noted, the logbook reveals sightings of vessels whaling in the vicinity, and the number that were seen chasing, cutting, or boiling. The following selected logbook entries reveal the nature of this information:

16 June 1852—'saw the *Herald* with boats fast'
17 June 1852—'saw 7 ships boiling and 3 more cutting'
23 June 1852—'40 sail in sight, 7 boiling and several chasing'
1 July 1852—'saw a ship take one'
5 July 1852—'10 or 15 sail in sight, most of them cutting or boiling'
7 August 1852—'saw 27 ships, 10 boiling and 2 cutting'
8 August 1852—'30 sail in sight, several boiling'

One must be cautioned about the possibility of repeated information for the same ship on successive days. Table 1 summarizes whaling activities observed by the *Pioneer* during 1852–3. In relative terms, the column labelled 'Boiling' is the most important, for it represents the end result of the other processes. Chasing may be unproductive, and cutting can be uncertain for if the weather changes suddenly, the lines holding the whale alongside may part, or the whale may have to be cast adrift. Furthermore, these figures must be considered as indicators rather than a total record since there tends to be uneven reporting of what other vessels were doing.

Table 1

Other whaling activities sighted by the *Pioneer* during Arctic seasons of 1852–1853

Season / Month	Activity: Chasing	Cutting	Boiling
1852			
May	1	1	2
June	7	4	12
July	11	12	23
August	3	5	12
1853			
May	—	2	15
June	—	7	32
July	—	1	—
August	—	4	23
Totals	22	36	119

WHALES SIGHTED

Table 2 summarizes whale sightings recorded by the *Pioneer*. This is, obviously, an unreliable record. For example, the logbook recorded 116 lowerings in contrast to the sightings. Thus, it would appear that the capture of whales was accurately recorded because it was the goal of the enterprise, that lowerings were of little importance, and sightings of even less importance.

Table 2

Summary of whale sightings by species by bark *Pioneer* 24 June 1851–8 April 1854

Species	Number
Bowheads	7
Finbacks	24
Grampus	1
Gray	3 whales and 1 school
Humpbacks	1
Killers	1 school
Porpoises	2
Sperm	1 whale and 1 school
Sulpher Bottom	2
Unidentified whales	4
Unidentified school	1
Totals	43 whales 4 schools 2 porpoises

SUMMARY OF VOYAGE

Table 3 summarizes whaling activities of the *Pioneer* as extracted from its logbook. During this three-and-a-half year voyage, the ship took or processed 20 whales, of which 16 were probably bowheads, three were sperm whales, and one was a gray whale. Some 60 whales, mostly bowheads, were also struck but lost during the voyage.

Information in the logbook concerning the whaling

Table 3

Summary of whaling activities of the bark *Pioneer*, 24 June 1852–8 April 1854

Species	Sightings	Struck, lost alive	Struck, lost dead	Recovered	Processed
Blackfish	—	7	—	—	13
Bowheads	7	28	1	—	10
Finbacks	24	2	—	—	—
Grampus	1	—	—	—	—
Gray	3 whales, 1 school	—	—	1	1
Humpbacks	1	1	—	—	—
Killers	1 school	—	—	—	—
Porpoises	2	—	—	—	1
Right	—	4	—	—	—
Sperm	1 whale, 1 school	4	—	—	3
Sulpher Bottom	2	—	—	—	—
Unidentified whales	4	20[1]	—	—	6[1]
Unidentified school	1	—	—	—	—
Totals	43 whales 4 schools 2 porpoises	59 whales 7 blackfish	1 bowhead	1 gray	20 whales 13 blackfish 1 porpoise

[1] Probably bowheads struck during the Arctic seasons.

activities of other vessels indicates that the 1852–53 Arctic whaling seasons were indeed prolific ones for the whaling industry. *Pioneer* recorded that other vessels reported taking 118 whales in 1852 and 76 in 1853. She also observed 78 other vessels cutting or boiling during 1852 and 84 during 1853. If the *Pioneer*'s known bowhead catch is also accounted for, this historical whaling record accounts for at least 203 bowhead whales taken in 1852 and 164 in 1853.

CONCLUSIONS

On the basis of the foregoing analysis of one logbook, the following conclusions are offered:

(1) Whereas the bark *Pioneer* was whaling primarily for bowheads in a relatively confined geographic area, the analysis of a logbook for a sperm whaling voyage would provide less information on the sightings and activities of other vessels. The wide distribution of sperm whales did not attract such a concentration of vessels as in the western Arctic Ocean.

(2) Despite the limitations noted throughout this paper, manuscript whaling logbooks are a primary source of information of major importance to scholars in numerous disciplines.

(3) The indexing and analysis of logbook information can be performed in a meaningful way only by specialists in various disciplines who are familiar with the subject and the nature and limitations of the literature. Interpretation of the extracted information by scholars is essential to meaningful research.

(4) Building a data bank of information extracted from up to a million pages from 4,000 surviving logbooks and journals in 60 institutions is a feasible undertaking that could release an enormous body of information useful to research in many fields. But it could be accomplished only as a major undertaking supported with massive grants. Selective indexing of logbooks for specific research, used together with other whaling sources, appears, therefore, to be a more realistic approach.

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Sperm Whale Stock Assessments and the Relevance of Historical Whaling Records

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ABSTRACT

The feasibility of using published historical records to reconstruct the catch history of eighteenth and nineteenth century sperm whaling is investigated. Production figures are incomplete, particularly for non-US whaling after 1839 and for all whaling prior to 1804. Other factors affecting their accuracy are oil sold in foreign ports, leakage from casks, oil shipped as freight and oil lost from shipwreck, fire, capture, etc. Oil yields per whale for US vessels averaged 33.58 ± 0.18 (S.E.) barrels for barks and ships, and 19.90 ± 0.92 (S.E.) barrels for brigs and schooners: there was no apparent trend in these yields over the period 1816–1925. These values, however, should be adjusted by a suitable factor to account for whales struck and lost. The distribution of catches by US whalers suggests that the North Atlantic may have been the most heavily fished stock. Measurements of catch per unit effort for the fishery are compounded by changes in whaling equipment (and hence probably efficiency) over time. In particular, whaling vessels increased in size, tryworks were installed, larger whale boats using sails and (later) centreboards were introduced, the toggle harpoon and bomb lance were developed, improvements in whale line were made and patent gear was invented for the windlass. Comparison of individual oil yield and body size with data from the modern fishery suggests that extraction was surprisingly efficient for small whales but rather inefficient for large sperm whales. It is not clear whether selectivity for larger animals occurred. A procedure for reconstructing the catch history is suggested, including a proposal that sperm whale availability be analysed through examination of the contact rate of vessels with sperm whales. Possible avoidance behaviour by sperm whales should also be investigated.

INTRODUCTION

Commercial exploitation of sperm whales falls into two main historical episodes, the first associated with primitive whaling practised in the eighteenth and nineteenth centuries where sperm whales were hunted and secured by hand-harpooning from open boats, and the second associated with modern whaling in which whales were hunted with propeller-driven catcher vessels and killed with harpoons equipped with explosive heads. The latter type of sperm whaling is almost exclusively confined to the twentieth century.

The first whalers to hunt sperm whales in an organized fashion appear to have been the inhabitants of New England from the port of Nantucket where six small sloops were engaged in deep-sea whaling by 1715. This enterprise really only expanded after 1750 when the demand for sperm oil by candlemakers increased (and the Davis Strait bowhead whaling was abandoned), but it suffered a severe setback at the advent of the American War of Independence in 1775. Very little whaling occurred thereafter until 1783 due to the loss of many vessels and the restriction of movement of others. The fishery at its peak prior to the War of Independence (from 1771 to 1775) yielded at least 45,000 barrels of sperm oil annually (Starbuck, 1878). At this time the fishery was almost completely confined to the Atlantic Ocean and to US vessels. After the war, however, the fishery steadily expanded though the reopening of hostilities between the USA and Great Britain caused a temporary setback. In 1789 the first whaler entered the Pacific Ocean via Cape Horn and in 1818 the whaling grounds in the Central Pacific were discovered. Shortly thereafter, in 1820, the Japan ground was opened up. By 1791 whalers were also active in the Indian Ocean at Delagoa Bay, and in 1823 the whaling ground at the Seychelles was discovered. Sperm whaling from the west coast of the United States (on a limited basis) apparently began around 1850. Great Britain entered the fishery around 1775, but had little success until 1785 (Beale, 1839), while France, Germany, Holland, Australia, Chile and New Zealand also participated at some time during the eighteenth and nineteenth centuries. This fishery reached its period of peak production between 1830 and 1850, when the total world sperm oil production has been estimated as averaging 146,000 to 147,000 barrels annually (Lyman, in IWC, 1969). This is estimated by Lyman to have been equivalent to an annual catch of 4,600 to 5,100 whales, while Scammon (1874) calculated that the US fishery produced an average sperm oil yield of 96,625 barrels annually from 1835 to 1872, which he estimated was equivalent to 4,253 whales killed. Thereafter the fishery declined steadily. The last true whaling voyage of this type was made in 1925 (Hegarty, 1959), although land-based fisheries using essentially the same techniques for capturing whales have persisted till the present day at Madeira and the Azores (Clarke, 1954).

Modern whaling is generally taken as starting with Svend Foyn's experiments in 1864, although this development initially only really affected the catch of the larger rorquals, principally blue and fin whales. Catches of sperm whales generally remained low until the 1930s. Thus the two 'episodes' of whaling overlapped by about 60 years (with some limited persistence of primitive whaling techniques in the North Atlantic throughout the present century). Absolute temporal separation of catches by the two types of whaling is therefore impossible, but because of the low level of catches during the main period of overlap, the choice of an arbitrary cut-off point between the two historical periods is not very significant. For the purposes of this paper, 1910 has been chosen as the start of modern whaling because reasonable data on the species composition of the catch are available from that date in publications of the Bureau of International Whaling Statistics (BIWS).

The modern whaling industry for sperm whales

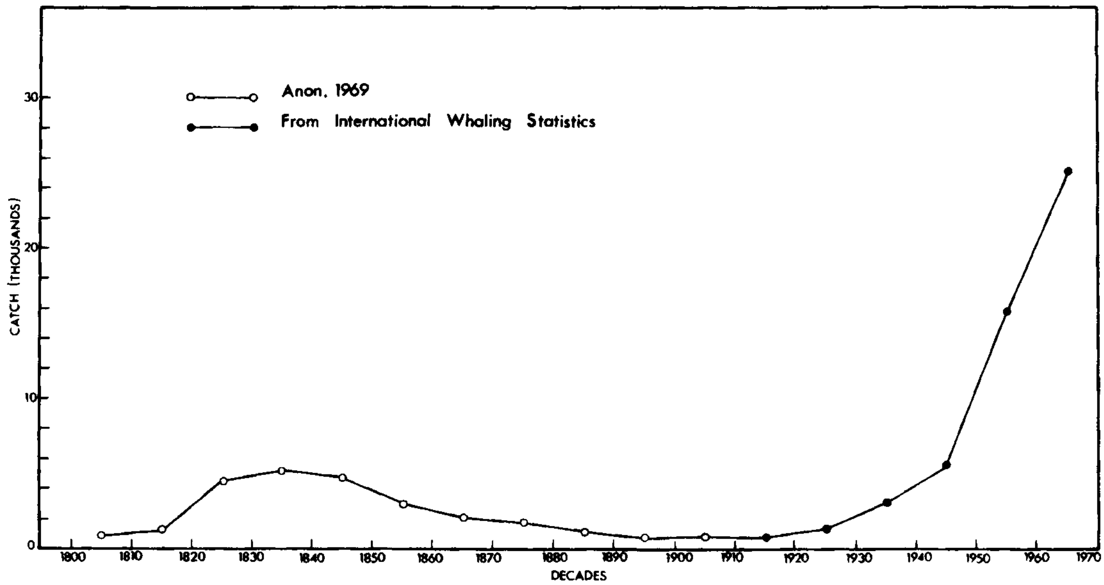

Fig. 1. Mean sperm whale catch per decade, 1800–1969.

remained at a low level from 1910 to 1930 but then began to increase substantially, particularly after the Second World War, reaching an average annual catch of 25,100 animals between 1960 and 1970. This is about five times the size of the estimated average catch at the height of the primitive fishery.

The major fluctuations in catch levels from 1800 to 1970 are shown in Fig. 1 based on data from Lyman (in IWC, 1969) and from BIWS publications.

IDENTIFICATION OF PROBLEM

In assessing sperm whale populations, the Scientific Committee of the International Whaling Commission has adopted 1946 as the base year, and equated this with the unexploited or initial population size (IWC, 1973). Given the extended history of sperm whale exploitation from the late 18th to early 20th centuries, and the long generation time for the species, reservations have been expressed over the justification for adopting 1946 as the initial population level, with its associated assumption that the population was stable at this time. It has been shown that the assumption of a positive net recruitment rate of only 0.01 in 1946 (i.e. a population slowly recovering from prior exploitation) could lead to substantially different estimates of both current and 1946 population levels, as well as of their proportional relationship to the 'real' initial level (Anon., 1976a).

Clearly this issue cannot be fully resolved until the size, nature and likely effects of the primitive catch have been further investigated. Because this fishery is already a matter of history, the type of investigation that can be carried out will depend largely on the nature of the data available. In this paper an attempt has been made to review what data already exist on the primitive fishery from published sources, this serving (it is hoped) to indicate where more information is required and whether further examination of published and unpublished historical records might provide these data. Unpublished sources have not been consulted owing principally to a lack of time and opportunity, though the author is aware that much valuable statistical information may exist in unpublished historical records.

THE SIZE AND EXTENT OF THE PRIMITIVE CATCH

Estimates of oil production

Although the officers of most of the nineteenth-century whalers seem to have recorded details of their catch in their official logs – usually in the form of daily notes on the numbers and species taken and oil yield – no detailed catch returns were ever submitted to a central authority. Thus a comprehensive set of actual catch statistics for the fishery does not exist and is certainly impossible to reconstruct now given the number of logbooks that must be lost. Sherman (1965) estimated that only 30% of logbooks and private journals relating to the US industry might survive. On the other hand, a substantial amount of information on the products of the US fishery has been accumulated, mainly based on returns in the *New Bedford Whaleman's Shipping List*, and is recorded where known for each cruise of each vessel by Starbuck (1878) and Hegarty (1959). This provides an indication of the progress of the US fishery, although records of production prior to 1804 are incomplete, and prior to 1770 are highly fragmentary.

Production figures available from 1804 may also be influenced by the following factors:

(1) Some oil was occasionally sold in foreign ports during the cruise in order to pay for repairs. Starbuck (1878) has recorded these transactions where known, but presumably many such transactions went unrecorded. Most, however, would presumably involve comparatively small amounts: in Table 1 the available data from Starbuck have been summarized and show that the average size of such sales was about 230 barrels. The extent of any bias arising from this factor is therefore probably not very great.

(2) Some oil must have been lost prior to landing due to leakage from casks. The extent of this is not possible to estimate, but it could have been more significant than sales in foreign ports (R. C. Kugler, pers. comm.). Calculations of the mean oil yield of whales taken, using Townsend's (1935) and Starbuck's (1878) data (see Fig. 2, p. 46), will already include an allowance for this factor, as they are based on the amount of oil landed.

Table 1

Sales of sperm oil overseas from US whalers, excluding sales from condemned vessels (from Starbuck, 1878)

Period (sailing date)	Total no. of vessels reported as selling sperm or unspecified oil	No. of vessels selling such oil with no amount specified	Total amount of sperm oil sold (bbls)	Average amount of sale (bbls)	Estimated total amount sold (bbls)
1820–9	6	5	139	139.0	834
1830–9	8	2	1,164	194.0	1,552
1840–9	41	6	6,431	183.7	7,533
1850–9	12	4	1,933	241.6	2,900
1860–9	5	0	2,863	572.6	2,863
Total	72	17	12,530	227.8	16,403

(3) Much oil was shipped back to the USA or to European markets as freight which was not recorded in the shipping journals and hence does not appear in the record (Starbuck, 1878). It is impossible to quantify the extent of this practice.

(4) Occasionally, vessels were wrecked, abandoned, sank, disappeared without trace, were condemned in a foreign port or were captured and burned by enemy vessels. As a consequence, the products of these cruises to that date frequently went unrecorded or were lost, although Starbuck (1878) has recorded several instances where products were salvaged or sent home prior to the disaster.

Lyman (in IWC, 1969) has used a figure of 15% as an addition to the production figures to account for both loss due to shipwreck and loss due to whales that were struck and either sank or escaped wounded.

Data presented by Starbuck (1878) and Hegarty (1959) have been analysed here in an effort to obtain a separate value for the amount of production due to vessels 'lost'. For ease of extraction, the losses are given against the year the vessel sailed from its home port and not the year it was actually lost, but the total number of losses each year is expressed as a proportion of the number of vessels (excluding freighters) returning to US ports that year. Because this procedure is not strictly accurate in a temporal sense, data have been presented in a grouped form, usually for each decade (Table 2). Vessels from which any part of the oil was salvaged or sent home prior to the disaster have been excluded from the losses recorded. This has been done in an effort to balance the fact that the vessels, when lost, must presumably have been carrying less oil on average than those vessels that returned safely to their nome ports. With this correction it is assumed reasonable to use the calculated loss rates given in the last column of Table 2 to adjust production figures proportionally. A constant value for loss rate (as used by Lyman) seems contraindicated: there is a slight, but definite tendency for the loss rates to increase as the fishery progressed, and in two periods much higher than average loss rates were recorded. Consequently the loss rate estimated for each period should be applied individually.

As a word of caution, it should be noted that the loss rates as calculated in Table 2 are for the whole US fleet (i.e. including right whalers, sperm whalers and mixed whalers), and it is possible that these different components of the fleet had different loss rates.

Besides these factors affecting the size of the reported production from the US fishery (all of which would tend to increase the production figures over those reported), there is the additional scarcity of comparable production statistics for the non-US whale fishery. Lyman (in IWC, 1969) seems to have used the percentage of non-US whalers calling at Honolulu as an indication of their contribution to the total catch. This does not appear to be entirely adequate.

Other nations involved in the sperm whale fishery included Great Britain, France, Germany, Holland, Australia, New Zealand and Chile. Published catch statistics for these countries are either unavailable, incomplete or not assembled in one place. Oil production figures available to the author for the British and Colonial fishery have been compiled in Table 3.

I have been unable to find any extensive published listing of the number of sperm whales taken or the amount of sperm oil landed in France by French whalers during the eighteenth and nineteenth centuries, and am informed by M. Thierry Du Pasquier of Paris that (so far as he knows) no such published list exists.

I have established an almost complete list of French whaling vessels from 1750 to 1868, and in most cases I know the amount of oil they

Table 2

Vessels lost to the US whale fishery due to natural and other disasters (from Starbuck, 1878, and Hegarty, 1959)

Period	Number of vessels: Wrecked (abandoned, sunk)	Condemned overseas	Burned	Captured	Missing	Lost rate (Vessels lost as mean proportion of vessels returning)
1804–9	1	1	0	0	1	0.022
1810–9	6	3	0	20	0	0.142
1820–9	17	7	1	0	1	0.029
1830–9	34	15	5	0	0	0.030
1840–9	57	36	4	0	1	0.044
1850–9	38	25	5	3	6	0.037
1860–9	30	3	1	21	0	0.059
1870–9	27	7	1	0	0	0.047
1880–9	44	5	0	0	0	0.073
1890–9	19	1	2	0	0	0.055
1900–9	14	0	1	0	0	0.065
1910–9	7	0	0	0	0	0.070
1920–5	2	0	0	0	0	0.170

Table 3

Sperm oil production of British and colonial fishery, 1800–1900 (in barrels)[1]

Year of import or export	Oil imported into GB		Oil exported to GB from Australia[3]	Oil produced in Tasmania[4]	Oil exported from New Zealand[5]
	British	Colonial[2]			
1800	10,808	—	—	—	—
1801	4,440	—	—	—	—
1802	8,848	—	—	—	—
1803	14,160	—	—	—	—
1804	15,616	—	—	—	—
1805	19,304	—	—	—	—
1806	18,704	—	—	—	—
1807	10,808	—	—	—	—
1808	13,448	—	—	—	—
1809	14,592	—	—	—	—
1810	11,280	—	—	—	—
1811	27,232	—	—	—	—
1812	15,192	—	—	—	—
1813	20,784	—	—	—	—
1814	21,560	—	—	—	—
1815	9,448	—	—	—	—
1816	28,040	—	—	—	—
1817	15,752	—	—	—	—
1818	27,184	—	—	—	—
1819	29,424	—	—	—	—
1820	21,736	—	—	—	—
1821	28,848	—	—	—	—
1822	48,088	—	—	—	—
1823	55,128	2,368	—	—	—
1824	47,424	1,200	—	—	—
1825	34,648	520	—	—	—
1826	54,687	3,726	3,985	—	—
1827	42,981	3,207	No ret.	—	—
1828	30,882	1,114	2,986	—	—
1829	43,068	7,855	8,498	—	—
1830	39,918	4,782	9,439	—	—
1831	57,030	15,134	15,086	—	—
1832	53,544	15,258	23,920	—	—
1833	33,138	25,044	33,446	—	—
1834	38,612	26,023	21,539	—	—
1835	54,072	21,702	27,828	—	—
1836	41,147	26,081	16,152	—	—
1837	29,941	25,552	24,573	—	—
1838	36,499	23,373	18,158	—	—
1839	40,811	12,695	15,153	—	—
1840	?	—	17,803	—	—
1841	?	—	16,132	—	—
1842	?	—	9,679	—	—
1843	?	—	8,105	—	—
1844	?	—	7,768	—	—
1845	?	—	12,944	—	—
1846	?	—	10,217	—	—
1847	?	—	11,658	3,415	—
1848	?	—	12,224	8,868	—
1849	?	—	8,421	3,819	—
1850	?	—	5,531	5,409	—
1851	?	—	9,804	9,096	—
1852	?	—	5,685	3,714	—
1853	?	—	1,959	3,135	—
1854	?	—	?	No ret.	—
1855	?	—	3,601	1,921	—
1856	?	—	?	1,584	—
1857	2,794[6]	—	?	No ret.	—
1858	—	—	?	No ret.	—
1859	—	—	?	2,026	—
1860	—	—	893	4,801	—
1861	—	—	?	2,958	—
1862	—	—	?	2,814	—
1863	—	—	?	No ret.	—
1864	—	—	?	No ret.	—
1865	—	—	1,248	No ret.	—
1866	—	—	?	1,287	—
1867	—	—	?	1,965	—
1868	—	—	?	5,385	—
1869	—	7,200[7]	?	3,914	292
1870	—	—	?	4,302[5]	1,143
1871	—	6,400[7]	?	6,328[5]	1,636
1872	—	5,776[7]	?	3,255[5]	114
1873	—	—	?	5,358[5]	265
1874	—	—	?	3,380[5]	265
1875	—	—	125	1,335[5]	489
1876	—	—	—	4,513[5]	870
1877	—	—	—	4,331[5]	571
1878	—	—	—	2,708[5]	705
1879	—	—	—	2,573[5]	599
1880	—	—	—	3,193	799
1881	—	—	—	1,695	—
1882	—	3,850[7]	—	2,525	—
1883	—	—	—	1,277	—
1884	—	—	—	1,296	—
1885	—	—	—	432	—
1886	—	—	—	No ret.	—
1887	—	—	—	±2,381	—
1888	—	—	—	1,373	—
1889	—	—	—	1,546	—
1892	—	—	—	499	—
1893	—	—	—	499	—
1894	—	—	—	2,026	—
1895	—	—	—	1,172	—
1899	—	—	—	749	—
1900	—	—	—	547	—

[1] One tun being taken as equivalent to 8 barrels, with all returns from 1826 (except where stated) being converted to the old wine measure by multiplying by 1.2003216.
[2] From McCulloch (1842) – except where stated.
[3] From Dakin (1938).
[4] From O'May (1957) – except where stated. Oil not declared as to whale or sperm allocated according to proportion in declared landings, while after 1868 all undeclared landings assumed to be sperm: production in 1869 assessed from value of landings using 120 pounds per tun (value in 1870 given by O'May).
[5] From Clark (1887).
[6] From McCulloch (1859).
[7] From Clark (1887) – oil conversion factor not used.

brought back. In the first half of the nineteenth century, no difference is usually made between whale oil and sperm oil, and we only know the number of sperm whales caught if we have the ship's logbook, or a detailed report from the master. In fact, even in the great period from 1835 to 1847, when there was about 50 French whalers at sea, and 20 to 30 returning each year, the total catch must have been quite small: I studied narrowly the campaigns of all Jeremiah Winslow's vessels...Out of 121 campaigns, returning to Le Havre, I counted that only 97 sperm whales were killed, or less than one per campaign. The average fishing of his ships was between 20 and 24 whales. The sperm whale oil brought back to France accounted for less than 5% of the total amount. No expeditions were made especially for catching sperm whales, and the vessels only took sperm whales when they found them on their way. The reason is that the price of sperm oil was much lower in France than in the United States. (J. Thierry Du Pasquier, *in litt.* 2 January 1978).

The German South Sea fishery started in 1836 and lasted until 1869, although it is possible that some voyages were made after that. A total of 60 voyages is known to have been made from German ports, of which 44 came from Bremen. Apparently, both sperm and right whales were taken, though as right whales decreased in number they were replaced (at the end of the 1840s and at the start of the 1850s) by bowhead whales (Oesau, 1939). Unfortunately the production statistics available only give returns of oil and baleen, with no indication of whether the oil was sperm or whale oil. The figures available for Bremen suggest a high proportion of whale oil in the returns: the

Table 4

Whale ships sailing from, and oil and baleen landed at Bremen (from Lindeman, 1869)

Year	No. of ships Baleen/Oil	Oil (bbls)	Baleen (lbs)	Baleen/ oil
1836	1	2,800[1]	20,000	—
1837	1	4,500	45,000	10.0
1838	1	4,000	40,000	10.0
1839	2	6,700	65,000	9.7
1840	2	7,000	70,000	10.0
1841	1	4,000	37,000	9.25
1842	6	20,050	181,000	9.03
1843	1	4,000	31,000	7.75
1844	4	11,900	90,200	7.6
1845	7	17,800	161,000	9.0
1846	2	7,900	93,000	11.8
1847	—	—	—	—
1848	1	4,000	27,000[2]	—
1849	2	—	—	—
1850	2	—	—	—
1851	3	—	—	—
1852	2	—	—	—
1853	—	—	—	—
1854	—	—	—	—
1855	1	—	—	—
1856	1	—	—	—
1857	3[3]	—	—	—
1858	1	—	—	—
1859	—	—	—	—

[1] Offloaded some of cargo elsewhere.
[2] According to Watjen (1914), part of this cargo was offloaded elsewhere.
[3] Ships did not return to Weser.

number of pounds of baleen per barrel of oil landed each year between 1837 and 1846 varied from 7.6 to 11.8 (Table 4). Starbuck (1878) gives the normal yield for right whales as from 8 to 10 pounds of baleen for each barrel of oil, with the yield for bowheads much higher. As the accent was apparently still on right whales until the late 1840s, the figures given in Table 4 would suggest that very few sperm whales were taken. Lindeman (1869) commented that the Germans were never involved in the South Atlantic sperm fishery, despite the smaller capital outlay involved and the favourable situation of their ports.

The Dutch attempted to enter the South Sea Fishery by chartering an American vessel in 1826. Thereafter five more expeditions were mounted, but in general the results were disappointing. For four expeditions the combined total of sperm oil produced only amounted to about 1,200 barrels, on a fifth a total of 16 whales (species unknown) was caught, and on the sixth 2,000 barrels (of which at least 300 barrels were sperm oil) are known to have been taken. The last Dutch vessel to attempt southern whaling returned in 1849 (Broeze, 1977).

Although there was a Chilean whaling company in the latter years of the nineteenth century, which purchased at least two New Bedford ships (E. A. Stackpole, *in litt.* 27 November 1977), I have been unable to trace any production or catch figures for this operation. It appears from a trade review for 1869 that a considerable quantity of the sperm oil produced by the Talcahuano fleet was imported into England (Clark, 1887).

In Table 5 oil production figures from Table 3 are summarized with oil production figures from the US fishery, and indicate that the contribution of non-US vessels was substantially larger for the period 1800 to 1839 than was suggested by Lyman, and when full

Table 5

Summary of US and British sperm oil production by decade, 1800–1929

Period	Total importation (bbls) from Starbuck (1878) & Hegarty (1959)	Total British and colonial production (bbls) from Table 3	Proportion of non-US production
1800–9	119,100[1]	130,728	0.52
1810–9	147,262	205,896	0.58
1820–9	649,511	430,254[2]	0.40
1830–9	1,263,344	650,661[2]	0.34
1840–9	1,305,834	114,231[3]+	0.08
1850–9	856,507	45,683[4]+	0.05
1860–9	536,156	28,551[5]+	0.05
1870–9	424,537	47,272[5]+	0.10
1880–9	246,170	17,842[5]+	0.07
1890–9	138,207	4,945+	0.03
1900–9	163,794	No data	—
1910–9	130,466	No data	—
1920–9	36,160[1]	No data	—

[1] Years for which no data available adjusted on a pro-rata basis.
[2] Higher value for colonial or Australian production adopted each year.
[3] Tasmanian production included in Australian figures.
[4] Higher value for Australian or Tasmanian production adopted each year.
[5] Australian and Tasmanian production considered separate, figure for total colonial production accepted when higher than Tasmanian plus New Zealand.

production figures for Britain and other nations become available, then presumably the non-US contribution will be even higher.

Once an acceptable estimate of total oil production is available, this can provide estimates of the total kill, provided the average oil yield per whale is known.

Average oil yield per whale

Scammon (1874) estimated that sperm whales (taken between 1835 and 1872) averaged 25 barrels each.

Bennett (1840) gave the oil cargo of the vessel on which he travelled from 1833 to 1836, *Tuscan*, as 1,953 barrels. This came from 78 whales that were killed and secured to the ship. This also gives a mean oil yield of 25 barrels per whale.

The English whaleship *Cyrus* took 63 sperm whales during the voyage which ended in 1806, and landed 163 tuns of oil, or 20.7 barrels per whale (Stackpole, 1972).

Townsend (1935) showed that the average oil yield of sperm whales taken by two vessels that made exceptionally large catches was 22.5 and 30 barrels respectively: this included whales killed and brought alongside but subsequently lost.

On the other hand, Hopkins (1922), in discussing a whale which made just over 47 barrels, stated that this was 'pretty near the average.... The average is always called "five and forty".' A figure of 40 barrels has apparently been adopted elsewhere as an indication of the mean oil yield (Kugler, 1981). It is just possible, however, that some confusion may have arisen between the yield from a medium-sized (or 'average') whale, and the average oil yield of the whales caught. Ashley (1938), for instance, stated that a whale that cut in at a 'mere forty-five barrels was just average'.

Lyman (in IWC, 1969) listed figures for the average number of barrels per whale for each decade from 1800 to 1929. The source of his data is not stated, but he would seem to have combined the oil cargo given by Starbuck (1878) for a particular cruise with the number of whales recorded for that cruise by Townsend (1935).

This combination of Starbuck and Townsend's data has also been made in the present paper. All cruises listed by Townsend on which less than 10 sperm whales were taken, however, have been excluded, as these were considered likely to increase the variability of the data. Some subjective culling of the data also had to be made. For instance, when it seemed clear that Townsend's information did not cover the whole cruise (i.e. when a considerable amount of whale oil and bone was declared by Starbuck but no baleen whales were recorded by Townsend, it would not be used). All cruises on which the calculated mean oil yield per whale exceeded 100 barrels were also excluded, as such a figure was considered unrealistically high. Finally, data were available for a total of 832 cruises. The mean oil yields per whale obtained were then summed for each decade, and their frequency of occurrence (grouped at five-barrel intervals) is shown in Fig. 2.

During a preliminary examination of the data, the impression was gained that oil yields for brigs and schooners might be lower than for ships and barks, so the data were extracted separately for the two classes of vessels (Fig. 2). The distribution of oil yield for brigs and schooners was then compared with that for barks and ships in five periods for which sufficient material existed (1850–59, 1870–79, 1880–89, 1890–99, 1900–25), and in each the oil yields per whale for the smaller vessels were significantly lower than for ships and barks (Mann–Whitney U test, two-tailed $P < 0.00014$; < 0.0062; < 0.0006; < 0.0028; and < 0.00014 respectively). This conclusion suggests either that brigs and schooners were taking smaller whales or that their efficiency of oil extraction was less than that of the larger vessels. Evidence given by Seabury (Clark, 1887) suggests that female sperm whales in the North Atlantic (where brigs and schooners normally operated) were considerably smaller than in the Pacific Ocean, but there may also have been technological reasons why a lower oil yield per whale was obtained by these smaller vessels. Whatever the reason, it is clear that for the purposes of examining trends in the average oil yield, data for the two classes of vessel must be considered separately.

A regression has been fitted by the method of least squares to the oil yield for ships and barks from 1816–29 to 1900–25, giving the estimating equation

$$y = 34.49 - 0.21x,$$

where $x =$ the time interval ($1816\text{–}29 = 1$ and $1900\text{–}25 = 9$) and $y =$ the mean oil yield per cruise in barrels. The regression coefficient is not significantly different from zero (t test, $P > 0.4$, 723 df), indicating that there was no definite trend in the oil yield per whale throughout the period under review. An overall mean value of 33.58 ± 0.18 (S.E.) barrels per whale can be calculated for this class of vessel.

A similar regression has been calculated for the data from brigs and schooners, giving an estimating equation

$$y = 21.32 - 0.20x,$$

in which the regression coefficient is not significantly different from zero (t test $P > 0.6$, 105 df). Thus there is also no trend in the oil yield per whale for brigs and schooners in the period covered by the data. An overall mean value for all 107 cruises can be calculated as 19.90 ± 0.92 (S.E.) barrels per whale.

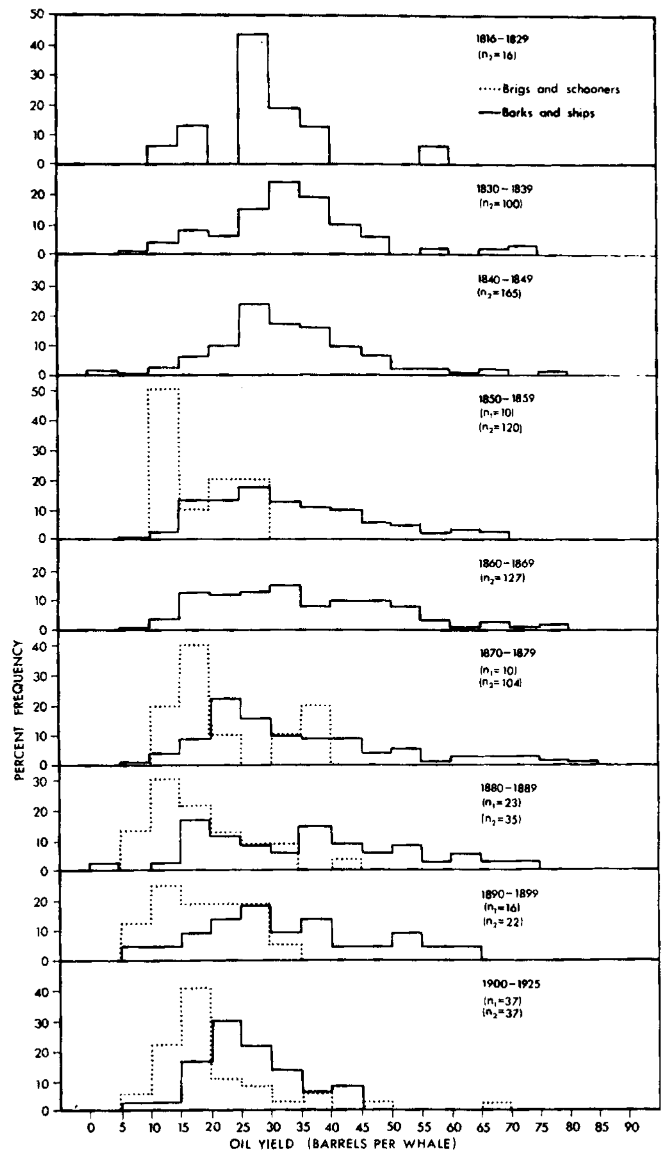

Fig. 2. Mean oil yield per whale per cruise for U.S. whaling vessels.

Because of the considerable difference in oil yields between these two classes of vessels, no one figure for the number of barrels per whale can be used for all vessels throughout the history of the fishery, and in order to provide a meaningful estimate of the mean oil yield in any period, it is necessary to know the relative contributions of oil cargoes from brigs and schooners and from ships and barks.

Although the numbers of brigs plus schooners and ships plus barks returning to the US each year are listed by Starbuck (1878), only the total amount of oil imported is given, with no breakdown by vessel-type. It is not possible to use the proportions of the two vessel-types returning directly as an indication of their relative contributions to the amount of oil imported each year, as the smaller vessels had a smaller capacity than the larger ships and barks, and so on average probably landed a smaller cargo. Time has precluded calculations of this nature which could easily be done from data available in Starbuck (1878) and Hegarty (1959).

It must also be remembered that oil yields per whale for non-US vessels might be somewhat different, and information on at least the proportions of oil taken by brigs and schooners and by ships and barks should be extracted if possible.

Whales lost before processing

Apart from the question of the average oil yield of the whales taken, there is the problem of the number of whales that were struck and lost, either through dying and sinking, or from escaping mortally wounded after they had been harpooned or lanced (note that the data given by Townsend (1935) and used to calculate mean oil yields above include those that were lost after being brought alongside, and presumably also those that were damaged by sharks while alongside). The chances of a sperm whale sinking after death were apparently less than for any of the baleen whales (Hohman, 1928). However quantitative data on this aspect of the fishery are lacking (sinking occurred in 'some few examples' – Bennett, 1840 – or 'rarely' – Davis, 1874). Obviously the proportion of mortally wounded whales that escaped can only be estimated. From logbook examination it should be possible to extract information on the number of whales lost through sinking, and also on the number of whales struck that escaped. For the latter, a factor accounting for those that were actually mortally wounded will have to be developed. If such data exist, whales recorded as spouting blood before escaping, or whales which escaped after being lanced as well as harpooned, might be considered as being mortally wounded.

In the absence of any data to contradict or confirm it, Scammon's (1874) factor of 10% to account for 'whales mortally wounded, lost after capture, etc.', could be adopted as a preliminary estimate of whales struck and lost. This would effectively lower the calculations of mean oil yield per whale to $0.909 \times 33.58 = 30.52$ barrels for barks and ships and $0.909 \times 19.90 = 18.09$ barrels for brigs and schooners, these yields then referring to the total number of whales killed rather than the whales brought alongside.

Geographical distribution of catch

Apart from the question of how many whales were taken, there is the question of where the primitive whaler made his catch. The history of the development of the fishery shows one whaling ground being discovered after another (see Introduction), and it is possible that different stocks of sperm whales were exploited at different rates, either for reasons of history, climate or convenience.

The Scientific Committee of the IWC has recognized the North Atlantic, North Pacific and nine separate 'Divisions' of the Southern Hemisphere as appropriate stock units. This has been done either in recognition of evidence for stock identity (or, where no such evidence existed, of major whaling grounds), or simply for convenience in manipulating the data (IWC, 1973; Best, 1974). Whether these actually correspond to separate populations is still a moot point: independent information on sperm whale distribution and migrations contained in Maury's detailed analysis of sightings from the primitive fishery (Maury, 1852 *et seq.*) has not been considered yet apart from in the North Pacific (Bannister and Mitchell, 1980), and could well provide useful data to complement modern analyses. In the meantime the IWC's 'stock' guidelines have been followed in an attempt to analyse distribution of the primitive catch. The charts given by Townsend (1935) show the positions of US eighteenth and nineteenth century whaleships (as given in their logs) on days when one or more sperm whales were taken, though in particularly well-frequented areas the positions of captures fell so thickly on the map that an estimated 10 to 20% of the available records were omitted. The number of individual data points has been counted for each of 11 different regions considered to correspond to sperm whale stocks as follows:

(1) North Atlantic (including the Gulf of Mexico, Caribbean Sea and Mediterranean Sea).

(2) North Pacific (westwards to 100° E). In this ocean, catches 'on-the-line' were separated into two northern and southern populations by drawing arbitrary lines that seemed to separate areas of high whale density close to the equator with those more distant from it. In April to September (the austral winter and boreal summer) this line ran approximately along longitude 8° N, while in October to March (the austral summer and boreal winter) it ran approximately along 6° S. This procedure was adopted to account for the differing seasonal migratory patterns of Northern and Southern Hemisphere sperm whales.

(3) South West Atlantic (south of the equator and between 60° W and 30° W).

(4) South East Atlantic (south of the equator and between 30° W and 20° E).

(5) South West Indian. (All waters in Indian Ocean between 20° and 60° E, including those north of the equator, in the Red Sea and the Persian Gulf.)

(6) Central Indian. (All waters in Indian Ocean between 60° and 90° E, including those north of the equator.)

(7) South East Indian. (All waters in Indian Ocean between 90° and 130° E, and including those waters north of the equator between 90° and 100° E. East of 100° E the northern boundary of this region was taken as the arbitrary line mentioned above, either north or south of the equator depending on the season.)

(8) East Australian. (All waters between 130° and 160° E, with the northern boundary being taken as the arbitrary line mentioned above).

(9) New Zealand. (All waters between 160° E and 170° W, with the northern boundary being taken as the arbitrary line mentioned above.)

(10) Central South Pacific. (All waters between 170° and 100° W, with the northern boundary being taken as the arbitrary line mentioned above.)

(11) South East Pacific. (All waters between 100° and 60° W, with the northern boundary west of 70° W being taken as the arbitrary line mentioned above, and east of 70° W as the equator.)

The results are shown in Table 6. Only 21,336 catch positions could be counted, whereas these are said to represent a total number of 36,908 sperm whales killed (Townsend, 1935). Individual counts for each region have therefore been increased on a pro-rata basis so that they total 36,908 and are taken to approximate to the number of whales killed in each region. However, Townsend (1935) only examined material pertaining to 1,665 voyages, whereas 13,927 voyages are known to have been made by American vessels (Sherman, 1965). It cannot be assumed that the catch distribution shown in Table 6 is

Table 6

Distribution of US sperm whale catches in the primitive fishery by stock division

Region	Townsend (1935)			Distribution of population	
	No. of catch positions	Whales killed			
		No.	%	No. ($\times 10^3$)	%
N. Atlantic	4,112	7,113	19.3	22.0[1]	2.3
N. Pacific	5,082	8,791	23.8	330.0[2]	35.0
S.W. Atlantic	1,143	1,977	5.4	32.7[3]	3.5
S.E. Atlantic	1,825	3,157	8.6	87.1[3]	9.2
S.W. Indian	1,461	2,528	6.8	101.4[3]	10.8
Central Indian	407	704	1.9	61.0[3]	6.5
S.E. Indian	1,165	2,015	5.5	57.8[3]	6.1
E. Australian	525	908	2.5	29.8[3]	3.2
New Zealand	1,965	3,399	9.2	42.0[3]	4.5
Central Pacific	1,676	2,899	7.9	96.2[3]	10.2
S.E. Pacific	1,975	3,417	9.3	82.6[3]	8.8
Total	21,336	36,908		942.6	

[1] IWC (1973).
[2] IWC (1978).
[3] IWC (1977).

typical of all these voyages, as it is clear that there were few logbooks available to Townsend from the period prior to 1830, when (for instance) there may have been a greater emphasis on catching in the Atlantic. Furthermore, the distribution of catches by non-US fleets must be taken into account, and without some investigation it would not be justified, on purely geographical grounds, to assume that such fleets operated in the same areas to the same extent as the US fleet.

Despite these reservations, the distribution of US catches from Townsend's data makes an interesting comparison with the distribution of sperm whale population sizes, the latter being taken from recent estimates of 'initial' (usually 1946 or 1947) or (in the case of the North Atlantic) 'current' populations (Table 6). It seems that a disproportionately large number of animals was taken from the North Atlantic Ocean relative to other areas, suggesting that if signs of overexploitation by the primitive fishery are to be detected, these might be most obvious in this region. It should be added that Townsend's data contain very little information prior to 1800: sperm whale catches were largely confined to the Atlantic Ocean prior to 1775, when production reached at least 45,000 barrels a year at the peak of the fishery (Starbuck, 1878).

EFFECT OF THE PRIMITIVE FISHERY

Ignoring short-term effects due to war and natural disasters, the progress of the US sperm whale fishery (using the annual importation of sperm oil as a measure of success) showed a development phase from 1715 to about 1820, a period of relative stability for about three decades, followed by a gradual decline till its termination in the third decade of the twentieth century. Inasmuch as the fishery originated in the USA, and as the US contribution to it over time was overwhelmingly the largest of all nations, the progress of the US industry can be said to represent the progress of the sperm whale fishery as a whole. Great Britain apparently ceased sperm whaling in 1853 (Anon., 1888), and France had no whaling fleet after 1866 (Clark, 1887).

What caused the decline of this industry from the mid-nineteenth century? Did it reflect a corresponding decrease in the availability of sperm whales, or were there other, non-biological causes that were more important? Opinions expressed on this subject vary widely. Starbuck (1878) listed the reasons for the decline as: (1) the scarcity and shyness of whales, requiring longer and more expensive voyages; (2) extravagance in fitting-out and refitting; (3) the character of the men engaged; and (4) the introduction of coal oils.

Hohman (1928) considered that 'foremost among the proximate causes of decay' of the industry was the loss of whaling ships due to the Civil War and mishaps in the Arctic. Between 1861 and 1866 vessel tonnage fell by 57% and the number of ships by 49%, mostly lost as prizes of war or sunk in blockades. In addition, 33 whalers were lost in the Arctic in 1871, with another 12 lost in 1876 and five in 1888 (although these were not primarily sperm whalers). Hohman considered that the 'most potent single cause of whaling decay' was the growing use of petroleum, which was competing successfully with sperm oil throughout the 1860s, 1870s and 1880s. He did not consider the deterioration in the character of crews to be a major cause of the fishery's decline.

Kugler (1981) was also of the opinion that the causes of decline were largely due to increasing competition from other sources of illumination. In his opinion, the decisions of whaling merchants to curtail or withdraw from sperm whaling were determined by factors that had less to do with attitudes about whale populations than with considerations of the market place.

Shuster (1972), however, did not accept the point of view that problems of demand rather than supply were responsible for the decline of the industry. He analysed production figures for US sperm whalers (i.e. those bringing home only sperm oil) operating in the Pacific for the period 1820 to 1849, and showed that oil production per ton of boat fell overall during the period but particularly after 1844. He concluded that excessive depletion of sperm whales was a major factor in the decline of the industry, though reduced demand for the product may have exercised an influence as well.

Published accounts by men with a first-hand knowledge of the fishery also differ in their interpretation of the situation. Beale (1839), in discussing the production of the British fishery up to 1836, stated that 'We perceive scarcely any or no diminution in the proceeds of the fishery'. He also made the following interesting observations concerning sperm whales on the Japan ground:

> the whales scarcely appear to be reduced in number. But they are much more difficult to get near than they were some years back, on account of the frequent harassing they have met with from boats and ships; so that they have now become well aware of the reckless nature of their pursuers, and they evince great caution and instinctive cunning in avoiding them.

Bennett (1840), referring to the period 1833 to 1836, stated that

> from the abundance of calves, accompanying the schools, and the great number of Sperm Whales yet visible, notwithstanding the incessant slaughter to which they have been exposed for nearly a century and a half, we are justified in believing that this species is peculiarly prolific.

Cheever (1851), however, who was apparently aboard the *Commodore Preble* sometime between 1842 and 1845, made the statement that

> it would seem, indeed, as if there could be very few sperm whales in the ocean of age, that have not been some time or other chased by

> a whaler, and their numbers are getting so greatly reduced, that the sperm whale fishing alone will not be much longer attempted.

That whalemen were indeed divided in their opinions is shown by the contents of a letter from the American consul (F. M. Ringgold) in Paita to the Assistant Secretary of State dated September 1858 (Hohman, 1928):

> whales have either become much more scarce, which some of the most experienced masters affirm – or they have become more knowing, more cautious and wilder – as others equally experienced assert.

It is clearly important that reasons for the decline of the primitive fishery should be fully investigated, for if a reduced abundance of sperm whales was a contributory factor it would have considerable significance in our understanding of the species' population size and dynamics. An analysis similar to that of Shuster (1972) might be useful in determining whether a reduced availability of sperm whales did occur. However, following the remarks of Beale (1839) and Ringgold (see above), a distinction should be made between reduced availability due to a scarcity of whales and reduced availability due to a change in sperm whale behaviour (the 'shyness' mentioned by Starbuck, 1878). In order to make this distinction, logbook records should be examined for (*a*) the number of days on which whales were seen as a proportion of the number of days searching, and (*b*) the number of times boats were lowered as a proportion of the number of sightings, and/or the number of times boats were lowered and whales fastened as a proportion of the number of times boats were lowered.

Apart from being able to determine whether a decline in sperm whale abundance did occur, however, there is the question of whether this decline could be measured quantitatively so that rates of change could be used to reach estimates of population size (i.e. by methods such as the De Lury, or the actual and expected catch). The difficulty of measuring catching effort accurately enough for it to be used in whale population estimates has been recognized recently (Anon., 1976b), and changes in efficiency are particularly difficult to monitor adequately. If any effort analysis is to be used for the primitive fishery, it might be considered from the unsophisticated nature of operations that technological advances were comparatively few and relatively insignificant in terms of increasing catching efficiency. Hohman (1928), for instance, stated that from 1830 to 1860,

> the increased production of the fishery as a whole was secured through a multiplication of vessels of the same type, rather than through any essential improvements in rig, hull, size, type of equipment, or methods of capture... The whaler of 1860 captured her oil and bone and brought her cargo into port in much the same manner as had her predecessor of 1830.

In fact, throughout the history of the fishery, continual improvements to vessels and gear were being made, such that 'there is hardly a fixture, or an implement, pertaining to the outfit that has not been improved upon...' (Scammon, 1874). Among the most important of these can be listed the following:

1. *Introduction of Tryworks On Board Vessels*

According to Ashley (1938), the first record of tryworks on board a vessel was in 1762, and in a very short while thereafter all American vessels were equipped with tryworks. Prior to this date the blubber was cut up and stored between decks until the vessels reached port, where trying-out would take place. The introduction of on-board processing of the blubber undoubtedly increased the efficiency of oil-extraction (sperm whale blubber, if not attended to as soon as possible, was likely to 'blast' so that the oil, when extracted, was black and unsaleable – Brown, 1887). In addition, the provision of tryworks on the whaling vessels meant that these vessels were free to venture farther from their home port to new whaling grounds, so producing the incentive to build larger vessels in which more oil could be stored.

2. *Increase in Vessel Size*

Prior to 1746 the fishery was largely prosecuted by small sloops of 38 to 50 tons, but these were then replaced by schooners and brigs of 100 to 130 tons. Around 1770 larger vessels were added to the fleet, and from 1771 to 1775 an average of 121 vessels with a mean size of 115.9 tons was employed in the sperm whale fishery. Between 1787 and 1789 (following the loss of shipping during the Revolutionary War) the fleet averaged 31 vessels with a mean size of 141.6 tons (Scammon, 1874). The expansion of the US fishery in the first half of the nineteenth century was indicated by an increase not only in the number of vessels operating, but also in the average size of the vessels themselves. From 1800 to 1850 the size of the fleet increased from roughly 30 to 560 vessels, while the mean tonnage of the vessels rose from about 190 to 310 tons (Table 7). At this stage of the fishery, ships and barks predominated. After 1860 the size of the fleet steadily declined (to 11 vessels in 1920), while the mean tonnage also fell initially but levelled off around 200 tons from 1880 onwards. In the latter stage of the fishery, brigs and schooners formed more than one third and up to 70% of the total fleet.

These changes in vessel size almost certainly reflected changes in fleet efficiency. The greater storage space of larger vessels obviously permitted voyages to be extended longer and farther, and the habit of shipping cargo home on other vessels which followed (Brown, 1887) increased the effective hunting range of each cruise (a possible exception to this is the Atlantic fishery, in which brigs and schooners were always usefully employed). Another advantage of larger vessels was the ability to carry more whaleboats. According to Brown (1887), ships and barks carried four boats for immediate use, with two or three spare, while brigs and schooners carried only two or three boats for immediate use, with one spare. The small sloops used at the outset of the fishery apparently carried only two boats (Scammon, 1874). The greater number of boats ready for immediate use undoubtedly permitted more effort to be spent when schools of sperm whales were encountered. It is not known whether (but is suspected that) the increase in size of ships seen from 1800 to 1840 was also accompanied by an increase in the complement of whaleboats carried; if so, this must have represented a significant increase in catching effort.

A further possible advantage of large vessel size was that such vessels may have been more robust and capable of operating (i.e. trying-out) in worse weather conditions than smaller vessels. If this was so, catching effort per cruise would be effectively increased, and it might mean that the larger vessels would be capable of operating in higher latitudes, so giving them access to larger whales on average.

Changes in rig accompanied changes in vessel size

Table 7

Composition of US whaling fleet at 10-year intervals, 1800–1920 (i.e., those ships at sea during some part of the year in question)[1]

	Vessel-types (Mean tonnage and sample size below total no.)					
Year	Sloops	Schooners	Brigs	Barks	Ships	Total
1800	4 (—)	2 (—)	0	0	25 (194.4: 5)	31 (194.4)
1810	2 (—)	1 (—)	2 (217: 1)	0	53 (239.2: 18)	58 (238.03)
1820	2 (—)	17 (—)	28 (159.7: 3)	1 (204)	124 (288.7: 77)	172 (282.88)
1830	0	3 (—)	15 (140.1: 9)	10 (208.7: 9)	216 (330.5: 188)	244 (316.86)
1840	1 (55)	10 (93.5: 8)	56 (143.5: 54)	74 (249.0: 74)	424 (339.9: 416)	565 (304.48)
1850	0	25 (111.2: 25)	25 (164.6: 25)	127 (250.8: 127)	381 (353.6: 381)	558 (310.89)
1860	0	40 (119.3: 40)	15 (146.0: 15)	246 (291.3: 246)	243 (370.6: 241)	544 (308.72)
1870	0	73 (98.5: 73)	18 (135.7: 18)	166 (271.0: 166)	43 (351.1: 42)	300 (231.18)
1880	0	49 (95.7: 49)	10 135.5: 10)	70 (272.3: 70)	0	129 (194.6)
1890	0	22 (98.8: 22)	5 (165.4: 5)	45 (284.6: 45)	1 (412)	73 (222.19)
1900	0	15 (115.7: 15)	2 (118.0: 2)	17 (257.9: 17)	0	34 (186.94)
1910	0	18 (149.7: 18)	4 (303.0: 4)	11 (260.9: 11)	0	33 (205.35)
1920	0	8 (207.3: 8)	0	3 (264.7: 3)	0	11 (222.95)

[1] Data from individual returns in Starbuck (1878) and Hegarty (1959), steam ships excluded.

(Table 7). Ashley (1938) commented on the superiority of the square-rigged vessel for deep-sea work. A bark was about as fast as a full-rigged ship and would lay-to much easier: this was an important feature as a whaler had to lay-to whenever boats were lowered or hoisted. Moreover she had to be handled at that time by no more than half a dozen ship-keepers, as the rest of the crew were engaged in catching whales. She also had to come about repeatedly in order to follow the whaleboats in chase, and the bark rig was far more easily handled and was quicker in stays.

3. *Increase in Size of Whale Boats*

According to Brown (1887), whale boats were about 20 feet long in 1724, and increased in size to 25 feet before 1800. By 1827 boats were 27–28 feet in length, and they remained this size until 1840, though the smaller class of whaling vessel still used 25 ft boats. In 1860 their length was increased to 28–29 feet for Arctic whaling, and subsequently to 30–31 feet. By 1887, however, 28 and 29 ft boats were more generally used, the largest boats in the Arctic fishery and the smallest in the southern fishery. The increase in whale-boat size was accompanied by an increase in the number of oarsmen from four to five – this took place in ships apparently some time after 1791 (Scammon, 1874).

In the sperm whale fishery the advantage of a larger whale boat would seem to lie in its greater robustness and stability, though too great a size might make the craft too heavy to pull and awkward to handle in an emergency.

There also seems to have been a change from clinker-built to carvel-built whaleboats in the American fishery between about 1850 and 1860, presumably because the latter made less noise when progressing through the water (Ashley, 1938).

4. *Introduction of Sail to Whale Boats*

Initially in deep-sea whaling, whales were approached in boats propelled by oars or paddles. It soon became evident that speed in 'going on to' a whale was highly important, but objections to the use of sails were raised on the grounds that they might frighten the whales, or might swamp the boat or endanger the crew during the actual capture. Eventually however, a patent mast-hinge was applied to the whale boat, allowing the sail to be raised and lowered with great ease, and according to Brown (1887) 'All whales are now struck under canvas, and a whaleman who does not sail on his whale under favorable conditions does not understand his calling'. Sail was introduced into the fleet in the 1820s (R. C. Kugler, pers. comm.), although the first direct evidence of a sperm whale being attacked under sail is a logbook sketch from 1834–36 (Ashley, 1938). At first the boats could only travel to leeward. Centreboards and the ability to go to windward did not appear until 1857 and were not generally adopted until the late 1870s (Ashley, 1938).

The introduction of sail clearly must have been a substantial advantage in catching operations. Brown (1887) gives the speed of a whale-boat in smooth water and with a well-trained crew as five knots for the first hour when using oars alone, and generally four knots for the second hour. Under sail the whale-boat might make seven or eight knots in a smooth sea with a good fresh breeze well aft on the quarter, though some whalemen claimed speeds of eight to 10 knots under sail. Besides giving greater speed under favourable conditions, going on a whale under sail had the added advantage of being quieter than when oars were used, and sails were invariably used (in connection with paddles) whenever the wind was about two knots.

5. *Toggle Harpoon*

Originally all whaling harpoons in the US fishery were of a sagittate shape with two fixed flukes. Whalemen complained however that these harpoons often 'drew' and so let the whale escape. A 'one-flued' harpoon (with one fixed barb) was introduced some time in the 1840s (Ashley, 1938), this possessing a weak spot at the neck so that the harpoon was supposed to bend (but not break) under pressure, but this harpoon was also found to be unsatisfactory. In 1848 Lewis Temple of New Bedford manufactured the first toggle-harpoon, with a movable barb, and this soon replaced all other types of harpoon in the US fishery (Brown, 1887). Being much less likely to draw from the whale under strain, it is extremely probable that this represented a major advance in catching efficiency. Ashley (1938) considered that the Temple toggle was

> the most important single invention in the whole history of whaling, since it resulted in the capture of a far greater proportion of the whales that were struck than had before been possible.

6. *Bomb-lance*

At the start of deep-sea whaling, whales were fastened with a hand-harpoon and then killed by repeated thrusts of a hand-lance. In 1846 an explosive lance fired into the whale from a gun was first invented, but this apparatus was not perfected until 1852. Thereafter it was introduced widely into the whaling fleet, '... thus inaugurating a new mode of capture, which in part revolutionized the process' (Brown, 1887). Instead of having to close with the whale (usually repeatedly) in an attempt to kill it, which could be a hazardous business, whalemen could now fasten on to a whale and then, standing off at a safe distance, kill it with a bomb-lance. Such guns were in fact accurate up to about 20–25 yards (Brown, 1887).

This innovation must have significantly reduced the proportion of whales struck and lost, and in bringing about more rapid death, could have enabled more animals to be taken in a given time. It is therefore likely that the introduction of bomb-lances was a major advance in catching efficiency. This is supported by the following comment:

> ...whalemen of the old school...always acknowledge that if it were not for the bomb-guns few whales could be taken at present in any ocean (Brown, 1887).

Ashley (1938), however, claimed that the guns were not so generally used in the sperm whale as in the bowhead whale fishery, and that the main objection to their use was the fact that unnecessary noise would frighten a pod of sperm whales so that the opportunity to take several whales would be lost.

7. *Whale-line*

As stated by Brown (1887), it was essential that the whale-line should be of the best quality of its kind, for if it parted, the whale would, of course, escape. Improvements to the line undoubtedly took place thoughout the development of the fishery, the line being usually made of the best hemp, though cotton and New Zealand flax were experimented with (Bennett, 1840). Later whale-lines were made of manilla fibre (Ashley, 1938). It has not proved possible, however, to document the chronology of these improvements; and to quantify their effect on the fishery would probably be impossible. Indirect evidence of improved techniques for securing whales may be obtained from an analysis of the proportion of whales struck that were lost, as recorded in logbooks. Such an analysis, however, would probably not be able to discriminate between increased efficiency due to any one of several factors.

8. *Patent Gear to Windlass*

According to Captain Seabury,

> in former years it was the custom to hang [the case] in the ship's tackles, and bail the oil out in buckets; the practice is still in use now in small vessels, but large ones, since the patent gear to the windlass has been in use, have usually hove the whale head in on deck,...(much more is saved in this way than in the old process of bailing them alongside;)... (Clark, 1887).

I am not aware of the period in which this development took place. Ashley (1938) puts its introduction as some time in the 1850s, but if it resulted in an improved efficiency of oil extraction as claimed, then it must have shortened voyages, as it would have taken fewer whales to reach a 'full ship'.

Captain Seabury's remark that the practice of hanging the case in the ship's tackles still persisted in small vessels may explain (at least in part) why brigs and schooners had a lower oil yield per whale than barks and ships (see above).

In view of all these probable improvements to catching and processing efficiencies, it seems that a catch/effort analysis for this fishery would be very difficult. More accurate monitoring of changes in sperm whale availability might be achieved through an analysis of the contact rate of vessels with sperm whales, rather than of the rate of capture, as searching techniques were probably more uniform than catching techniques throughout the history of the fishery. As outlined above, however, a parallel investigation should be made of any possible changes in the 'avoidance behaviour' of whales with time.

THE NATURE OF THE FISHERY

Composition of the catch

Apart from the oil yield of each whale taken, it appears that most logs made no reference to the length or sex of the whales taken. Allen and Kirkwood (1976) have shown that when attempting to understand the likely effects of the primitive fishery, it is important to know something about the catching strategy of the whalers. In particular, the likely sex-ratio and age at recruitment of the catch have a considerable bearing on the level of the residual effect of exploitation that might be apparent at the start of the modern fishery. However, the published record gives only occasional information relevant to these topics, and although considerable data are available on the mean oil yield of the whales taken on each cruise, a breakdown of the catch in the form of individual oil yields for each whale taken can only be obtained from further logbook inspection.

At this stage, however, it is useful to examine some of the published statements in order to obtain an approximate indication of the correlation between sex and size of whale and oil yield.

Female sperm whales obviously gave less oil than males. According to Seabury (in Clark, 1887),

> Female... whales have been caught that made 50 barrels, though they do not often yield more than 35 barrels. They vary much in size in different places. In the Caribbean Sea, Gulf of Mexico and along the Gulf Stream through the Atlantic, they run small, and full-grown cows will not average over 15 barrels. Those caught in the Pacific Ocean near the equator as far as longitude 135° west, average about 25 barrels while those caught farther west and in most parts of the Indian Ocean, run smaller.

Bennett (1840) stated that a large female occasionally made 50 barrels, but that the usual average was 20 to 30 barrels. Cleveland (in Murphy, 1947) is in general agreement: cows are said to rarely exceed 25 or 30 barrels, 20-barrel cows being commoner, though he had once or twice taken 40-barrel cows. Individual records of oil yield from cows are 'upwards of 77 barrels' from three cows (i.e. an average of at least 25.7 barrels each – Bennett, 1840), 20 barrels (Bennett, 1840), 30 barrels (Hopkins, 1922), three small cows of about 20 barrels each (Hopkins, 1922), 16 barrels (Beale, 1839), and four cows giving 65 barrels (i.e. averaging 16.3 barrels each – Davis, 1874).

Bennett (1840) stated that a large male occasionally made 100 barrels but that the usual average for an adult male was 70 to 90 barrels. Cleveland (in Murphy, 1947) mentioned a bull that gave 130 barrels, but stated that 'bulls giving 100 barrels are exceedingly rare'. Starbuck (1878) also commented that sperm whales which yield 100 barrels 'are considered very large, but this yield is occasionally exceeded'. He then gave instances of whales giving 107, 130, 137, 145, 156 and just over 162 barrels.

Ashley (1938) stated that a big sperm whale was one that cut in something over 80 barrels; 'anything over ninety barrels was a giant'. Seabury (in Clark, 1887) has given the best summary this author has seen of the variation in oil yield and the social organization of male sperm whales, from which, assuming the social behaviour of the species is still the same today, some conclusions could be drawn regarding variation in oil yield with size.

> The largest sperm whale that I have seen taken... was 120 barrels; though I have heard of one that made 148 barrels. The male or bull, when full grown, varies from 70 to 110 barrels, very seldom going beyond the latter amount, and is from 50 to 70 feet long... The male or bull whales seem to separate from the cows and calves when about the size of 35 barrels, as we seldom get them in the schools of the mother and its young to make more oil than that, and we find the young bulls in pods or schools beyond that size; we find them in what we call 40-barrel bulls, where they generally go in larger numbers than they do as they increase in size; we find them again in smaller schools of about the size of 50 barrels, and again about 60 barrels, where we sometimes see eight or 10 together, and 70 barrels four or five, and beyond that, one, two and three, except on New Zealand Ground, where the large whales go in larger bodies.

In an effort to analyse the relationship between oil yield and body size, a compilation has been made of published figures of oil yield for whales for which measurements of length were also available or could be deduced (Fig. 3). These were all either described as male or could be assumed to be male from the size of the oil yield. Some of the measurements of length emanating from whalemen or unskilled observers were considered excessive (e.g. 90 feet in Starbuck, 1878). In these cases, or where no measurements of length existed, the width of the tail flukes was used to obtain an estimate of body length, assuming that tail width in physically mature males was 25% of body length (Nishiwaki, Ohsumi and Maeda, 1963). This measurement was chosen as being probably reasonably reliable, given that the tail section was frequently severed and brought on board, and that there could be little confusion over the method of measurement.

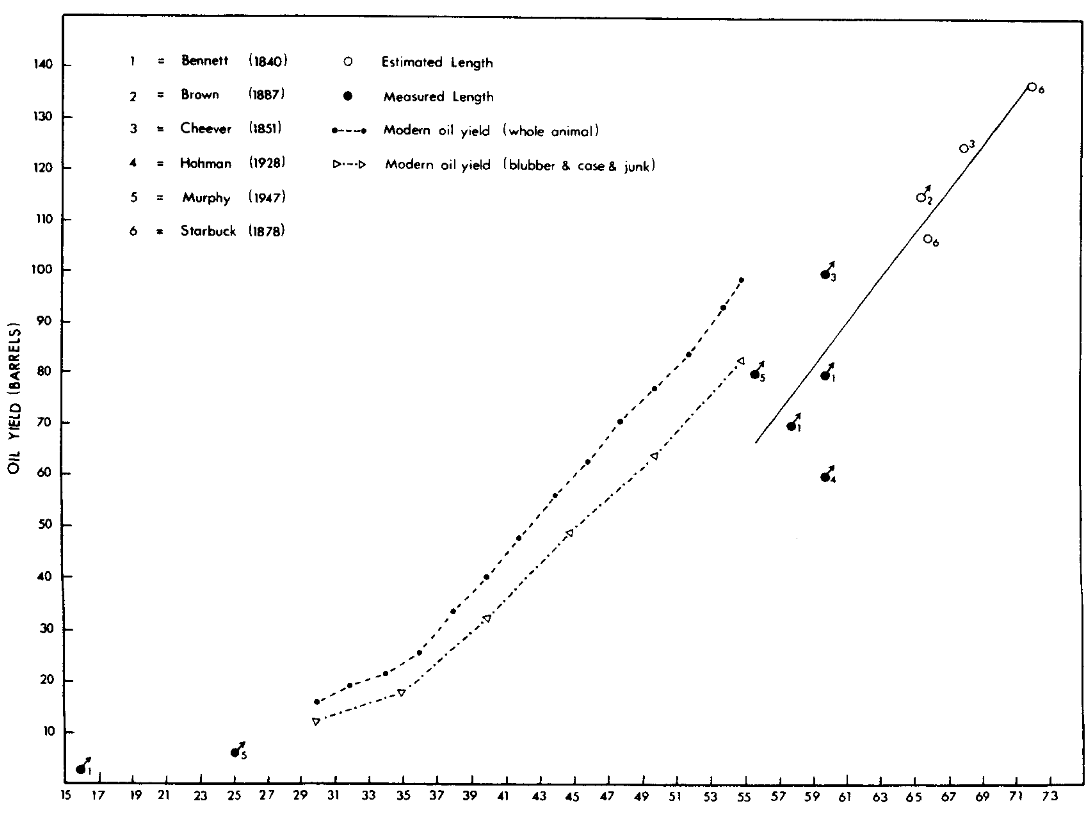

Fig. 3. Relationship between oil yield and size of sperm whales in primitive and modern fishery.

Table 8

Oil yields of various carcass components of sperm whales

Length of whale (ft.)	Meat		Blubber		Bones		Internal organs		Others[1]		Blubber+others	
	% body wt.	% as oil	% body wt.	% as oil	% body wt.	% as oil	% body wt.	% as oil	% body wt.	% as oil	Total %	Total %
30	32.8	1.6	33	14.9	10.9	3.8	14.8	1.2	8.5	6.0	27.5	76.0
35	33.1	1.7	33	14.9	10.3	3.6	11.6	0.9	12.0	8.5	29.6	79.1
40	33.4	1.7	33	14.9	9.9	3.5	9.5	0.8	14.2	10.1	31.0	80.6
45	33.7	1.7	33	14.9	9.6	3.4	7.9	0.6	15.8	11.2	31.8	82.1
50	33.9	1.7	33	14.9	9.3	3.3	6.7	0.5	17.1	12.1	32.5	83.1
55	34.1	1.7	33	14.9	9.0	3.2	5.8	0.5	18.1	12.9	33.2	83.7

[1] Assuming spermaceti to comprise 50% of total weight of 'others' (Omura, 1950), and the remaining 50% (mostly case and junk) to have same oil yield as blubber.

Unfortunately, it is clear that most data on length and oil yield came from particularly large specimens, probably because these were exceptional animals and so some trouble was taken to record their dimensions. This may have introduced a bias into the data.

The relationship between body length and oil yield from the modern fishery (from Best and Surmon, 1974) has also been included in Fig. 3, where the units of measurement have been converted from modern barrels (42 US gallons) to the old wine barrels (31.5 US gallons). These data are not comparable with that available from the primitive fishery because open-boat whalers only utilized the blubber, case, junk and occasionally tail flukes. In order to make the comparison more meaningful, estimates have been made of the relative proportion of the modern oil yield contributed by the blubber, case and junk. The relative weights of the different components of the carcass given by Omura (1950) have been multiplied by the oil yields for such components (Table 8). The latter were based on data given by Berzin (1971), with values of 97% for spermaceti, 45% for blubber, 35% for bone, 8% for viscera and 5% for muscle being adopted.

This analysis shows that a surprisingly high proportion of the total oil yield of a sperm whale is found in its blubber and head matter, varying from 76% in small (30 feet) animals to 83.7% in large (55 feet) animals. A comparison with the modern yield of oil that could be expected from processing only the blubber, case and junk shows that the primitive fishery was rather inefficient in extracting oil from large animals, but surprisingly efficient for small animals (Fig. 3). This may be because (as noted above) the entire case plus junk of smaller animals (usually said to be less than 40 barrels in size) was lifted on deck while the case of larger animals was bailed out while hanging over the side in the ship's tackles. This suggestion is supported by the observation of Seabury (in Clark, 1887) that large whales usually made '38 per cent head' and smaller ones 'not... over 30 per cent'. The data in Table 8 indicate that the potential oil yield of the case plus junk in a 30 foot whale would be 28.7% of the total available in the primitive fishery, while in a 55 foot whale the case plus junk would comprise 46.4% of the total. This indicates that less of the available head oil was extracted from larger than from smaller animals.

From the data given in Fig. 3 it might be possible to construct an approximate trend line of oil yield against body size, using a combination of data from the modern fishery and that available from the primitive fishery. However, logbook examination might reveal further instances where dimensions of the sperm whales caught as well as oil yield were recorded, and the additional data should be incorporated if available.

Selectivity of catching operations

Mitchell (1977) has raised the possibility of primitive whalers selecting for large sperm whales, particularly adult males accompanying schools containing females (i.e., 'schoolmasters'). In this he is supported by the remarks of Ashley (1938) that 'the intensive pursuit of the Sperm Whale began about one hundred years ago, and for fifty years big whales were singled out for capture whenever a pod was sighted'. Kugler and Clarke (1976), however, tended to refute this:

> Boats approaching a school of whales generally attempted to take the largest ones that presented a reasonable chance of capture. The range of choice was limited by the capabilities of the boats and the risks of the encounter were sufficiently great that the most vulnerable appearing, rather than the largest, whales were generally selected.

Due to the fact that the ultimate aim of the cruise was a 'full ship' rather than the achievement of any numerical quota, there would seem to be a strong incentive for the largest possible whales to be taken, so that the ship would be filled quicker. Remarks to this effect have appeared in some accounts of exhortations to the crew by officers during the chase e.g. '– she's an 80-barrel whale;... pull ahead – spring, b-t ye, that whale will shorten our voyage six months –' (Chase, in Hohman, 1928).

One semi-popular account relating to the taking of schoolmasters is contradictory. Hopkins (1922) in one place stated,

> The whales in the school were, most of them, rather small cows; but there were two bulls of good size, about eighty or ninety barrels... The boats devoted their attention to them.

Later, however, the same author stated,

> The school consisted principally of rather small cows, under the charge of two or three bulls as schoolmasters. We could not find the bull which had been fighting, and did not look for the others, for schoolmasters are always pugnacious devils...

Cheever (1851) tended to confirm the latter statement:

> A large herd of females is generally attended by two or three bulls, who are said to exhibit the usual jealousy of intruders, and engage in fierce contests to maintain their rights. The same powers which they are thus capable of exerting against each other, are sometimes employed against their human assailants;....

If in fact the potential danger of attack acted as a deterrent for the prospective harpooner, so producing negative selection, it would appear that the young or

'40-barrel' males and old females might have been the most actively avoided, as they were believed to be the most troublesome to encounter (Bennett, 1840; Beale, 1839). However, although large whales were considered by some whalers to be generally less active and more easily killed, such animals were also sometimes known to attack whaleboats with great ferocity when wounded (Beale, 1839). The 'fighting whales' that attacked whaleboats and even whaleships were usually large bulls (Starbuck, 1878).

From the published material available, therefore, it does not seem possible to establish whether any size selectivity definitely operated in the fishery. If logbook observations are detailed enough, it may be possible to gain further insight into the problem of schoolmaster selection through an examination of encounters with 'school-whales'. Failing this, knowledge of the nature of the size composition of the catch gained from oil yield analyses might enable deductions to be made concerning the selective nature of the fishery.

DATA REQUIRED FROM HISTORICAL RECORDS

In conclusion, the following would seem to be the subjects for which an examination of logbooks and other historical records is needed to evaluate the effect of the primitive fishery on sperm whale stocks.

(*a*) A comprehensive compilation of annual production figures for the entire history of the sperm whale fishery, using published and unpublished sources (such as customs records), and including data from all nations involved. Production figures from different sizes of vessel should be kept separate.

(*b*) Construction of a size composition for the catch within specified stock areas at regular intervals throughout the history of the fishery. This will involve the examination of logbooks for extraction of individual oil yields for each whale caught. Data from brigs and schooners will have to be kept separate.

(*c*) Information on the number of whales that sank after being killed as a proportion of the number brought alongside the ship for processing (from logbook examinations).

(*d*) Information on the number of whales struck and lost (without sinking) as a proportion of the number brought alongside the ship for processing, and similar information (if available) on the number of whales that escaped spouting blood or that were harpooned and lanced before escaping (from logbook examinations).

(*e*) Separation of catches by stock division (from logbook examinations).

(*f*) Information on the number of days on which sperm whales were seen, and the total number of days spent searching (from logbook examinations).

(*g*) Information on the number of times boats lowered and whales fastened, and the total number of times boats lowered (from logbook examinations).

(*h*) Information on the dimensions (particularly total length and tail width) and sex of animal killed, to be correlated with oil yield figure for same animal (from logbook examinations).

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HWR/10

Proposed Methodology for Abstracting Sperm Whale Data from Logbooks

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INTRODUCTION

Earlier studies, based on data aggregated by voyage and already compiled (Starbuck, 1878), have demonstrated a significant decline in barrel yields of vessels engaged in sperm whaling during the first half of the nineteenth century. Indeed, the decline as so reflected was dramatic, from near capacity average yields in the 1820s to much reduced yields fewer than 25 years later, despite longer and longer voyages (Shuster, 1972). Voyage totals, while useful for some purposes, however, do not permit much insight into several important issues, not the least of which, for example, are the separation of the cause of such increasing scarcity into numerical versus behavioural factors, the affect of whaling on the size distribution of individual whales and more detailed study of geographical distribution over time. This paper does not discuss in detail the numerous uses to which logbook data, once abstracted, can be put (Shuster, 1975). Rather, it gives some suggestions on the availability and methods of abstraction of logbook data which can be marshalled on these and other issues.

GENERAL AVAILABILITY OF LOGBOOK DATA

Before discussing the availability of logbook data through compilation, it should be noted that a massive compilation has already been done at least once (Townsend, 1935). Townsend examined logbooks for 744 vessels comprising 1,665 voyages, a mammoth undertaking. He used these logbooks to record the location where some 53,877 whales were taken, and most of these (36,908) were sperm whales. Townsend then prepared charts showing seasonal distribution for each month of the year. Unfortunately his published work aggregated out all of the other data which he may or may not have also recorded. Most importantly, it can be speculated that he may have kept notes on at least the dates the whales were captured. Thus, access to these notes might produce an immediately analysable set of data by which to determine any change in sperm whale distribution over time, not to mention other analyses which might be possible depending on what other notes Townsend may have kept. The author has made inquiries to several potential repositories of Townsend's notes without success. The first methodological suggestion is thus: send out the alert wherever possible for Townsend's notes.

Assuming Townsend's notes remain absent, or, if found, do not give complete data, it will be necessary to embark on the painstaking effort of compiling data from the logbooks themselves. Based on the author's personal experience, it takes at least three hours to glean from the typical logbook the information described below, and that assumes one is familiar with the language used, has compilation forms prepared in advance, and has the logbooks available on microfilm so that careful handling of unique and antique manuscripts does not slow the task. A sample data compilation form is appended to this paper (Appendix 1).

It has been estimated that a total of 13,927 whaling voyages were made by American vessels. Logbooks and/or private journals are available for only about a quarter of this group (Sherman, 1965). The implication that complete data for each sperm whale killed is available is obviously untrue: at best a large, but not even majority sample will be available. This is important to remember in order to prevent frustration because only rarely, if ever, will a single logbook record all the categories of information sometimes available. As long as one is dealing with samples, the concept of subsamples is much more palatable. Whalemen were not meticulous naturalists.

Starbuck estimated that 225,521 sperm whales were killed by American whalers between 1804 and 1866 (Starbuck, 1878). The author believes that the actual number was closer to 300,000 by American vessels (Shuster, 1975). A complete study of all existing American logbooks would thus produce a sample, with varying amounts of information on each, of up to a maximum of 75,000 sperm whales. It should be noted that Townsend obtained data for his 36,908 sperm whales by analysing 1,665 voyages, or about 22 whales per voyage. Since there are roughly 3,200 existing logbooks (Sherman, 1965), this provides an independent estimate that, at best, data for perhaps 65,000 individual sperm whales killed can be obtained.

In many respects a compiler seeking information on sperm whales is more fortunate than those studying other species. First, the nineteenth-century whalers captured more sperm whales than any other species, so that the potential sample is larger. (As against the 225,521 for sperm whales, Starbuck estimated 193,522 for all species of right whales. Approximately 70% of the Townsend sample was sperm whales.) Second, the whalers themselves usually identified sperm whales specifically, but, more often than not, identified other species as simply 'whales'. Third, there are numerous voyages which produced all or nearly all sperm whale oil, thus producing a double check on the species type. For example, there are approximately 100 such voyages in the Nicholson Collection of the Providence Public Library alone. Similar estimates of such voyages in the major logbook collections can be made by comparing the list of the logbooks typically furnished by such collections with the Starbuck listing. Since the Nicholson Collection contains approximately one quarter of the known existing logbooks (Sherman, 1965), it can be estimated that there are perhaps 400 surviving logbooks of voyages predominately for sperm whales. (There were 563 voyages from Nantucket and New Bedford between 1820 and 1849 which produced only sperm oil, Shuster, 1972).

A second suggestion is that in order to maximize the efficiency and accuracy of what is an extremely time-consuming process, a list of such voyages for each major collection should be made, and data compiled from these logbooks first.

USE OF COMPUTERS

Clearly if a sample can be developed of anything like 60,000–70,000 sperm whales killed, not to mention the numerous other observations of sperm whales not taken, computer analysis is immediately suggested. This is especially the case since the data are fragmentary and must thus be handled by the type of groupings that computer programs permit. A third suggestion is that the data be compiled using objective notations or categories, rather than subjective notes. The categories of information described below can be treated in this way.

VOYAGE DATA

For many purposes it will be useful to identify an individual sperm whale observation with a particular voyage and the aggregate data for that voyage. A fourth suggestion is that perhaps the most convenient way to do this would be to photocopy the entire Starbuck listing, as updated (Hegarty, 1959), and assign a number to each voyage chronologically. Access would then be provided through the voyage number to the voyage data as listed by Starbuck or derived elsewhere. If further voyages are discovered, these could be assigned additional numbers, although the Starbuck listing is so complete as to make it unlikely that a large number would be found. Starbuck lists the following data for each voyage:

1. Port
2. Name of vessel
3. Type of vessel (ship, bark, brig, etc.)
4. Tonnage of vessel
5. Name of captain
6. Managing owner or agent
7. Whaling ground
8. Date of sailing
9. Date of arrival
10. Sperm oil resulting from voyage (barrels)
11. Whale oil resulting from voyage (barrels)
12. Whalebone resulting from voyage (pounds)

Starbuck also gives additional information, including a listing, where known, of any amounts of the three products sent home so that three additional items can be gleaned from Starbuck:

13. Sperm oil sent home (barrels)
14. Whale oil sent home (barrels)
15. Whalebone sent home (pounds)

The additional data suggest a few other categories of interest:

16. Whether vessel lost
17. If lost, location when lost
18. Whether vessel sold
19. If sold, location where sold

Most of the 19 categories can be quantified for computer analysis, eg., the various ports can be listed alphabetically and each assigned a number, as can vessel types, whaling grounds, etc. Only the name of the captain and managing agent are perhaps not conveniently treated in this way.

In addition to the data as derived from the Starbuck listing, data from a given logbook should be tied to the voyage number and the following additional information given per the logbook's figures if available:

20. Author's name
21. Date logbook begun
22. Date logbook ended
23. Sperm oil resulting from voyage (barrels)
24. Whale oil resulting from voyage (barrels)
25. Whalebone resulting from voyage (pounds)
26. Sperm oil sent home (barrels)
27. Whale oil sent home (barrels)
28. Whalebone sent home (pounds)
29. Number in crew upon sailing

Transfer of the Starbuck listing to a computer, as updated, would permit immediate generation of a list of vessels which took sperm oil alone or a certain percentage of sperm oil (say 90%). It would also allow various comparisons to be made between voyages.

A listing of all voyages in this way would permit cross references to studies of different whale species and to additional logbooks as found, etc. That is, use of Starbuck as a master voyage list would permit early concentration on sperm whale voyages without precluding the convenient expansion of the data base for other purposes of a later point in time. Each individual whale sighting would be keyed to one voyage number, permitting access to much voyage data without repeating it for each observation.

INDIVIDUAL SPERM WHALE OBSERVATION DATA

The above steps should precede an organized assault on the logbooks available. Once the logbooks themselves are taken up, various categories of information can be obtained which require further explanation. It is useful in compiling the data from any logbook to examine first its beginning and ending pages. At times, for example, these will give a list of whales killed by date, location and barrels. There were several reasons for doing this, among them the desire to have a handy summary for future use of the most fruitful grounds by season, and to assess the contribution of each of the various ship's boats. Whatever the reason, such a listing gives an instantly useful reference against which to compare and supplement the logbook account. It is sometimes the case that only by reference to these summary accounts can the barrel yields of individual whales be determined.

The following discusses the various facts which should be compiled at least for those days on which sperm whales were sighted:

A. *Date*

This is one variable which nearly every logbook will contain for each observation. More narrative journals may be less complete. Even logbooks, particularly toward the end of a long voyage, may begin summarizing several weeks at a time – in handwriting which is often less and less legible. Nevertheless, most logbook observations will have a precise date or permit a very close approximation.

B. *Location*

With nearly as much regularity as the date, logbooks contain complete records of location by longitude and latitude on a daily basis. If not available for a given date, it is usually possible to note an approximate latitude and longitude by extrapolating between contiguous dates and/or noting a reference to a nearby landmark (eg. 'French Rock 25 miles to SW'). It is of immense use to a compiler to have maps available (especially the Pacific Ocean), and to build up a location index for the many islands and formations which no longer appear on maps, at least under their nineteenth-century names. Thus even assuming French Rock does not appear on any available chart, it can still be used as a reference point if the compiler has found from previous logbooks that French Rock has been noted in the area of approximately 30° S and 170° W.

A computer program could be developed to treat the Pacific in 10° squares in order to analyse the factor of location with meaningful samples. As seen below, location is a critical variable in any analysis.

C. *Sex*

Usually logbooks do not state the sex of the sperm whale taken, with two exceptions: (1) when a cow whale and/or calf are killed, or (2) when a large solitary bull whale is taken. When available, these data should be compiled. An experienced compiler will in time be able to recognize at least some males by location, size, etc. without an express reference, but compilation should still only reflect an express comment on sex by the logbook writer.

D. *Number of whales sighted*

Most logbooks record whether whales sighted were plural or singular. If plural, there sometimes will also be either the characterization 'large school' or an estimate of the numbers involved, eg. '2 or 3 sperm whales going fast'. Thus four categories suggest themselves:

- (i) plural
  - (*a*) no further characterization
  - (*b*) characterization as 'large' school
  - (*c*) estimate of numbers involved
- (ii) singular

The author has found what others have noted, *viz.* that the proportion of single sightings (large bulls) generally increases with the latitude north and south from the equator (Berzin, 1972).

E. *Distance*

Not often, but enough to make it worthwhile to record, a logbook will indicate the distance from the ship when the sperm whales were first sighted. If given, the distance is almost invariably estimated in miles and can be recorded as such. This variable is one of the several which may develop greater insight on the question of behavioural versus numerical scarcity, particularly if a behavioural learning curve should turn out to reflect an increased short-range awareness by the sperm whales of approaching ships and/or boats.

F. *Number of boats lowered*

Most frequently a logbook writer will indicate only if boats were lowered or not, but if so, he will sometimes indicate how many. The decision on the number of boats to lower was usually of an all or nothing variety, depending on factors such as the weather, lateness in the day, proximity to the whales, number of whales, the whales' behaviour, etc. There were times, however, when a ship's captain, in assessing these same factors, would order less than a full complement of boats to be lowered. The following are suggested compilation categories to be applied to the question of whether boats were lowered:

- (i) affirmative
  - (*a*) unspecified number
  - (*b*) specified number
- (ii) negative

G. *Whales harpooned and taken*

In the event no boats were lowered, the number of whales harpooned and tried out is obviously zero. When boats are lowered, however, there are numerous possibilities before trying out a whale for its oil. As many different possibilities exist in fact as accounts written about each attempt. Nevertheless the following suggested scheme covers the categories for which numerical observations may be available:

- (i) number of whales harpooned
- (ii) number of whales escaped
  - (*a*) mortally wounded
  - (*b*) not mortally wounded
  - (*c*) indeterminate
- (iii) number of whales tried out (taken)

H. *Barrel yield*

Often, but somewhat less than half the time, logbooks will give the barrel yield for individual whales. At times the logbook will give an estimate on the day of capture followed by an actual figure when trying out is completed several days later. The author has found a very close relationship between such numbers where both exist, and this suggests that such estimates not later accompanied by an actual figure are reliable enough to be used as the barrel yield.

There are several ways to obtain barrel yields aside from a text figure. First, the summary schedule often found at the beginning or end of a logbook may supply such information. Second, the whale stamp may contain a barrel figure. Third, there is a procedure which is far more complex but which may be possible with computer analysis. Barrel yields for one or a few whales may be derived by comparing the total barrel figure at two different dates with the number of whales taken between the two dates. For this reason and others it is worthwhile for a compiler to keep a separate summary sheet reflecting the dates on which a vessel 'spoke' another, at which times the other vessel's total barrels might often be recorded. A sample compilation sheet for such encounters is given in Appendix 2.

Even where individual barrel yields for each whale are not available, a voyage average yield can be obtained by dividing the total logbook (or Starbuck listing) sperm oil yield by the number of sperm whales taken. If a significant population pressure was being exerted by nineteenth-century whalers on sperm whales, this would possibly be reflected by decreasing average yield per whale. It should be stressed, however, that even this hypothesis must be analysed with location in mind (Shuster, 1975).

The reason for this qualification is that a whaling captain's objective was maximum total barrels in the shortest possible time, and he was largely indifferent to how many whales this took. Thus a ground typified by small young whales could be superior to an area location for fewer, but much larger, whales, depending on the relative numbers on each ground. The proportions would of course themselves change over time as a function of the amount of whaling in each. In short, it is conceivable that population pressure could actually result in larger whales being taken on the average if the ground of smaller whales was the first depleted.

A small preliminary sample developed by the author suggests that such a process may actually have taken place in the Pacific as a whole. Three facts taken together suggest this. First, in voyages commenced between 1832 and 1858, sperm whale size increased with the distance from the Equator (Table 1). Second, using the same whale sample, the average size did not decrease significantly in three decades involved (Table 2). Third, there may have been some tendency in the three decades to shift location and, especially in the 1840s, to seek the larger whales found in higher latitudes (Table 3).

Table 1

Average individual sperm whale barrel yield, 1832–1858, by latitude (number of observations in parentheses)

Latitude	Average barrel yield
Over 40° S	70 (2)
30–39° S	57 (48)
20–29° S	54 (26)
10–19° S	35 (32)
0–9° S	39 (124)
0–9° N	24 (79½)
10–19° N	29 (18)
20–29° N	48 (9)
30–39° N	35 (9)

Table 2

Average individual sperm whale barrel yield, 1830s–1850s (number of observations in parentheses)

Decade (voyage commencement)	Average barrel yield
1830–9	39 (129)
1840–9	40 (95)
1850–9	35 (123½)

Table 3

Percentage of sperm whales taken at different latitudes from the equator, 1830s–1850s
(number of observations in parentheses)

Decade (voyage commencement)	Degrees from equator	
	0–19°	Over 20°
1830–9	82 (106)	18 (23)
1840–9	51 (48)	49 (47)
1850–9	81 (99½)	19 (24)

The above merely suggests that a failure of average sperm whale size to decrease is not necessarily inconsistent with increasing numerical scarcity. It is a hypothesis neither proven nor disproven by preliminary data.

I. *Time between lowering boat and return*

Although not often, logbooks occasionally report on a regular basis up to four times in the day:
(i) time of lowering
(ii) time of striking
(iii) time killed
(iv) time whale alongside

Any or all of these times should be recorded if available. The times have a bearing on (i) how closely the whales permit themselves to be approached, and (ii) whether enough time remained in the day to permit a hunt unimpeded by darkness.

J. *Sea conditions*

Among the various sea conditions which a logbook may note, it should only be necessary to indicate in a yes or no manner if the logbook refers to conditions being (i) rough, or (ii) foggy. Both conditions have a direct bearing on the difficulty of taking whales.

K. *Other*

There are of course numerous other facts which can be abstracted from whaling logbooks. Among these, the following may lead to interesting analyses.

(i) *Miscellaneous cetological data.* Especially for larger whales but occasionally for smaller ones as well, a logbook may note not only a whale's barrel yield but also some other aspect of its size, eg. overall length, length of jawbone, etc. These could be compiled and eventually the relationships between these various measures developed.

(ii) *Wind and whale direction.* Logbooks usually note the wind direction and often note the direction sperm whales appear to be travelling, both before and after being 'gallied'. These three directions could be compiled. The relationship of wind and whale direction is frequently pointed out in logbook and journal accounts:

> Sperm whales when frightened (or as whalemen say, 'gallied') as a rule run to the windward. I have seen them gallied in a calm and turn in the direction from which the wind blew last, and keep that course for hours. It has puzzled many men as well as myself to account for their being able to keep a straight course for hours and never vary a point by the compass from it (Haley, 1967).

The behaviour of 'going to windward' may have been acquired with a learning curve experience on various grounds; if so this fact would be of extreme interest.

CONCLUSION

Logbooks provide an extremely varied sample of sperm whale data. To be most useful, compilation of such data should be organized by a formulated plan. This paper has summarized the author's own suggestions for such organization.

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Appendix 1
LOGBOOK DATA COMPILATION FORM

Ship:	Type:	Port: Tons:	No. men upon sailing	Date of sailing: Return:	Results:	Sperm oil	Whale oil	Note

						No. of whales							
			Whales sighted				Escaped		Tried out				
Date	Location	Sex	No.	Distance	No. boats lowered	Harpooned	Mortally wounded	Not mortally wounded	No.	Bbls.	Time between lowering boats and return	Sea conditions	Comments

Appendix 2
OTHER SHIPS SEEN AND REPORTED (MONTHS OUT AND RESULTS)

Reporting ship			Reported ship									
						Results						
						Oil						
Name	Port	Date of sailing	Name	Port	Months out	Sperm	Whale	Total	Bone	Date	Location	Comments

HWR/6+7

Potential of Whaling Logbook Data for Studying Aspects of Social Structure in the Sperm Whale, *Physeter macrocephalus*, with an example – the ship *Mariner* to the Pacific, 1836–1840[1]

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ABSTRACT

Good logbooks and journals documenting sailing vessel whale fisheries pursued from open boats, and containing at a minimum daily entries with locality, weather, catch and production data, are a useful source for study of some aspects of the social structure of the sperm whale, *Physeter macrocephalus*. Removals of large bachelors might have affected pregnancy rates in mixed schools contributing to declines in population abundance if sailing vessel whalers took the largest bulls on the breeding grounds during the mating season. An example of a good sperm whaling logbook is presented – the ship *Mariner* of Nantucket, G. W. Gardner, Jr., Master, to the Pacific, 1836 to 1840. In the take of 82 sperms, there were seven large bachelors (each yielding over 50 barrels of oil) of which four were killed on the breeding grounds during the mating season. Other potential uses of such logbook data are discussed

INTRODUCTION

The sperm whale is the largest of the Odontocete or toothed whales. Most notably amongst all cetaceans it shows strong sexual dimorphism, only partially overlapping ranges of socially mature males and females (a kind of 'parapatry of the sexes'), and a social structure involving seasonal and geographic segregation of the populations by age and by social and sexual state.

SPERM WHALE SOCIAL STRUCTURE

The general features of this social structure and behaviour has been modelled or diagrammed by many (Gaskin, 1970, Fig. 9; Ohsumi, 1971, Fig. 5; Mitchell, 1977a, Fig. 1; Best, 1979, Fig. 7). The following is taken from Best's (1979) summary:

The mature females, and suckling and immature males and females, comprise the basic social grouping in sperm whales, the 'mixed school', found in lower latitudes all year round. The immature males and females remain in the mixed school. Sometimes 'juveniles' segregate out in small isolated schools. Many females remain in the mixed schools. All likewise remain in lower latitudes.

The puberal males or 'small bachelors' (35–38 ft in length) then segregate out and form all-male groups. These become sexually mature at approximately 19 years of age, grow into 'medium bachelors' (40–45 ft – apparently the '40 barrel bulls', see below) and they undergo hormonal-induced aggressiveness resulting in territorial spacing and separate into smaller schools of 'large bachelors' at 45 ft and longer. These males then become socially mature and competition for 'schoolmaster' status occurs for access to or 'possession' of mature females in mixed schools. The large bachelors (the 'empereurs' of French whalers, e.g. Maynard, 1861, vol. 1, p. 66; Maynard and Dumas, 1937) unsuccessful in winning or servicing harems migrate to higher latitudes.[2]

This seasonally 'parapatric' migration of the sexes avoids competition for food between these mature males, and the females and juveniles. The reservoir of large, seasonally unsuccessful but socially mature bulls are those which open-boat whalers encountered polewards of 40 degrees N and S (e.g. Jones, 1861, p. 67), and it was often the large bulls in mixed schools on the breeding grounds which showed so much aggressiveness and which sometimes attacked boats and even ships (cf. Whipple, 1954, p. 56–72; Beale, 1839; Cheever, 1849; Starbuck, 1878).

TAKING THE LARGEST BULLS, AND MANAGEMENT IMPLICATIONS

The relevance of this social structure and behaviour in the sperm whale to international whale management is almost as complicated as the social structure itself. One aspect of simple, direct fishing for large sperm whales, and the resulting long-term implications for management, is as follows:

Early American pelagic whalers usually worked in middle and lower latitudes, and encountered mixed schools of whales during the reproductive and indeed all seasons. Due to the general preference of all whalers to take large animals whenever available, and in spite of the danger inherent in taking large sperm whales, could there have been selection for large socially mature bulls – the 'school masters' servicing the mature females – thereby affecting the pregnancy rate in schools?

[1] Revised and reviewed; based on HWR/Docs. 6 and 7 from International Workshop on Historical Whaling Records, Sharon, Massachusetts, September 1977.

[2] I am oversimplifying here for the sake of discussion – see Caldwell, Caldwell and Rice, 1966, p. 683 *et seq.*; Best, 1979, p. 250–251, 273 *et seq.*; and Botkin *et al.*, 1980. It is unclear whether the large bachelors take annual turns in becoming schoolmasters or whether the same mature bull may service a harem year after year as a result of competition or dominance.

One of the earliest and most reliable accounts of this pelagic fishery stated that:

After being struck with the harpoon or lance, females and young bulls make the most violent efforts to escape, and being remarkably quick in their actions they frequently afford considerable danger and trouble. Those young bulls which yield about forty barrels of oil,... are perhaps the most difficult to destroy, and sometimes make great havoc among the men and boats.

The large whales, such as make eighty or more barrels, not being nearly so active, and probably not feeling so acutely, are generally, by expert whalers, easily killed, and with less damage to those employed than the smaller ones (Beale, 1839, p. 160).

Some whalers considered the large bulls 'fighters' and sometimes had to go to great lengths to kill them (e.g. Slocum, 1907, p. 928, 930; Starbuck, 1878, p. 159; Ashley, 1926, p. 82; an 80 barrel whale, 'one of the knowing kind', Sawtell, 1962, p. 66). However, many accounts emphasize the relative ease with which large bulls could be lanced after the first strike (e.g. Scammon, 1874, p. 78; Bullen, 1898, p. 71, 323).

The large whale is generally very incautious, and if alone, he is without difficulty attacked and easily killed, as he frequently, after receiving the first blow from the harpoon, appears hardly to feel it, but continues lying like a 'log of wood' on the water before he rallies or makes any attempt to escape from his enemies.

Large whales are sometimes, but rarely, met with remarkably cunning and full of courage, when they will commit dreadful havoc with their jaws and tail. The jaw and head, however, appear to be their principal offensive weapons (Jones, 1861, p. 176).

Likewise the difficulty in killing pugnacious 40 barrel bulls was part of the whaler's experience and lore (Bennett, 1840, vol. 1, p. 265–266, vol. 2, p. 206; Murphy, 1947, p. 99–102; Munger, 1967, p. 17).

The total number of whales killed in the early American fishery may not in itself reflect the total impact on populations. If there was selection for large, socially mature bulls at the time they were inseminating females, and the bulls were removed early in the breeding season with effective replacement (cf. Best, 1970) of the schoolmaster being relatively slow, the pregnancy rate should have fallen. A decline in population abundance might have been compounded by selection for large sperm whales (Mitchell, 1977a: Mitchell and Kozicki, 1978), even if one to three or more mature males associated with a mixed school (Caldwell, Caldwell and Rice, 1966; Best, 1970, Table 12; Best, 1979).

Clearly the schema (Mitchell, 1977a, Fig. 1; Best, 1979, Fig. 7) shows that this could be so. Was it so in the past? It is here that only historical log book information can help resolve the issue and aid in assessing the impact of the early fishery on the stocks of sperm whales.

Examination of some selected logbooks showing the barrel yield or length of all whales taken from given schools could help resolve whether the socially mature bulls were selected for. (This would clearly show up in such catch records since the yield from a mature bull is so much greater than the maximum for mature cows, and from '40 barrel' and smaller bulls, especially from the 'Case',[3] and spermaceti oil was the desired product of the fishery.) If for example large bulls were taken during the reproductive season (Mitchell and Kozicki, 1978) from even one third of the schools this could have a serious impact on the reproductive rate of the sperm whales.

These and other arguments were sufficiently compelling to the Scientific Committee of the International Whaling Commission (IWC) that in 1976 the importance of the role of the schoolmaster (IWC, 1977a; 1977b; Best, 1979) was codified in a new regulation in the Schedule of the IWC, protecting adult males over 45 ft during the breeding season in lower latitudes from exploitation in the Southern Hemisphere (IWC, 1977c). Since adult females attain a maximum length of approximately 38 ft, and males do not become socially mature until lengths of 45 ft and over, this difference of seven feet can easily be judged in the field, and gunners can avoid taking the adult bulls.

While many whaling operations are regulated by body length limits, these are usually lower limits. The sperm whale fishery in the Southern Hemisphere was unique in having both a lower and an upper limit. Further substantiation of this argument for a maximum length limit for the Northern Hemisphere sperm whales (Mitchell and Kozicki, 1978) resulted in the Scientific Committee recommending that the maximum length limit be put in force for the Northern Hemisphere at its 1977 meeting (IWC, 1978).[4] (Some sperm whale stocks apparently cross the equator, and there is no reason to consider northern any different from southern sperm whales for those populations which do not).

The IWC devised a management procedure using as part of its baseline the assessment of initial ('virgin') population size, compared to present population size. If the present population is approximately 50% of initial, or less, then the Whaling Commission's new management procedures would tend to regard that whale stock as a 'protected' stock. There are other complexities in these procedures, but if the stock is about 40–60% of initial size or above, it might be called a 'sustained management' or an 'initial management' stock depending on its relation to the calculated level of maximum sustainable yield.

The sperm whale fishery comprised the largest fishery for great whales in the world, with thousands of whales being taken per annum, in 1977 when the first draft of this paper was written. My concern then and now was that in its sperm whale stock assessments, the IWC has assumed *a priori* that the 1946 stock abundance of sperm whales represents initial ('virgin') stock size. I believe this assumption was unjustified, and have emphasized in the Scientific Committee of the IWC that there was a long history of pelagic exploitation of the sperm whale in nearly all oceans by American, British and other whalers.

[3] Up to one-sixth of the entire produce of oil from a large bull will come from the 'case' or spermaceti organ (Bennett, 1840, vol. 2, p. 224). This could be up to 10 barrels from an 80 ft. (sic) sperm (Olmsted, 1969, p. 66), 12–14 barrels from a large bull (Bennett, 1840, vol. 2, p. 161; Zollers, 1892, p. 93; 10–20 from the 'trunk', Dudley, 1726, p. 259) and a 100 barrel bull will give 15 to 17 barrels from the case (Jones, 1861, p. 61). Munger (1967, p. 17) gives a production of 27 barrels from the case of a 120 barrel whale, 'the largest whale we have heard of being captured on this ground' in the southwest Atlantic, and Haley (1948, p. 218) 15 barrels from a similar sized whale. Ashley (1926, p. 77) stated that 31 barrels 'drawn off' from the case of a 100 barrel sperm was a record. One pugnacious bull yielded 115 barrels, 'one-half of which was head matter' (Davis, 1874, p. 234; and cf. p. 188, where 107 barrel whale comprised of body, 73.5, junk, 14.5 and case, 19 barrels, and 137 barrel whale where head made 52 barrels and case, 27). A more conservative view was that a large whale 'will usually make 38 per cent head' and its case might yield 8–12 barrels of pure spermaceti (Seabury *in* Clark, 1887, p. 73; and see Goode, 1884, p. 11; and Best, this volume).[d*]

[4] The Scientific Committee's recommendation was subsequently approved by the Commission at a special meeting in 1977 (IWC, 1979). This essay was written in 1977 and was addressed to the issue of the use of data from logbooks – I have not attempted to substantially update the text or references regarding current sperm whale management problems.

* Letter superscripts refer to notes added in proof on p. 80.

This sperm whale exploitation was well underway by 1800, and the fleet successively fished the North Atlantic, South Atlantic, Indian Ocean, South Pacific, the 'Hawaii grounds,' and the North Pacific (especially the 'Japan grounds,' see Gilmore, 1959; Bannister, Taylor and Sutherland, 1981). I query why American sperm whalers went so far from the US east coast for up to four years, unless local sperm whale abundance had dropped greatly. Also, there is clearly a trend from approximately two to more than four year voyages through the history of the fishery (cf. Hohman, 1928, p. 84; Shuster, 1972, p. 354, nt. 9). While economic arguments will not be marshalled here, the logic seems internally consistent: the farther you sail, for a longer period of time, the more it costs. Why sail so far, for so long, unless you have to? Whales must have been less abundant or less catchable, or both, near home port.

I suggest that sperm whales were depleted to a low and uneconomic level in the North Atlantic, and possibly the South Atlantic, most likely before 1860.[5]

In my view, an important procedure to follow in examining early American and other sperm whaling logbooks is to not only summarize the catch but also to examine the composition of the catch in as many good logbooks as possible which give satisfactory data (cf. Best, this volume). It would be useful to know the percentage of socially mature bulls in the catch per school, how many different schools were fished and what percentage of a single school was taken. The selection pressure on the population of adult bulls would be difficult to quantify, but there are clearly a number of ways of examining the hypothesis of population collapse due to selective fishing for mature bulls from logbook data.

(A similar argument was constructed for possible depletion of the northern bottlenose whale, *Hyperoodon ampullatus*. That species is restricted to the North Atlantic Ocean, and was fished heavily between 1880 and 1915. Catches declined precipitously but some analyses indicate that catches alone might not have been responsible for the suspected abrupt decline in population abundance that occurred (Mitchell, 1977b). The bottlenose whale has a complicated social structure and the adult males were being selected for their spermaceti-like oil. A population collapse might have been accelerated due to the selective killing of the adult males. Only logbook data will serve to confirm or refute this idea, but there are few good logbooks available for the bottlenose whale fishery.)

OTHER SPERM WHALE PROBLEMS FOR WHICH HISTORICAL LOGBOOK DATA MIGHT BE USEFUL

The discussion so far has been directed toward only one problem – an hypothesis regarding the importance of the role of the socially mature bull in lower latitudes, and possible fishing pressure on this particular age/sex class as it might have affected long-term population abundance of the species. (And, in the logbook sample discussed below, this is one of the most clear-cut parameters available since, even though sex is not usually given, high oil yields clearly identify large bulls in the logbook data.)

There are a number of other population structure features which might be studied with logbook data; although not feasible without a large sample of good or even exceptional journals and logbooks, I suggest that these include: the relative abundance and composition of isolated schools of juveniles; possibly the number of calves observed per mature female; cow–calf behaviour especially with regard to whalers striking a calf to facilitate capture of the cow; and distribution, abundance and herd composition of bachelor schools, seasonally, by size of whale and by area. These are all dependent on data

Two apparently opposing views are at hand to explain the decline of the American sperm whale fishery after *ca* 1845: that it was due to market factors, especially competition from other products (Starbuck, 1878; Hohman, 1928) and a shift to products from other whale species (Kugler, 1981), or to decreasing local availability of sperm whales (Shuster, 1972) and successive depletion of whaling grounds worldwide. Shuster (1972) ran regressions of production per voyage (landed barrels of sperm oil) against vessel tonnage for a sample of 563 voyages by ships only (excluding barks, brigs, etc.) within the period 1820–1849. He found a decrease of from 7.5 barrels in the 1820s to less than 5 barrels per vessel-ton in the late 1840s (not yield per individual sperm whale over the 19th century as Martin, 1981, stated). Shuster interprets this as evidence 'that the sperm whale was becoming a scarce resource' by 1850. I believe Shuster has correctly identified the trend. However, voyage length, used but discounted as of little added value by Shuster in his calculations (1972, p. 356), in fact doubled during the period in question. The encounter of whales by a ship was due to chance, the successful capture less so, but the decision to return to home port was a decision made by the Master on the basis of economics – was the ship nearly full-up or should the cruise be extended until it was? (The longest whaling voyage on record, by the *Nile* of New London, lasted from May 1858 to April 1869, more than ten years – Starbuck, 1878, p. 565; Ashley, 1926, p. 103.) The increased length of voyages gives insight into sperm whale abundance for this period, and indicates that whalers increased their effort markedly in the one parameter they were free to modify at any time – the decision when to return to home port. Thus, while the price of sperm whale oil was one dollar per gallon or more from 1847 to 1877, and attained two dollars for a short period after the Civil War, the sperm whale fishery nevertheless began its long decline. Admittedly, competition of other industries contributed somewhat, but the whaling fleet continued to sail, and return with losses, due to decreasing catches per year of vessel effort. Competing industries such as cotton textiles (1846) and the California gold rush (1849) certainly diverted some labor (Brandt, 1940, p. 53) but the whaling industry depended on unskilled labor, much of it recruited from foreign countries (Brown, 1887, p. 219–220; Hohman, 1928, p. 300; Flayderman, 1972, p. 85).

The Civil War (1861–1865), the Stone Fleet (1861) and the 1871 loss of the (balaenid-hunting) Arctic fleet changed the economics of the industry. Economically oriented studies of the sperm whale industries' decline should examine the factors at work between *ca* 1845 and 1861 when sperm oil landings declined but the dollar value of landings was nearly maintained (e.g. Chart 7, Brandt, 1940). 'The decline from that [1837], to 1860 at least, must be attributed to a destruction of whales in excess of their rate of reproduction' (Harmer, 1928, p. 64).

Another problem is that with successive whaling grounds being opened up in the early 19th century, different stocks of sperm whales were being exploited. Thus the overall downward trend (beginning in the period 1830–1844, Shuster, 1972) may obscure some severe declines in abundance for local grounds. Studies of sperm whale abundance on a catch per vessel basis have validity throughout the history of the fishery, economic aspects aside, but should be limited to analyses of data from one stock unit or geographical area.

If the American sperm whaler tried for all sperm whales sighted, catch data is useful in interpreting pod and school composition – but if selection for large whales was common, then lowerings for and capture of mature bulls analyzed over time can give an index of depletion. The simplest analysis would be the percentage of fifty barrel and larger bulls in the catch, in small samples of log books per decade, 1820–1870 (cf. Bannister, *et al.*, 1981). The circumstantial evidence appears to me to indicate that the cause of the sperm whale fishery's decline was decreased abundance of suitable sperm whales, the effect being a long-term decline in capital investment in the fishery. The shift to other products and industries was a consequence of the decline, not the cause.

from kills of entire pods, admittedly not a common occurrence in the sailing vessel sperm whale fishery.

Other important, basic data can be more easily extracted from logbooks. The disjunct distribution of whales is often the first clue to separateness of stock or population units (Bannister and Mitchell, 1980). Also, but less likely, the discovery of clearly marked and attributable harpoons in sperm whales could comprise precise documentary evidence of migration routes and stock identity. (For example, the same whale was struck on two occasions, 360 miles and 19 days apart, Jones, 1861, p. 248; Starbuck, 1878, p. 123 for *Barclay* and *Hector* strikes, and p. 154 for others; and see Chippendale, 1953, p. 113.)

In addition to these, measures of initial or early population abundance are important and might be obtained from historical records. These could be either direct estimates, or indices of abundance through long time series of data.

Commonly used methods of analysis of whale abundance include:

(1) age-based population structure analyses such as cohort analyses;

(2) tag-recapture experiments of various kinds;

(3) estimates of initial size (or of sustainable yield) through interpretations of cumulative catch and history of exploitation data;

(4) census data, especially shipboard or aircraft, in which sightings are related to area searched and extrapolated to total range of occupancy; and

(5) various measures of effort, in which some catchability quotient is related to the change in catch of whales through time, and results are extrapolated back to an estimate of initial population size.

Obviously, whaling logbook data generally cannot be used for cohort analyses or tag/recapture analyses (unless numerous, well-documented marked harpoons are recorded, which appears unlikely), but it may be possible to do part or all of some analyses of cumulative catch, censuses, and catch/effort, from the data found in exceptionally detailed logbooks and journals.

A logbook or journal adequate for useful analyses would contain, at a minimum, daily dated entries with locality and weather data, and details of whales attempted and killed, including also some information on yield.

MATERIALS AND METHODS

A logbook is the formal record of a vessel's voyage, usually kept by the Chief Mate and turned in to the company or owner at the end of the voyage, while journals are the informal, perhaps more anecdotal and less consistent accounts kept by anyone on the voyage (Sherman, 1965, p. 32, 39 ff). Approximately 3,200 voyages are represented by logbooks and journals from the American whale fishery in institutional and other collections, comprising about one-quarter of the 13,927 voyages known to have been made (Sherman, 1965, p. 8). During the period 1804 to 1876, and based upon an average yield of 25 barrels per sperm whale and 10% killed being lost, 225,521 sperm whales were killed according to the estimate of Starbuck (1878, p. 661n), and plats from 1,665 voyages representing the positions on which 36,908 sperms were taken in the 19th century were charted by C. H. Townsend and A. C. Watson (Townsend, 1935, p. 18, charts A, B).

Whaling journals and logbooks contain much information that is personal and entertaining (Johnson, 1971), poetic and creative (Miller, 1979), and it is apparently even remunerative to collect such manuscripts (e.g. Johnson, 1981, 1982), but the emphasis here is on the relevance of the statistical and anecdotal data to whale biology and conservation. For example, whalers' terminology for units of whales encountered could be precise, such as the whale, pod, school and body of whales hierarchy of Bennett (1840, vol. 2, p. 171–172). Entries in logbooks and journals likewise can convey much information, some of it in abbreviated or symbolic form such as the use of a drawing or stamp of a tail for whales seen and of an entire whale for one captured (Browne, 1846, p. 292).

The question is whether this historical whaling information (Martin, 1981; Kugler, 1981) can be useful either with original, anecdotal descriptions of aspects of whale biology, or, whether in the aggregate, sufficient and consistent data exist for biologically useful analyses relevant to current whale conservation needs. American voyages are well indexed (Starbuck, 1878; Hegarty, 1959, 1964; and references in Sherman, 1965, p. 194–202), as are some existing collections of logbooks and journals (e.g. Sherman, 1965; Langdon, ed., 1978). [Since the 1977 workshop for which the first draft of this paper was prepared, some work has been carried out specifically on sperm whale problems from logbook-derived data (e.g. Bannister and Mitchell, 1980; Bannister, Taylor and Sutherland, 1981).]

The logbook used here as an example for discussion is the following:

> 'Journal of a Voyage to the Pacific Ocean in the Ship *Mariner* of Nantucket Whaling by George W. Gardner. Jn In the years of 1836, 1837, 1838, 1839, 1840.' Original logbook in author's collection, 34 x 21 cm, comprised of 192 pages and continuous entries for period 14 IX 1836 to 20 VI 1840 with supplementary compilations at end, and whale 'stamps'. (Starbuck, 1878, p. 327 records for this voyage: Mariner. Ship. 349 tons. Geo. W. Gardner, jr., Captain. Matthew Crosby, Managing Owner or agent. Pacific Ocean. Sailed 14 September 1836. Arrived 20 June 1840. 1,925 Bbls sperm-oil.)

Capt. Gardner, a successful Nantucket whaling captain, was the son of George W. Gardner Senior (Fig. 1). Gardner Senior discovered the 'offshore grounds' off Peru (Stackpole, 1953, p. 266) and has been quoted by historians for other descriptions and discoveries (e.g. Stackpole, 1953, p. 354, 446; Sharp, 1969, p. 208):

> I began to follow the sea at 13 years of age, and continued in that service 37 years. I was a shipmaster 21 years. I performed 3 voyages to the coast of Brazil, 12 to the Pacific Ocean, 3 to Europe, and 3 to the West Indies. During 37 years I was at home but 4 years and 8 months. There were 23,000 barrels of oil obtained by vessels which I sailed in. During my following the sea, from the best estimate I can make, I have travelled more than 1,000,000 miles.
>
> I was taken by the English in the late war, and lost all the property I had with me (Macy, 1835, p. 221; cf. Hohman, 1928, p. 85).

The son had a thoroughly professional whaling captain as an example and might be expected to emulate his father in meticulously documenting his own voyages. Geo. W. Gardner, Jn. sailed on two voyages on the *Maria* with his father as Master (1822–1825, 1825–1828), then on the *Richard Mitchell* (wrecked, 1828), *Harvest* (1828–1831) and *Mariner* (1832–1836) under other Masters before attaining command of the *Mariner* on this voyage (1836–1840). He was captain on the *Nantucket* (1841–1845) and the *Narragansett* (1855–1860).[c]

I consider this Gardner logbook to be one of the better

Fig. 1. Portrait of Nantucket whaling Capt. Geo. W. Gardner, Sr. Unsigned, oil on canvas, 66.5 x 56.0 cm, author's collection.

examples of a comprehensive record of a three and one-half year voyage (cf. Figs. 5–6) kept by a literate man. In this case, the logbook keeper was Gardner, Jn., the master himself, with no indication that the chief mate had an input.

The logbook is illustrated with whale 'stamps', comprising tails of whales representing sightings (and unsuccessful attempts), and entire whales for captures, both serially numbered throughout the voyage (cf. encounter numbers in Table 1; and Figs. 2–4). Near each 'stamp' for captured whales there is also indicated the oil yield in barrels, and one to four dots documenting which boat took the whale – usually Starboard, Larboard or Waist Boat.

From this logbook, sperm whale encounters (sightings, or catch attempts and captures; Table 1) and entries by day for weather conditions for the first few days of the voyages (Table 2) have been extracted. These data extractions took a total of 12 person-days of work.

Also, attempts to kill whales were evaluated, especially the escapement and the mortality in the escapement. This is a record of how many whales were harpooned, and perhaps lanced, but escaped so severely wounded that they died. The Gardner (*Mariner*) logbook was scored for these data, using a key originally devised for bowhead narratives (Mitchell, Ms. 1977) as follows:

1. Sighted/Otherwise encountered (ship approach)
   - 2a. Not attempted/lowered for, etc.
   - 2b. Attempted/lowered for, etc.
     - 3a. Not struck
     - 3b. Struck ('escapement' = not stowed down, 4b/c)
       - 4a. Struck, retrieved and flenched (includes 'stinkers', floating carcasses)
       - 4b. Struck, retrieved, not flenched/lost before processing
       - 4c. Struck, not retrieved[a]:
         - 5a. Harpooned, not lanced, escaped alive
         - 5b. Harpooned, not lanced, dead, lost
         - 5c. Harpooned, lanced, escaped alive
         - 5d. Harpooned, lanced, dead, lost
         - 5e. Harpooned, poisoned/bacillus
         - 5f. Harpooned, not retrieved, insufficient data to make finer judgment
         - 5g. Harpooned, iron drew

RESULTS AND DISCUSSION

It is my presumption that all whales listed in this logbook as encountered were in fact sperm whales. There are some exceptions in the data and these are indicated (e.g. 'pilot whales' in Table 1). However, Gardner did not number them in his sightings. A few whales sighted and referred to as 'finners' or right whales in the log book also were not counted by Gardner and are not entered in Table 1, which is a summary of his sequentially numbered encounters only. This indicates that the log is internally consistent in that Gardner only numbered encounters with his 'target species,' the sperm whale (Fig. 2). Thus, this voyage is clearly for sperm whales, and he did not report any 'whale oil' landed (Starbuck, 1878, p. 327).

However, Gardner's listing of encounters is probably an accurate count of whale schools. Exact counts of the number of individuals seen by him are certainly not forthcoming from this logbook, but some encounters comprised one or two whales. On some days, up to seven whales were killed (Fig. 3).

Documentation of the total number seen could lead directly to population estimates. However, efforts to carry out a strip census analysis will not be useful since the data in the logbook shows that while many encounters are precisely documented, sightings of more than one or two whales were sometimes termed 'many.' Thus, accurate counts were not kept of the total number of whales seen. However, some information is available on pod size, both within the logbook and from other, modern sources such as sighting cruises and mass strandings – thus estimates could be carried out based on the number of encounters with schools in different regions, similar to the usage in current line transect calculations. If some logbook keepers dutifully recorded all whales sighted, a study of relative abundance of sperm, right, humpback and finner whales on some grounds might be possible.

Rather than a sightings or abundance analysis, such logbook data may lend itself to analysis of the number of encounters with schools which is clearly available, and changes in the school size or in its composition (e.g. judged by barrel-yield per whale).

A catch/effort analysis might be possible from this type of logbook data, in that there is exact data on the duration of the voyage, an entry for each day at sea, and for every day there is weather information (Table 2, Figs. 5–6) and an indication of lowerings. In addition, there are data on the number and size of each whale caught (Table 1). This would be most useful if logbooks by the same keeper (and/or under the same Master) were available for

(continued on p. 70)

Table 1

Sperm whale encounter data extracted from the *Mariner* logbook

Year/month/day	Whale encounter number[1]	Escaped[2]	Killed	Barrel yield per whale	Boat taking whale	Cumulative barrels aboard vessel	Latitude	Longitude	Weather
1836 09 27	1	1 (2a)	1P	—	—	—	38° 12′ N	38° 30′ W	Good
1837 01 27	1P	—	1P	—	—	—	08° 24′ S	80° 25′ W	Good
1837 02 07	3P	2 (4c)	1P	—	—	—	05° 49′ S	86° 45′ W	Poor
1837 02 23	2	1 (3a)	—	—	—	—	04° 01′ S	104° 40′ W	Poor
1837 02 25	3	1 (3a)	—	—	—	—	05° 31′ S	106° 05′ W	Mod.
1837 03 26	4	—	1	17	1	—	02° 00′ S	143° 50′ W	Good
1837 03 26	4	—	1	18	1	—	02° 09′ S	144° 39′ W	Good
1837 03 26	4	—	1	17	2	—	02° 09′ S	144° 30′ W	Good
1837 03 26	4	—	1	18	2	—	02° 09′ S	144° 30′ W	Good
1837 03 26	4	—	1	7	3	77	02° 09′ S	144° 30′ W	Good
1837 04 01	5	—	1	59	1	136	06° 15′ S	146° 50′ W	Good
1837 04 07	6	1 (3a)	—	—	—	—	14° 48′ S	149° 15′ W	Good
1837 05 18	7	—	1	13	2	149	Equator	169° 20′ W	Good
1837 05 19	8	1 (5f)	—	—	—	—	Equator	170° 00′ W	Good
1837 06 08	9	—	1	50	3	199	28° 11′ N	173° 30′ W	Good
1837 06 14	10	1 (3a)	—	—	—	—	29° 30′ N	172° 45′ W	Poor
1837 06 15	11	1 (3a)	—	—	—	—	29° 44′ N	172° 40′ W	Good
1837 06 19	12	—	1	36	1	235	29° 32′ N	174° 30′ E	Good
1837 06 20	13	1 (3a)	—	—	—	—	29° 23′ N	174° 30′ E	Good
1837 06 21	14	—	1	46	2	281	29° 28′ N	174° 00′ E	Good
1837 06 21	15	1 (3a)	—	—	—	—	29° 28′ N	174° 00′ E	Good
1837 06 24	16	—	1	36	2	317	29° 21′ N	173° 20′ E	Good
1837 06 25	17	—	1	36	2	353	29° 20′ N	173° 25′ E	Good
1837 06 25	18	1 (2a)	—	—	—	—	29° 20′ N	173° 25′ E	Good
1837 06 28	19	1 (3a)	—	—	—	—	29° 30′ N	173° 00′ E	Good
1837 07 22	20	—	1	23	1	376	28° 20′ N	178° 00′ E	Good
1837 09 11	21	1 (3a)	—	—	—	—	29° 25′ N	176° 30′ E	Good
1837 09 12	22	1 (3a)	—	—	—	—	29° 30′ N	177° 00′ E	Good
1837 09 18	23	—	1	50	3	426	29° 36′ N	175° 20′ E	Good
1837 09 19	24	1 (2a)	—	—	—	—	29° 40′ N	175° 00′ E	Good
1837 09 20	25	1 (3a)	—	—	—	—	29° 20′ N	174° 50′ E	Good
1837 09 20	26	1 (3a)	—	—	—	—	29° 20′ N	174° 50′ E	Good
1837 09 26	27	—	1	33	2	459	29° 14′ N	173° 10′ E	Good
1837 10 13	28	—	1	75	2	534	29° 10′ N	177° 50′ W	Good
1837 11 25	29	1 (5g)	—	—	—	—	22° 39′ N	158° 30′ W	Good
1837 11 26	30	—	1	18	2	—	22° 39′ N	158° 30′ W	Good
1837 11 26	30	—	1	18	3	—	22° 39′ N	158° 30′ W	Good
1837 11 26	30	—	1	17	2	—	22° 39′ N	158° 30′ W	Good
1837 11 26	30	—	1	17	3	—	22° 39′ N	158° 30′ W	Good
1837 11 26	30	—	1	12	1	—	22° 39′ N	158° 30′ W	Good
1837 11 26	30	—	1	8	2	—	22° 39′ N	158° 30′ W	Good
1837 11 26	30	—	1	7	2	631	22° 39′ N	158° 30′ W	Good
1837 12 19	31	1 (3a)	—	—	—	—	24° 42′ N	112° 32′ W	Good
1837 12 20	32	1 (3a)	—	—	—	—	24° 20′ N	112° 42′ W	Good
1838 01 02	33	1 (5a)	—	—	—	—	Off Cape Pulmo		Good
1838 01 18	34	1 (3a)	—	—	—	—	18° 10′ N	104° 30′ W	Good
1838 01 18	35	1 (3a)	—	—	—	—	18° 10′ N	104° 30′ W	Good
1838 02 01	36	1 (3a)	—	—	—	—	02° 25′ N	106° 30′ W	Good
1838 02 14	37	1 (2a)	—	—	—	—	Equator	119° 00′ W	Good
1838 02 15	38	—	1	30	3	661	01° 01′ N	119° 30′ W	Good
1838 02 16	39	1 (3a)	—	—	—	—	Equator	119° 40′ W	Good
1838 02 17	40	—	1	23	3	684	01° 11′ N	119° 55′ W	Good
1838 02 24	41	—	1	20	2	704	01° 18′ S	122° 50′ W	Good
1838 02 26	42	1 (2a)	—	—	—	—	01° 01′ S	123° 30′ W	Good
1838 02 26	43	1 (3a)	—	—	—	—	01° 01′ S	123° 30′ W	Good
1838 03 09	44	1 (3a)	—	—	—	—	Equator	127° 30′ W	Good
1838 04 12	45	—	1	20	1	—	18° 50′ N	149° 20′ W	Good
1838 04 12	45	—	1	30	2	754	18° 50′ N	149° 20′ W	Good
1838 05 06	46	1 (5a)	—	—	—	—	26° 16′ N	161° 50′ W	Good
1838 05 24	47	—	1	77	2	831	30° 00′ N	177° 00′ W	Good
1838 06 08	48	1 (3a)	—	—	—	—	28° 30′ N	173° 40′ E	Poor
1838 06 24	49	—	1	100	2	931	29° 20′ N	173° 10′ E	Good
1838 07 01	50	1 (3a)	—	—	—	—	28° 00′ N	172° 30′ E	Good
1838 07 02	51	1 (5a)	—	—	—	—	28° 00′ N	172° 30′ E	Good
1838 07 02	52	1 (3a)	—	—	—	—	28° 00′ N	172° 30′ E	Good
1838 07 04	53	1 (3a)	—	—	—	—	28° 30′ N	173° 05′ E	Good
1838 07 04	54	—	1	50	2	981	28° 30′ N	173° 05′ E	Good
1838 07 05	55	1 (3a)	—	—	—	—	28° 58′ N	173° 00′ E	Poor
1838 07 09	56	1 (2a)	—	—	—	—	28° 37′ N	172° 30′ E	Mod.
1838 07 23	57	1 (2a)	—	—	—	—	29° 30′ N	168° 00′ E	Good
1838 08 18	58	1 (3a)	—	—	—	—	29° 30′ N	168° 00′ E	Good
1838 09 12	59	—	1	42	1	1,023	29° 00′ N	173° 40′ E	Good

Table 1 (*continued*)

Year/month/day			Whale encounter number[1]	Escaped[2]	Killed	Barrel yield per whale	Boat taking whale	Cumulative barrels aboard vessel[4]	Latitude	Longitude	Weather
1838	09	13	60	—	1	42	1	1,065	28° 20′ N	173° 00′ E	Good
1838	09	14	61	1 (3a)	—	—	—	—	28° 29′ N	173° 00′ E	Good
1838	09	16	62	1 (3a)	—	—	—	—	30° 00′ N	173° 00′ E	Good
1838	09	28	—	—	1[3]	55	0	1,120	29° 40′ N	178° 45′ W	Mod.
1838	10	27	63	1 (3a)	—	—	—	—	24° 30′ N	152° 20′ W	Good
1838	10	28	64	—	1	20	1	—	24° 06′ N	152° 30′ W	Good
1838	10	28	64	—	1	18	1	—	24° 06′ N	152° 30′ W	Good
1838	10	28	64	—	1	20	3	—	24° 06′ N	152° 30′ W	Good
1838	10	28	64	—	1	22	2	1,200	24° 06′ N	152° 30′ W	Good
1838	10	29	65	—	1	18	3	—	22° 22′ N	153° 00′ W	Good
1838	10	29	65	—	1	12	2	1,230	22° 22′ N	153° 00′ W	Good
1838	10	31	66	1 (2a)	—	—	—	—	20° 54′ N	154° 41′ W	Good
1838	11	02	67	1 (3a)	—	—	—	—	Off Maui		Mod.
1839	01	03	68	1 (3a)	—	—	—	—	07° 30′ N	143° 00′ W	Poor
1839	01	04	69	1 (3a)	—	—	—	—	07° 00′ N	142° 40′ W	Good
1839	01	17	70	1 (3a)	—	—	—	—	07° 40′ S	140° 30′ W	Good
1839	01	18	71	1 (3a)	—	—	—	—	07° 25′ S	140° 15′ W	Good
1839	01	19	72	—	1	13	3	—	07° 00′ S	140° 35′ W	Mod.
1839	01	19	72	—	1	15	2	—	07° 00′ S	140° 35′ W	Mod.
1839	01	19	72	—	1	16	3	1,274	07° 00′ S	140° 35′ W	Mod.
1839	01	21	73	—	1	13	1	—	07° 55′ S	140° 45′ W	Mod.
1839	01	21	73	—	1	16	2	1,303	07° 55′ S	140° 45′ W	Mod.
1839	01	24	74	—	1	10	2	—	07° 30′ S	140° 40′ W	Mod.
1839	01	24	74	—	1	13	1	—	07° 30′ S	140° 40′ W	Mod.
1839	01	24	74	—	1	13	3	1,339	07° 30′ S	140° 40′ W	Mod.
1839	02	04	75	1 (3a)	—	—	—	—	03° 20′ S	141° 50′ W	Mod.
1839	02	20	76	—	1	5	2	—	Off Robert's Island		Good
1839	02	20	76	—	1	11	1	1,355	Off Robert's Island		Good
1839	02	26	77	—	1	23	3	—	07° 10′ S	141° 12′ W	Good
1839	02	26	77	—	1	20	3	1,398	07° 10′ S	141° 12′ W	Good
1839	03	25	78	1 (3a)	—	—	—	—	08° 36′ S	144° 35′ W	Good
1839	05	09	79	—	1	18	4	—	02° 51′ S	150° 50′ W	Good
1839	05	09	79	—	1	18	1	1,407	02° 51′ S	150° 50′ W	Good
1839	05	16	80	—	1	12	2	—	01° 28′ N	157° 00′ W	Good
1839	05	16	80	—	1	12	3	—	01° 28′ N	157° 00′ W	Good
1839	05	16	80	—	1	12	2	—	01° 28′ N	157° 00′ W	Good
1839	05	16	80	—	1	12	1	1,455	01° 28′ N	157° 00′ W	Good
1839	06	04	81	—	1	6	3	—	Equator	173° 20′ W	Good
1839	06	04	81	—	1	16	1	1,477	Equator	173° 20′ W	Good
1839	06	08	82	2 (5d)	1	16	4	—	Equator	173° 51′ W	Mod.
1839	06	08	82	—	1	6	2	1,499	Equator	173° 51′ W	Mod.
1839	06	09	—	—	1[3]	11	2	—	Equator	173° 55′ W	Poor
1839	06	10	83	1 (5d)	1	15	4	—	Equator	174° 00′ W	Good
1839	06	10	83	—	1	5	3	1,530	Equator	174° 00′ W	Good
1839	07	06	84	1 (3a)	—	—	—	—	30° 00′ N	174° 48′ W	Mod.
1839	07	07	85	1 (3a)	—	—	—	—	29° 22′ N	173° 30′ E	Good
1839	08	03	86	—	1	39	3	1,569	29° 43′ N	173° 00′ E	Good
1839	08	04	87	1 (3a)	—	—	—	—	30° 02′ N	173° 40′ E	Good
1839	08	05	88	1 (2a)	—	—	—	—	30° 10′ N	173° 20′ E	Poor
1839	08	10	89	—	1	71	1	1,640	30° 15′ N	172° 30′ E	Good
1839	08	23	90	1 (2a)	—	—	—	—	30° 30′ N	172° 40′ E	Poor
1839	08	28	91	1 (2a)	—	—	—	—	30° 48′ N	171° 00′ E	Poor
1839	08	29	92	1 (3a)	—	—	—	—	30° 13′ N	171° 56′ E	Poor
1839	09	15	93	—	1	24	3	1,664	29° 00′ N	173° 20′ E	Poor
1839	09	23	94	—	1	42	3	1,706	28° 20′ N	173° 55′ E	Mod.
1839	10	03	95	—	1	30	3	—	29° 14′ N	175° 00′ E	Good
1839	10	05	96	1 (3a)	—	—	—	—	29° 20′ N	175° 30′ E	Good
1839	10	08	97	—	1	61	2	1,797	29° 00′ N	179° 59′ E	Poor
1839	11	16	98	1 (3a)	—	—	—	—	22° 04′ N	155° 20′ W	Mod.
1840	01	13	99	—	1	14	1	—	09° 34′ S	142° 36′ W	Good
1840	01	13	99	—	1	14	2	—	09° 34′ S	142° 36′ W	Good
1840	01	13	99	—	1	13	3	1,838	09° 34′ S	142° 36′ W	Good
1840	01	17	100	1 (3a)	—	—	—	—	09° 40′ S	142° 00′ W	Good
1840	02	05	101	1 (3a)	—	—	—	—	12° 12′ S	144° 16′ W	Good
1840	02	28	102	—	1	14	1	—	27° 07′ S	149° 21′ W	Good
1840	02	28	102	—	1	14	2	—	27° 07′ S	149° 21′ W	Good
1840	02	28	102	—	1	14	3	—	27° 07′ S	149° 21′ W	Good
1840	02	28	102	—	1	14	1	—	27° 07′ S	149° 21′ W	Good
1840	02	28	102	—	1	14	1	1,908	27° 07′ S	149° 21′ W	Good
1840	02	29	103	1 (2a)	—	—	—	—	27° 00′ S	149° 40′ W	Poor
1840	04	03	104	1 (2a)	—	—	—	—	54° 33′ S	87° 50′ W	Poor
1840	06	07	105	1 (5a)	—	—	—	—	29° 06′ N	65° 12′ W	Good
1840	06	11	106	—	1	8	3	—	34° 14′ N	68° 44′ W	Good

Table 1 (*continued*)

Year/month/day	Whale encounter number[1]	Escaped[2]	Killed	Barrel yield per whale	Boat taking whale	Cumulative barrels aboard vessel	Latitude	Longitude	Weather
1840 06 11	106	—	1	20	2	—	34° 14′ N	68° 44′ W	Good
1840 06 11	106	—	1	8	3	1,944	34° 14′ N	68° 44′ W	Good
Totals		2a = 13 3a = 44 5a = 4 5d = 2 5f = 1 5g = 1 65	82			1,944 or 1,925[5]			

[1] P = pilot whale. Numbering system as used by Gardner.
[2] Code in parentheses (see text and notes a, b, added in proof).
[3] Dead ('stinker').
[4] As indicated by Gardner in logbook.
[5] Number given by Gardner in the last entry for the voyage (20 June 1840) accounting for some leakage.

many voyages – ideally in the same or similar vessels – giving long time series of comparable data.

A major concern is the consistency of such logbook data. Each captain had his own system, but there usually is an entry for each day at sea, an attempt each day to obtain precise locality data, and sometimes information on sea state and visibility.

An example of the detailed weather data (Table 2) indicates that Gardner used internally consistent terminology, which can be recognized in the following outline:

1. A description of the wind and sometimes the sea state, in terminology such that it might be scored using the Beaufort Wind Scale. Comments on handling the sails aid in interpretation of these data.

2. Sighting and/or hunting conditions, usually included in the above, or can be inferred, which can be scored as follows (after Canadian C/E form; see IWC, 1976): 1, clear; 2, haze; 3, rain; 4, intermittent fog; 5, 'black thick' fog; 6, no hunting or watch due to darkness.

Results of scoring the attempts to kill whales to evaluate the escapement and the mortality in the escapement (Table 1) indicate that a quarter of the encounters (80/108 = 74%) did not result in a capture. Of the 52 non-capture attempts, 44 (or 85%) were lowered for and chased but not struck. Only 13 (or 20%) were not lowered for. Loss rates were low: only 6 (or 6/86 = 7%) were struck and probably killed but not retrieved. Two more were struck but probably not killed and if these were included this figure would be 9%[b].

A total catch of 82 sperm whales were taken on the voyage (Table 1), yielding a total of 1,925 barrels of sperm oil (mean 23.5 bbls/sperm whale). Size distribution of the whales taken, as reflected in oil yield, was:

Yield/whale (bbls)	Number of sperm whales
0–10	10
11–20	45
21–30	8
31–40	5
41–50	7
51–60	2
61–70	1
71–80	3
81–90	0
91–100	1

This catch includes two carcasses found at sea, representing moribund escapement from another vessel, not numbered in the sequential encounters (Table 1). (I have made no corrections here for this – but it would be highly relevant in a larger study if carcasses were as commonly found as indicated in this logbook.)

The oil yield should be corrected by area and date of operation (i.e., to separate out mature bulls and their high yield), and also for the number of whales killed per day. The yield per whale is likely to be significantly lower when two or more are killed, and efficiency of flensing, extraction and processing drops.

Also, from a number of logs, not just a single good one, the average yield per whale could be calculated for each leg of the cruise north and south of 40° N and 40° S (the approximate limits of migration of cows). Then, with an added correction for leakage, the yield should be compared to the total annual landings of barrels of sperm oil for the years considered for all nations. In order to prorate the distribution of the total catch by ocean basin, a sample of the best logs, up to 10% of the total number of voyages known for a given year, should be indexed for cruise tracks relative to ocean basin and 40° N and 40° S latitude. Then, the total oil production from a cruise could be taken as yields in the same percentages of the total as the time spent in each area, with corrections for greater yield per whale from polewards of 40° N and 40° S. (This emphasizes that an important parameter in indexing and using logbooks is a precise breakdown of the cruise track, cf. Figs. 5–6).

In order to more fully interpret these yield data, it would be useful to have a 'yield' curve based on known yield in barrels by size of each sex for this fishery or period. Such data might not be readily obtainable in detail from logbooks as only in exceptional cases was sex or total length of killed whales recorded (Murphy, 1947, p. 57), but data from modern sperm whaling operations should be applicable (see e.g. Best and Surmon, 1974; Best, this volume).

Whaler's knowledge of oil yield was that cows give up to 35 barrels of oil, males separate from the cows and calves when about the size of 35 barrels and strongly associate in all-male schools as '40-barrel bulls,' and older bulls yield 50–70 barrels (Captain H. W. Seabury *in* Clark, 1887; quoted by Best, 1979, p. 227). Cows make

(continued on p. 77)

Table 2

Abbreviated examples of the weather entries from the logbook of the *Mariner* for approximately the first six weeks of the voyage. Most entries have additional detail on wind direction.

Year	Month	Day	Weather[1]
1836	09	14	'Ahead middle part calm latter part a moderate breeze'
1836	09	15	'First part of these 24 hours a gentle breeze from WSW beating up the Vineyard Sound'
1836	09	16	'Gentle breeze from NE and pleasant the first part of these 24 hours'
1836	09	17	'Fresh breezes and pleasant the first and middle parts of these 24 hours latter part light breezes and a heavy swell'
1836	09	18	'Gentle breezes and pleasant the first part of these 24 hours. Latter part fresh breezes'
1836	09	19	'Strong breezes and cloudy the first part of these 24 hours. At 5 p.m. took in the light sails and double ruffed the topsails. Middle part strong gales and heavy rain. Latter part a pleasant breeze'
1836	09	20	'Moderate breezes and pleasant the first part of these 24 hours and mid part. Latter part fresh breezes and squally'
1836	09	21	'Fresh breezes and pleasant all these 24 hours. Took in the misin top gallant sail and double ruffed the topsails'
1836	09	22	'First part of these 24 hours strong breezes from North and pleasant course EBS. Ship under double ruffed topsails — courses and jibb. Latter part — moderate under single ruffs'
1836	09	23	'Moderate breezes and pleasant the first part of these 24 hours. — headed east by the wind, all sail out. Latter part nearly calm'
1836	09	24	'First part of these 24 hours — breeze from SW course EBS, all sail out'
1836	09	25	'Moderate breezes and pleasant all these 24 hours - all sail out'
1836	09	26	'Gentle breezes and pleasant all these 24 hours - all sail out'
1836	09	27	'Moderate breezes and pleasant all these 24 hours'
1836	09	28	'Gentle breezes and pleasant the first and middle parts of these 24 hours. Latter part calm and cloudy'
1836	09	29	'Calm and cloudy the first part of these 24 hours, and middle part a moderate breeze, latter part wind SSE, headed east all sail out very pleasant'
1836	09	30	'Gentle breezes and cloudy all these 24 hours - all sail out'
1836	10	01	'Gentle breezes and cloudy all these 24 hours - all sail out'
1836	10	02	'Gentle breezes and cloudy the first part of these 24 hours - middle part breeze SBE, latter part very pleasant'
1836	10	03	'Gentle breezes and pleasant all these 24 hours - all sail out'
1836	10	04	'Moderate breezes and cloudy the first part of these 24 hours - at 4 p.m. the wind started to NW in a squall - part fresh breezes and squally'
1836	10	05	'Fresh breezes and pleasant all these 24 hours - all sail out'
1836	10	06	'Fresh breezes and pleasant all these 24 hours - all drawing sail'
1836	10	07	'Gentle breezes and pleasant all these 24 hours - all sail out'
1836	10	08	'Gentle breezes and pleasant all these 24 hours'
1836	10	09	'Gentle breezes and pleasant the first part of these 24 hours, middle part much the same, latter part squally'
1836	10	10	'Moderate breezes and squally the first part of these 24 hours, middle and latter part pleasant - all sail out'
1836	10	11	'Moderate trades and squally the first part of these 24 hours, all sail out. Middle part, the water looked so green and weather squally that we took in the light sails. Latter part was very green indeed, wind about NE and very pleasant - all sail out.'
1836	10	12	'Moderate trade and pleasant the first part of these 24 hours - all sail out, middle part pleasant, latter part green water again.
1836	10	11	'Gentle trades and pleasant the first part of these 24 hours. No land in sight at noon and a small breeze and very pleasant'
1836	10	14	'Gentle breezes and pleasant all these 24 hours'
1836	10	15	'Gentle breezes and cloudy the first part of these 24 hours. Latter part pleasant'
1836	10	16	'Gentle breezes and pleasant the first part of these 24 hours, middle part variable winds and heavy rains, latter part pleasant again'
1836	10	17	'Moderate breezes and heavy rains the first part of these 24 hours - all sail out, middle and latter parts calm and pleasant'
1836	10	18	'First part of these 24 hours calm, middle and latter part a moderate breeze - all sail out occasionally between the squalls'
1836	10	19	'Moderate breezes and squally the first part of these 24 hours, middle and latter parts a very gentle breeze - all sail out'
1836	10	20	'Calm the first part of these 24 hours. Middle part a gentle breeze, latter part a fine breeze - all sail out'
1836	10	21	'Moderate breezes and pleasant the first part of these 24 hours, middle part squally with thunder and lightning, shortened sail accordintly. Later pleasant again'
1836	10	22	'First part of these 24 hours nearly calm, middle part squally with heavy rains. Latter part cloudy, rainy, squally weather made and shortened sail as occasion required'
1836	10	23	'Fresh breezes and squally the first part of these 24 hours. Latter part more moderate'
1836	10	24	'Moderate breezes and cloudy the first part of these 24 hours, middle part squally, latter part calm and cloudy'
1836	10	25	'Gentle breeze from SSE and squally looking weather, middle and latter part pleasant and a moderate breeze - all sail out'
1836	10	26	'Moderate breezes and pleasant all these 24 hours - all sail out'
1836	10	27	'Moderate breezes and pleasant all these 24 hours'
1836	10	28	'Moderate breezes and pleasant all these 24 hours - all sail out'
1836	10	29	'Moderate trades and pleasant all these 24 hours - all sail out'
1836	10	30	'Moderate trades and pleasant all these 24 hours - all sail out'
1836	10	31	'Moderate trades and pleasant all these 24 hours - all drawing sail'
1836	11	01	'Moderate trades and pleasant all these 24 hours - all drawing sail out'
1836	11	02	'Moderate breezes and pleasant all these 24 hours'

[1] Blanks indicate unreadable text in logbook.

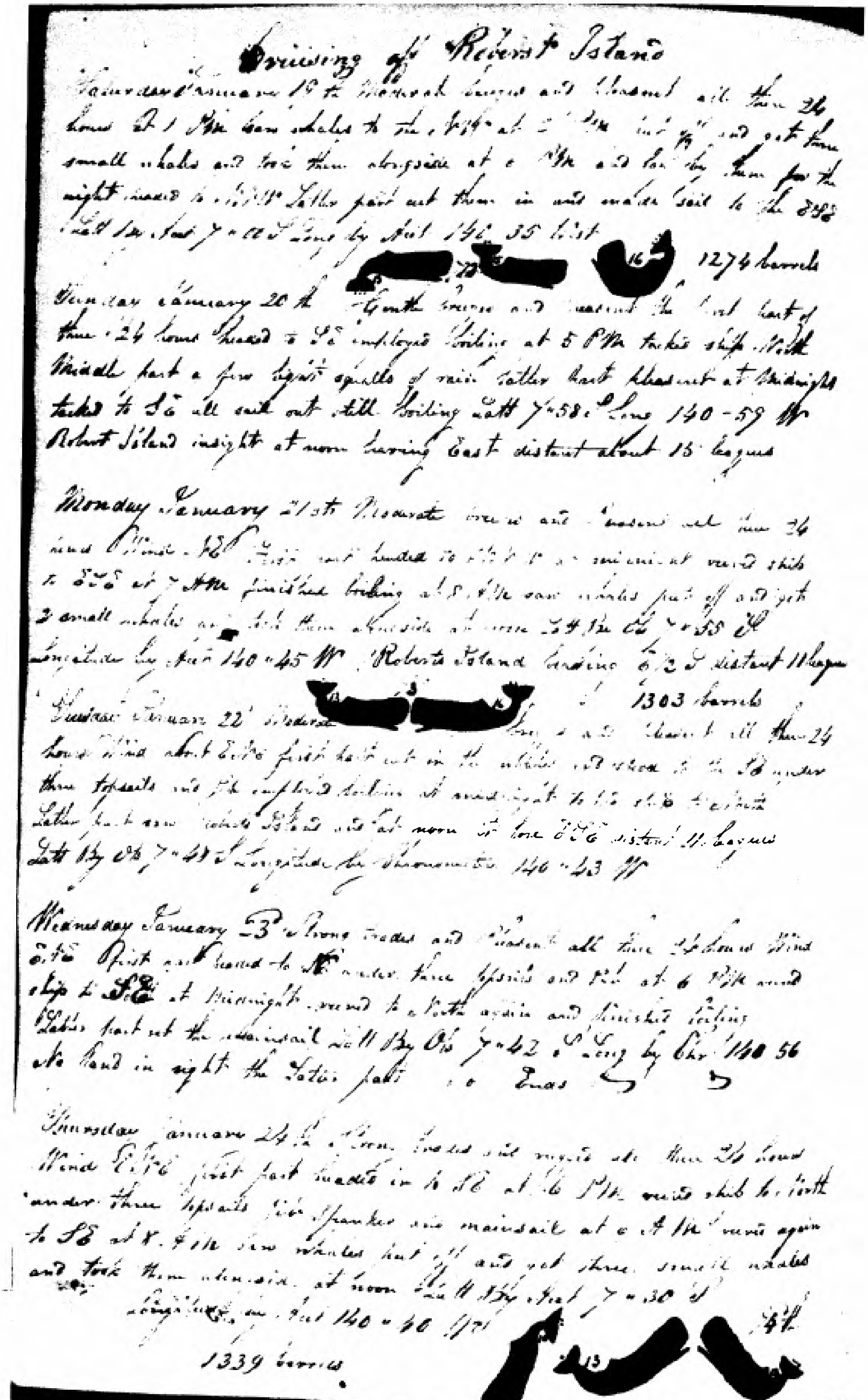


Fig. 2. Gardner's whale 'stamps' in the *Mariner* logbook appear to be drawings, all slightly different but many possibly from the same outline. His entries remain laconic, but here, by encounters 72–74, well into the more than three and one-half year trip when it is obvious that he will make a good voyage, the attitude of his whale 'stamps' may indicate good humour on the part of the Master, or something about the behaviour of the whales he hunted.

Bound in towards California from the Islands

420

Friday November 24th Gentle trades and Pleasant all these 24 hours laying off Oahu at 3 PM the boat returned onboard with a native in the room of Adam Green and we kept off SW to double the SW end of Oahu Middle part doubled around Barbers Point and headed to NBE by the wind in company with the Catawba and Henry Astor at noon the middle part of Oahu bore ENE distant 25 miles saw Moui to the NWby

421

Saturday November 25th Gentle trades and pleasant all these 24 hours First part headed NBE at 3 PM saw whales fast of and struck a small one but the iron drew and he escaped at sunset took up our boats and stood to the SSE until 9 PM and then tacked off to NNE under easy sail in hopes to fall in with the whales in the morning at daylight saw them close to the ship put off and at 8 AM got fast all 3 boats so Ends employed killing whales saw the Henry Astors boats off she got something

Sunday November 26th gentle breezes and pleasant all the first part of these 24 hours at 5 PM took 7 small whales alongside and shortened sail for the night headed NNE the middle part of Oahu bearing SSE distant 16 leagues middle part a ship passed to windward a boiling supposed to be the Henry Astor at daylight commenced cutting at 7 AM wore ship it being very rugged and a strong trade wind saw an english barque to windward on the opposite tack at noon got 3 of the whales in Latt by Obs 22 - 39 N Longitude by account 158 - 30 - 00 West

423 631 barrels onboard now

Monday November 27th Strong trades and rugged all these 24 hours Wind East first part headed to South employed cutting to leeward at sunset finished cutting and wore ship to NNE under a double reefed main topsail and foresail and commenced boiling latter part headed NEBN employed boiling out the mizzen topsail close reefed Latt by Obs 23 - 10 N Long by Acct 158 - 30 West

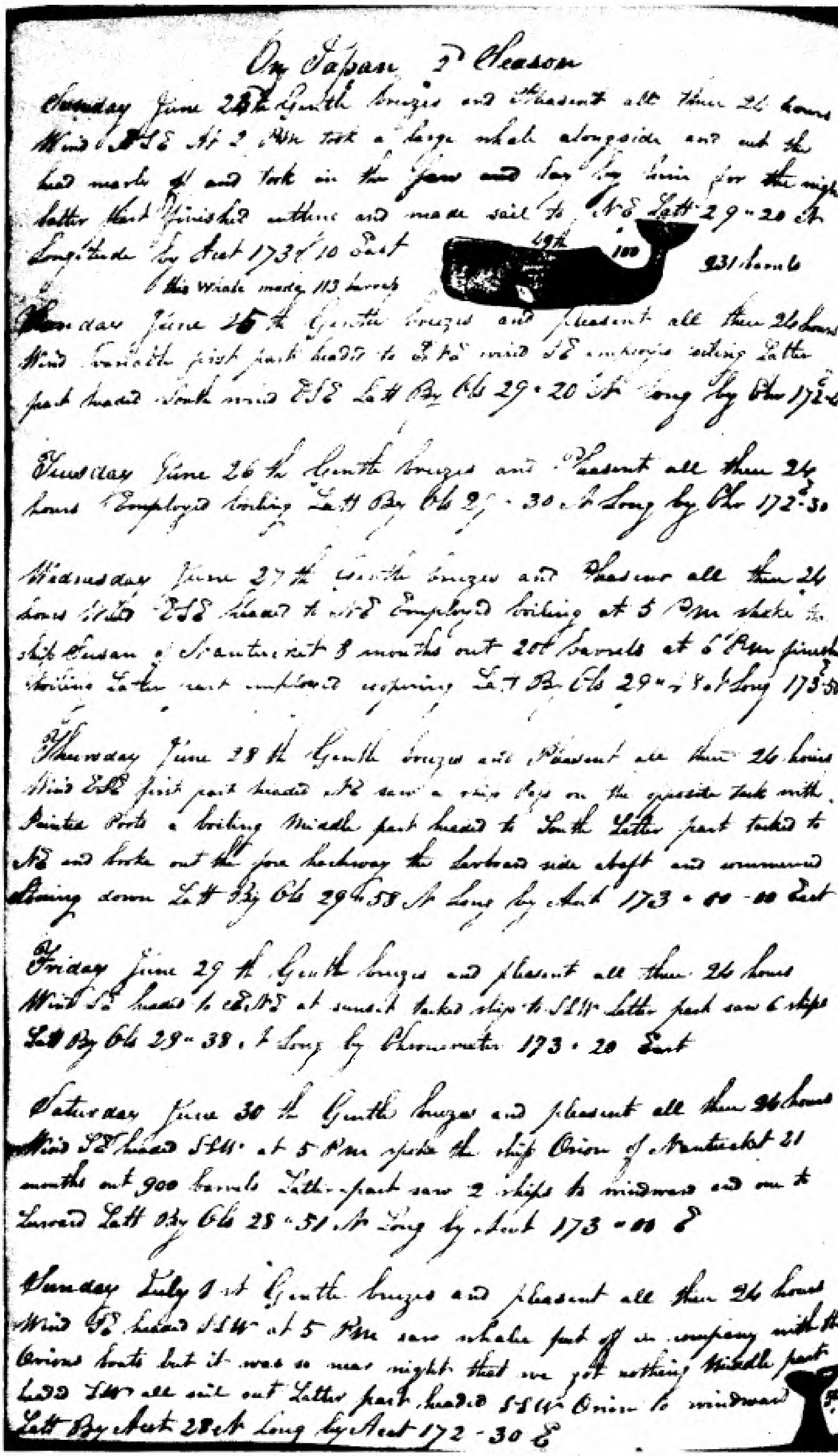
424

Tuesday November 28th Strong trades and very rugged all these 24 hours headed from NNE to NBW employed boiling Latt By Obs 24 - 00 N

425

Wednesday November 29th Strong trades and squally all these 24 hours headed North Employed boiling under double reefed topsails So Ends Latt by Obs 25 - 00 N Longitude by Acct 158 - 20 - 00 West

Fig. 3. After striking and losing a small whale (encounter 29) near Oahu, the *Mariner* took seven whales on the 25th and 26th of November 1837 – these ranged from seven to eighteen barrels each. The American sperm whaler was not always selective, and at times by taking everything that crossed his bow, may have collected information that will allow the whaling historian to examine the composition of pods.



On Japan 2d Season

Sunday June 24th Gentle breezes and pleasant all these 24 hours Wind N.N.E. At 2 P.M. took a large whale alongside and cut the head mostly off and took in the jaw and lay by him for the night latter part finished cutting and made sail to N.E. Latt 29 - 20 N Longitude by Acct 173 - 10 East

49th 100 931 barrels

This whale made 113 barrels

Monday June 25th Gentle breezes and pleasant all these 24 hours Wind South first part headed to E. mid S.E. employed boiling Latter part headed South wind E.S.E. Latt By Obs 29 - 20 N Long By Obs 172 - 40

Tuesday June 26th Gentle breezes and pleasant all these 24 hours Employed boiling Latt By Obs 29 - 30 N Long By Obs 172 - 30

Wednesday June 27th Gentle breezes and pleasant all these 24 hours Wind E.S.E. headed to N.E. Employed boiling at 5 P.M. spoke the ship Susan of Nantucket 8 months out 200 barrels at 6 P.M. finished boiling Latter part employed coopering Latt By Obs 29 - 28 N Long 173 - 50

Thursday June 28th Gentle breezes and pleasant all these 24 hours Wind E.S.E. first part headed N.E. saw a ship lying on the opposite tack with Painted Ports a boiling Middle part headed to South Latter part tacked to N.E. and broke out the fore hatchway the larboard side aft and commenced stowing down Latt By Obs 29 - 58 N Long by Acct 173 - 00 - 00 East

Friday June 29th Gentle breezes and pleasant all these 24 hours Wind S.E. headed to E.N.E. at sunset tacked ship to S.S.W. Latter part saw 6 ships Latt By Obs 29 - 38 N Long by Chronometer 173 - 20 East

Saturday June 30th Gentle breezes and pleasant all these 24 hours Wind S.E. headed S.S.W. at 5 P.M. spoke the ship Orion of Nantucket 21 months out 900 barrels Latter part saw 2 ships to windward and one to Leeward Latt By Obs 28 - 51 N Long by Acct 173 - 00 E

Sunday July 1st Gentle breezes and pleasant all these 24 hours Wind S.E. headed S.S.W. at 5 P.M. saw whales put off in company with the Orions boats but it was so near night that we got nothing Middle part laid S.W. all sail out Latter part headed S.S.W. Orion to windward Latt By Acct 28 - 08 N Long by Acct 172 - 30 E

Fig. 4. During the 'Second Season, on Japan' whales were sighted at 7 a.m. on Saturday, 23 June 1838 and boats from the *Mariner* 'put off and chased about 14 miles at noon struck a large whale'. This page of the logbook shows the account of the cutting in and trying out over many days of this whale, the largest bull taken on the cruise. Apparently the 49th encounter (the 50th was a sighting only), this kill resulted in a cumulative total of 931 barrels of oil on board, and was labelled as producing 100 barrels but an intercalation notes that 'this whale made 113 barrels'.

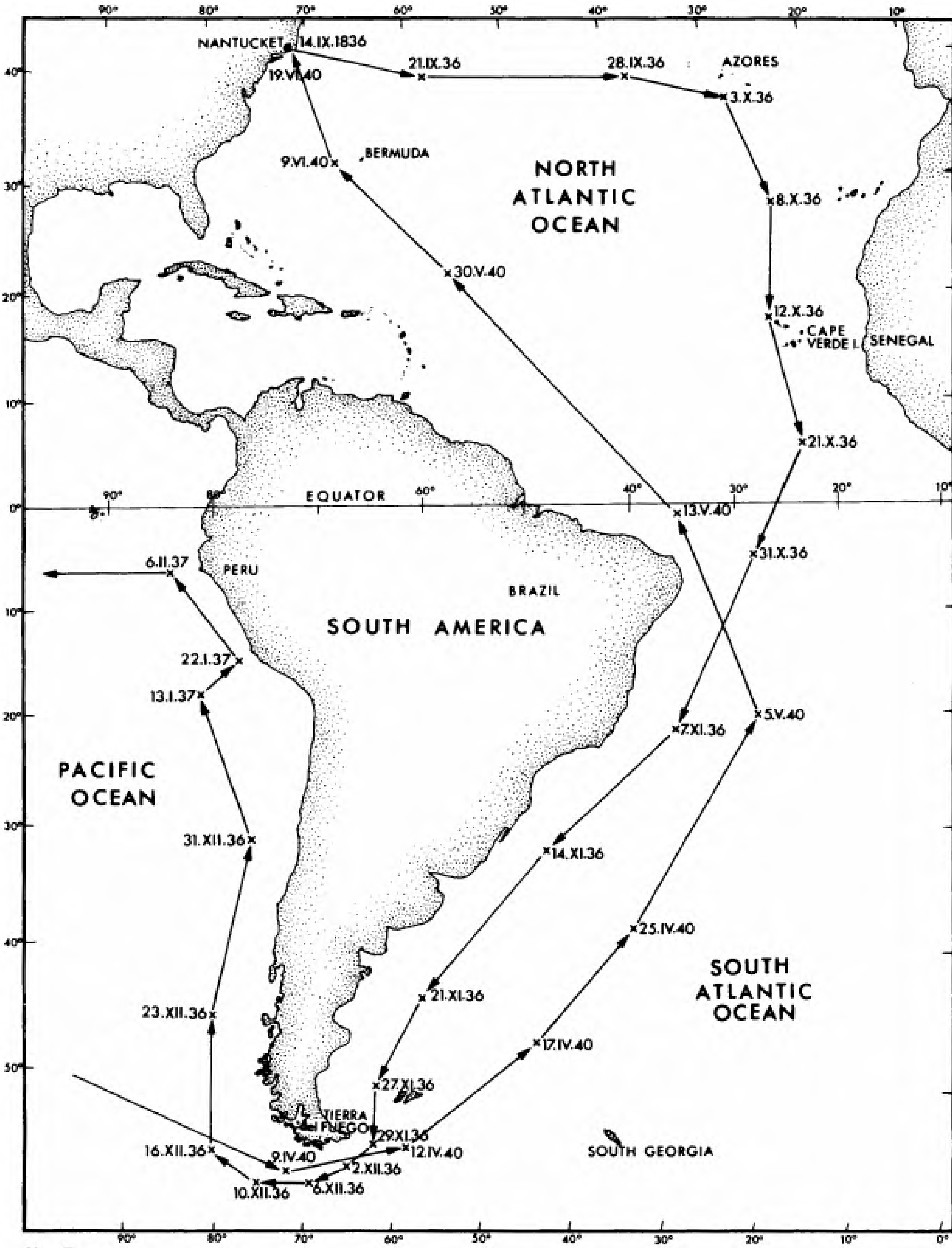


fig 5

Figs. 5–6. Charts showing track of the sperm whaling ship *Mariner*, Nantucket to the Pacific and back, 14 September 1836 to 20 June 1840. (5) Outward bound, east to the Azores and south to the Cape Verdes in the Autumn of 1836, then round Cape Horn on the way to three years on the Pacific grounds, followed by return directly to Nantucket in Spring 1840. (6) Working north through the Coast of Chile Ground, Callao Ground and Galapagos Ground, then west through the Offshore Ground, before settling into an annual itinerary. This itinerary, repeated for three years, included Summer hunting on the Japan Ground and Autumn on the Hawaiian Ground, with Winter and Spring either at the On The Line Ground or in the Tuamotu Archipelago. (The single exception was a winter 1837 cruise off Lower California and the Offshore Ground. The itinerary otherwise accords well with the description and recommendations of the contemporary Charles Wilkes, 1845, vol. 5, pp. 487–93; and see: Hohman, 1928, pp. 150–1; Townsend, 1935; and Bennett, 1840, vol. 2, p. 182.) Note that the tracks shown are approximate.

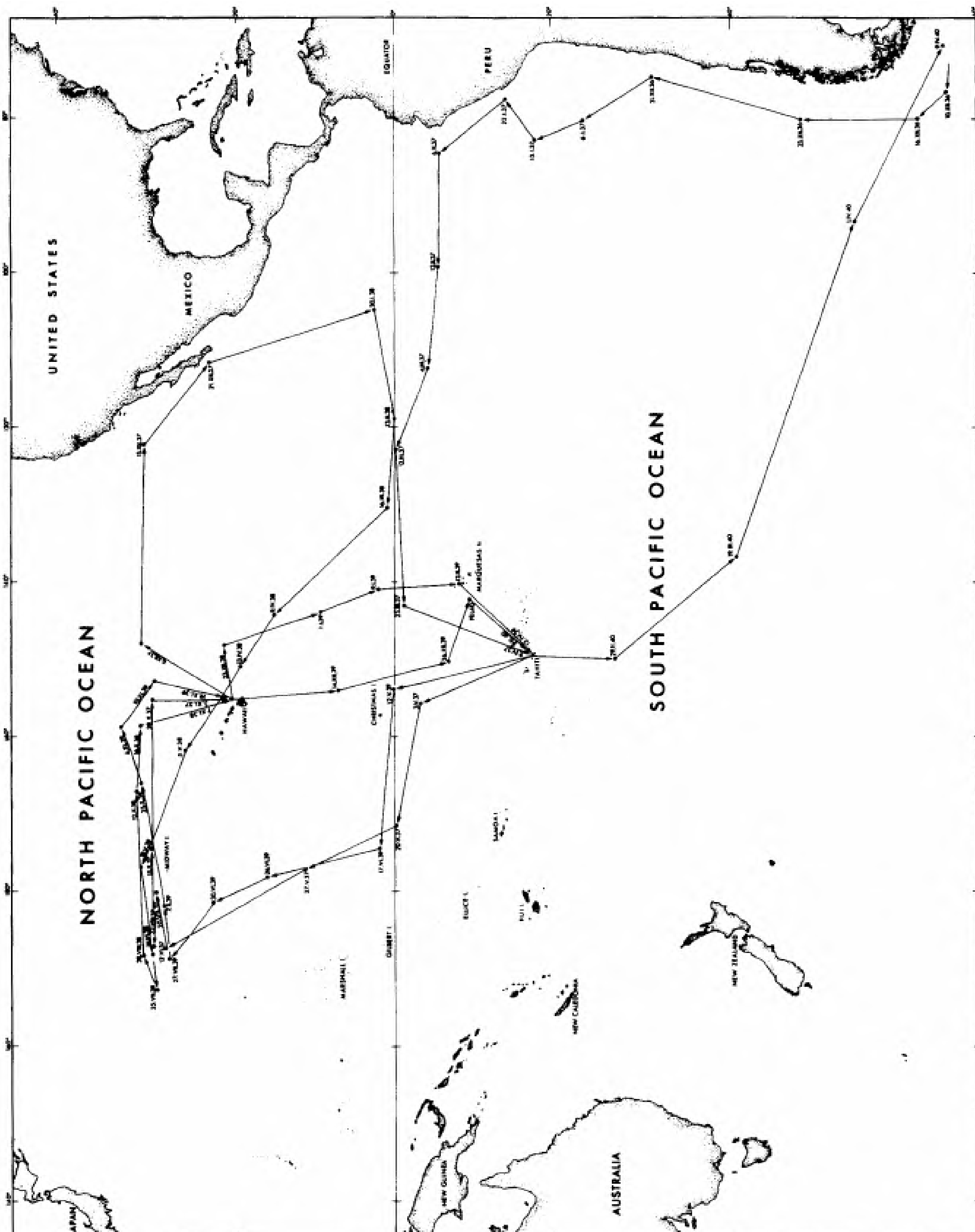

NORTH PACIFIC OCEAN
SOUTH PACIFIC OCEAN
UNITED STATES
MEXICO
PERU
EQUATOR
HAWAII
TAHITI
MARQUESAS I.
MIDWAY I.
CHRISTMAS
GILBERT I.
MARSHALL I.
ELLICE I.
SAMOA I.
FIJI I.
NEW CALEDONIA
NEW ZEALAND
NEW GUINEA
AUSTRALIA
JAPAN

fig 6

from eight to 40 barrels (Macy, 1835, p. 228), and (larger ones?) average 25–30 barrels (Stevenson, 1904, p. 190) with a maximum of 50 (Bennett, 1840, vol. 2, p. 155). The (larger?) bulls average 75–90 barrels with a maximum of 145 (Stevenson, 1904, p. 190, 192; Bennett, 1840, vol. 2, p. 155). Scammon (1874, p. 76) stated that a 'large' bull would yield 85 barrels, True (1884, p. 9) gave a range of 60–150 barrels, and Goode (1884, Sect. I, Text, p. 11) gave specific examples of 80 to 120, 127, 130, 150 and 154 barrel bulls. Thus, probably any sperm whale yielding over 40 barrels, certainly 50, was a bull, and the maximum for bulls was approximately 150 barrels.[6]

Of the seven whales the *Mariner* captured that yielded over 50 barrels each (Table 1; Fig. 4), four were taken in the North Pacific during the mating season (March–August, cf. Mitchell and Kozicki, 1978, table 1 and contained references), south of 31° N.

If the *Mariner* catch composition was typical of the American sperm whaling fleet, mature bulls were probably selected for and were certainly taken during the mating season.

Details of such selection may never be known. I take it that if, in some accounts of the hunt, selection is mentioned in a few, then it occurred to some unknown degree. Further if a circumstantial argument can be made for it that accords with known and diverse aspects of the hunt, then it likely occurred with some frequency when opportunity permitted.

The point here is that in encountering pods or schools, whalers would not always find large bachelors in them, and I believe that their propensity would be to take any and all available whales. When large bachelors were available, I believe they were selected for since they were easier to kill than 40 barrel bulls, the yield was two to three times as great as the 40 barrel bulls or a large cow, the tenure of the harpooner was enhanced, and the length of the voyage was shortened. Also, large bachelors might have been more easily sighted and followed.

Published literature mentions some selection for the largest animals in schools. Capt. B. D. Cleveland preferred 'the large animals from among the lesser' in mixed groups of fifty or more (Murphy, 1947, p. 46); and, 'we again stood toward the school, and the mate singled out one huge fellow nearest us, and happily the largest of the school, as our prize' (Nordhoff, 1855, p. 103; and see Brown, 1887, p. 276; Crapo, 1893, p. 17; Bullen, 1898, p. 219; Cook, 1926, p. 9 (ambiguous); Chippendale, 1953, p. 91–92; Hegarty, 1965, p. 61). Some of these statements are indicative but not conclusive of size selection. One of the earliest Pacific accounts explicitly stated that approximately 12 sperms were killed near the Galapagos Islands in April, 1794, among which was only 'one bull-whale' (Colnett, 1798 [1968], p. 147). However, the extent of such selection is unknown.

Other indirect evidence for size selection comes from anecdotal descriptions of the bounty posted on board ship for the man first sighting a whale successfully taken (e.g. Flayderman, 1972, p. 92). In at least turn of the century sperm whaling, the bounty varied, 'its value depending on the size of the whale' (Hegarty, 1965, p. 92). There might even be a larger reward specifically for a 100 barrel sperm (Chippendale, 1953, p. 51). The significance to all crew members of catching large whales to shorten the voyage was obvious: 'we fell in with an immense sperm whale, which happened to be just the sort of one we required to complete our cargo' (Beale, 1839, p. 173).

One knowledgeable historian of whaling took size selection on faith and advanced a novel argument for its consistent occurrence (Ashley, 1926, p. 73). He mentioned the two largest teeth, eleven inches long and the pair weighing 8 lb, 7 oz, from a sperm whale 90 ft (sic) long killed off the River Plate by Capt. G. Winslow, bark *Desdemona* in the late 1870s, and regarded them as the largest ever taken:

> A hundred-barrel sperm bull sixty-five feet long is a very large whale and an exceptional animal. Nowadays a whale this size will have teeth weighing at the extreme less than two pounds apiece, generally very much less. But in old examples of scrimshaw it is by no means uncommon to find teeth very much heavier. These large teeth can only be explained in two ways. In the days before the Sperm Whale herds were depleted, there must have been exceptional whales, either larger or older than are found to-day. The intensive pursuit of the Sperm Whale began about one hundred years ago, and for fifty years big whales were singled out for capture whenever a pod was sighted. In that fifty years, judging by the increase in time required to fill a ship, probably ninety per cent of all Sperm Whales were killed off, and since the big ones were especially sought and presented the bigger targets, it is to be presumed that very few whales alive at the beginning of that period lived to see the end of it.

While the mature sperms were not hunted for their teeth, the ivory and some bone was saved for scrimshawing (Flayderman, 1972) and as trophies of exceptional whales (e.g. Stackpole, 1958, p. 10, legend; Johnson, 1982, item 64).[7] Ashley's comparison is well taken, but not conclusive.

Selection for large bachelors might have resulted in some or all of those encountered being chased or even

[6] A cursory search of readily accessible literature turned up the following specific examples: *50 or over* (Perkins, 1854, p. 61), *60* (Macy, 1835, p. 229; Jones, 1861, p. 219; Hammond, 1956, p. 40; Olmsted, 1969, p. 181), *70* (Lay and Hussey, 1828, p. 13; Bennett, 1840, vol. 1, p. 392, vol. 2, p. 206–207; Davis, 1874, p. 204; Starbuck, 1878, p. 121n; Sawtell, 1962, p. 24–25, 66; Bannister, Taylor and Sutherland, 1981, p. 826), *80* (Bennett, 1840, vol. 1, p. 394–395; Jones, 1861, p. 157; Cheever, 1849, p. 193; Bullen, 1898, p. 334; Robbins, 1899, p. 101; Murphy, 1947, p. 57; Haley, 1948, p. 57; Chippendale, 1953, p. 98, 129; Sawtell, 1962, p. 37, 40–41; Williams, 1964, p. 310; Stackpole, 1976, p. 43; Whipple, 1979, p. 71), *90* (Starbuck, 1878, p. 123; Ferguson, 1936, p. 68; Chippendale, 1953, p. 121; Munger, 1967, p. 17), *100* (Starbuck, 1878, p. 124; Jones, 1861, p. 157; Robbins, 1899, p. 50; Davis, 1874, p. 188; Tripp, 1938, p. 51; Whiting and Hough, 1953, p. 202; Whipple, 1954, p. 67), *110* (Hazen, 1854, p. 77; Brown, 1887, p. 261; Johnson, 1982, item 64), *120* (Browne, 1846, p. 217; Millett, 1924, p. 22n; Ferguson, 1936, p. 69; Haley, 1948, p. 218; Munger, 1967, p. 17), *130* (Davis, 1874, p. 188; Starbuck, 1878, p. 155; Robbins, 1899, p. 180; Murphy, 1947, p. 46), *140* (Davis, 1874, p. 188; Ashley, 1926, p. 77; Miller, 1979, p. 9, 190).

'A number of captains report Sperm Whales yielding from 80 to 120 barrels each' (B. Russell *in* Goode, 1884, p. 11; cf. Capt. Seabury *in* Clark, 1887, p. 11). The largest yields specifically mentioned are 142 barrels (which Miller, 1979, p. 9, considers 'probably wishful thinking'), 145 barrels taken by Captain Norton of New Bedford ship *Monka* on the 'offshore ground' (or *Menkar*, Starbuck, 1878, p. 155n; reported by Davis, 1874, p. 188 who strove 'to avoid guessing'), and 150 and 154 barrel whales captured by Captains Allen and Tilton, respectively (Goode, 1884, p. 11). The Nantucket ship *Harvest* took a 156 barrel sperm in 1853, and Capt. Briggs of the New Bedford bark *Wave* took a 162 barrel, 5 gal. sperm on 2 August 1856 (Starbuck, 1878, p. 155). 'The largest Sperm whale ever taken yielded 162 barrels and 22 gallons of oil. It was captured off French Rock by the Bark Alaska, Captain Charles W. Fisher, 1884, Jonathan Bourne, Agent' (Anon., 1933, p. 25; recollected as 168 barrels and 22 gallons by Bodfish, 1936, p. 95).

[7] The origin of American scrimshaw may date as far back as 1776 (Flayderman, 1972, p. 90), was mentioned in logbooks and journals at least by 1826 (Stackpole, 1958, p. 51), and is well documented from 1828 (Crosby, 1955; Flayderman, 1972) until the end of American sailing vessel whaling.

captured, but would not preclude the taking of smaller animals when encountered. The removal of large bachelors from mixed groups during the breeding season might have had an effect on the population (Mitchell, 1977a) of shorter duration than the taking of many smaller animals (Allen and Kirkwood, 1970). In the *Mariner* log 8.5% of the total catch was comprised of mature males (over 50 barrels), but up to 7 whales were taken from one school. Thus both factors must have occurred in the fishery, which depended on the tactic of taking whales of all sizes and the largest whenever available. If as I suggest there was some selection for large bachelors, and it had a partial role in depressing 19th century stock levels, it is unlikely that depleted sperm whale stocks began recovery 'as early as 1844' (Kugler, 1981, p. 325). The same factors continued to operate for a much longer period. Pelagic whalers continued to sail through and to work the same grounds until late in the 19th century, and many were combination whalers pursuing a multispecies fishery based on other whales but taking sperms whenever encountered.

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Notes added in proof

[a] Another category could be added, '5H., Harpooned/lanced, escaped spouting blood,' as this is occasionally noted in logbooks and is a sign of mortal wounding.

[b] The 'killed' column in Table 1 is essentially code 4a. I arbitrarily assume 100% mortality in the 'escapement' (4b, 5a–e), comprising those whales harpooned and/or lanced but not processed so as to be recorded in production statistics.

[c] And see: E. A. Stackpole, 1983. The first adventures of a veteran Nantucket whaling master. *Historic Nantucket* 30(3): 6–10. [N.V.].

[d] In his final 'Account of oil stoved down onboard ship mariner' Gardner calculated there were 1,318 barrels of 'body' oil and 618 barrels of 'head' oil, giving a ratio of 2.13:1 or an average of 31.3% yield from the head.

HWR/9

The Galapagos Islands: a Preliminary Study of the Effects of Sperm Whaling on a Specific Whaling Ground

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INTRODUCTION

The Galapagos Islands, located off the coast of Peru, intersected by the equator and 90° W, provide an interesting opportunity to study the effects of sperm whaling on a specific whaling ground. The waters off these islands, at the intersection between the northernmost reaches of the early Pacific sperm whaling up the South American coast and the jumping-off point for the western expansion of sperm whaling throughout the Pacific Ocean, were fished as fully as any other area.

American whalers first entered the Pacific around Cape Horn in 1791 (Sanderson, 1956), and rapidly thereafter made their way up to the Galapagos Islands (Ommanney, 1971). Various subjective accounts give an overview of the history of this ground.

SUBJECTIVE ACCOUNTS

The results of four early English voyages centring primarily on this area are known. The ship *Rattler*, on a voyage from 1792 to 1794, visited the Galapagos where

> in April [1794] they saw many Spermacet[i] Whales, especially young ones. They killed five here, and [Captain] Colnett believed he had discovered the general rendezvous of these whales from the coast of Mexico, Peru and the Gulf of Panama who came here to calve (Jenkins, 1921).

The ship *William* captured over 100 sperm whales on a voyage which commenced in April 1796, lasted two and a half years, and produced a full hold. In one stretch of 18 days during January 1797, this ship and another killed between them 42 whales off these islands. These are impressive numbers both on a voyage and on a short-term basis. The whales themselves, however, were small on the average. Full capacity of the *William* was probably not in excess of 2,500 barrels, or at most 25 average barrels per whale (Stackpole, 1972).

The whaleship *Cyrus* achieved a full ship after only a year and a half of sailing around the Galapagos on a voyage from 9 July 1804 to 24 June 1806. She obtained about 163 tuns (or 1,630 barrels) from 63 whales, or an average of 26 barrels per whale (Stackpole, 1972).

The fourth ship, the *Argo*, had a voyage of twenty months (July, 1808–February, 1811), mostly whaling in the Galapagos ground. She obtained a full cargo of 2,500 barrels (Stackpole, 1972).

During this early period, from the 1790s until the War of 1812, these grounds were a 'favorite' one for whalers (Stackpole, 1972). In one instance for example, in May of 1809, one ship off Narborough Island in the Galapagos spoke to ten other whaleships in the space of one day (Stackpole, 1972).

Melville, in his sketches entitled *Encantadas* (Spanish for Enchanted Isles, another name for the Galapagos) published in 1854, described Galapagos whaling in this early period. Narborough Island in the group is very close to Albemarle Island. Between them are two bays, Weather Bay and Lee Bay, connected by the Narborough channel between the two islands. As described by Melville:

> The whales come here at certain seasons to calve. When ships first cruised hereabouts...they used to blockade the entrance of Lee Bay – when, their boats going round by Weather Bay, passed through Narborough channel, – and so had the Leviathans neatly in a pen (Melville, 1854).

As late as 1841, Olmsted referred to the Galapagos as 'a favorite "cruising ground" of whalers' (Olmsted, 1841), and two years earlier, Beale listed it as one of the 'favorite places of his [the sperm whale's] resort' (Beale, 1839). Subsequent references are typically in the past tense, however. Scammon reported in 1874 that they had been 'frequently visited' in the period before 1812 (Scammon, 1874). Captain Ellsworth West, describing his voyage on the *James Arnold*, which began at the end of 1882, referred to visiting 'an old, off-shore whaling ground in the vicinity of the Galapagos Islands'. Here, at this later date, he said '[w]e found it pretty dry cruising' (West, 1965).

These subjective accounts can be summarized as giving the following capsule history of this ground. The Galapagos were quite productive from 1790 to 1810, were still a favourite ground up to perhaps 1840, but were progressively abandoned thereafter, having become scarce in whales. During these periods, the grounds were frequented by schools of smaller sperm whales, cows and their young.

OBJECTIVE DATA

Objective data from logbooks can confirm and shed further light on this subjective history. There are three decades for which the present data contain a sufficient number of observations to be meaningful – the 1830s, 40s and 50s. The relative paucity of observations in the 1860s may in itself be an indication of the subjective trend.

The following data were derived from logbook or journal accounts for the following voyages:

Vessel	Port	Departure date
Alexander Coffin	Nantucket	16 December 1832
Balance	Bristol, R.I.	2 December 1833
Marcella	New Bedford	26 May 1836
North America	New London, Conn.	11 October 1839
Lion	Providence, R.I.	16 June 1844
Balaena	New Bedford	16 September 1853
Joshua Bragdon	New Bedford	29 October 1853
Laetitia	New Bedford	12 June 1857

For the purpose of analyzing logbook observations, the Galapagos ground has been defined as the four geographical squares bounded by 10° N and 10° S, and 80° to 100° W.

Seasonality

The kill of 42 whales in 18 days on the Galapagos ground by the *William* and another ship in company in 1797 occurred in January (Stackpole, 1972). The *Rattler's* observations of 1794 were made in April.

Individual logbook data suggest that by the 1830s the most frequent sightings were made in the months of July, August, September and October (Table 1). In each decade these four months accounted for 65%, 47% and 49% respectively of the annual sightings. Either there was a seasonal change from the 1790s or, more likely, the 1790s had large numbers of whales throughout the year. The fact that only eight voyages contributed to the objective data makes the seasonal pattern perhaps unduly susceptible to the personal whims of a few captains.

Table 1

Percentage of sperm whale sightings by month, Galapagos ground, 1830s–1850s (number of observations in parentheses)

Month	Decade 1830s	1840s	1850s
January	4 (3)	25 (7)	8 (7)
February	3 (2)	0 (0)	2 (2)
March	4 (3)	7 (2)	2 (2)
April	0 (0)	4 (1)	2 (2)
May	0 (0)	11 (3)	3 (3)
June	6 (4)	7 (2)	8 (7)
July	22 (15)	14 (4)	4 (4)
August	20 (14)	11 (3)	11 (10)
September	17 (12)	18 (5)	17 (15)
October	6 (4)	4 (1)	17 (15)
November	10 (7)	0 (0)	13 (12)
December	7 (5)	0 (0)	13 (12)

Single versus school sightings

The percentage of sightings involving schools rather than individual whales shows that the figure was a very constant and high level in each decade, ranging from 93% to 96% (Table 2):

Table 2

Plural sightings, Galapagos ground, 1830s–1850s

Decade	Number of sightings	Number of plural sightings	Percentage
1830s	58	55	95
1840s	27	26	96
1850s	42	39	93

Whales taken per sighting

The average number of whales taken per sighting did not decrease in the period. It was 0.83 in the 1830s and '40s then rose to 0.95 in the '50s (Table 3). A decrease would be especially consistent with a hypothesis of behavioural scarcity, but it is not yet known whether these later levels are significantly higher or lower than those for the virgin ground of the 1790s.

Average barrel yield

The average barrel yield of the whales taken decreased from 37 barrels in the 1830s, to 33 barrels in the 1840s, to 23 barrels in the 1850s (Table 4). These figures are consistent with increasing numerical scarcity, but in light of the probable low average yields in the 1790s, must be interpreted with caution. In any event, the average whale size was not large in any of these decades.

Table 3

Whales taken per sighting, Galapagos ground, 1830s–1850s

Decade	Number of sightings	Number of whales taken	Average
1830s	58	48	0.83
1840s	24	20	0.83
1850s	44	42	0.95

Table 4

Average barrel yield, Galapagos ground, 1830s–1850s

Decade	Number of whales taken	Total barrels	Average barrels
1830s	47	1,750	37
1840s	12	395	33
1850s	16	373	23

CONCLUSION

The objective data from logbook accounts tend to bear out the subjective observations of various commentators and give further suggestions concerning them. That schools of smaller whales frequented the area is confirmed. The decrease in average size is a possible indication of depletion. The fact that the number of whales taken per sighting did not decrease perhaps suggests that here at least increasing scarcity reflected numerical more than behavioural factors. Further study is needed.

Finally, these facts can be contrasted to other grounds, for example – the South American coast further south between 30° and 40° S and 80° to 90° W. Here there were plural sightings of not 95% but 75% of the total, and average barrel yields of not 30 but rather 80 barrels. Studies of other whaling grounds need to be made in order to obtain an overview of the patterns and effects of nineteenth-century whaling.

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The Hunt of the Greenland Whale: A Short History and Statistical Sources

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AVAILABLE STATISTICS

The historian of the hunt of the Greenland whale, or bowhead, is in the fortunate and rare position that he can use detailed statistical material of reasonably good quality regarding the catches by the Dutch and Germans, the leading whaling nations in the seventeenth and eighteenth centuries. Dutch whaling statistics start in the year 1661, German statistics in 1669, and reach into the nineteenth century, when Arctic whaling died out. Whaling statistics in other countries, i.e., Great Britain, France, Spain and Denmark, seem to be lacking for the seventeenth century, but can probably be located for the eighteenth and nineteenth centuries in the British archives of whaling ports like London, Hull, Whitby, Dundee, Peterhead and other towns, and in Danish archives in Copenhagen.

Only the Netherlands now have national whaling statistics which comprise all ports in that country. They were collected in Dutch archives and compiled by the German economic historian, professor Hermann Wätjen, and published by him in 1919. National statistics of Arctic whaling have not been published and probably not been collected for other European countries. This is remarkable when one is aware of the availability of much material in local archives, the general interest shown by the public in whales and whaling, and the diligence of a host of economic historians in their research of other industries.

The explanations for this neglect are probably that collecting and compiling whaling statistics is 'donkey work' – hard and time consuming, and not generally liked. Also, whaling history is a queer occupation to most people who are not strictly professional economic historians.

The difficulties of collecting and compiling old whaling statistics are partly explained by their origin. They were composed in the seventeenth and eighteenth centuries by private persons on private initiative. These men were owners of whaleships, merchants in whaling products, brokers, speculators and possibly persons who considered whaling statistics as a hobby. Whaling figures were important for business prospects of catches and sales of whaling products as international commodities. Many people owned parts in whaleships and whaling gear and were therefore interested in the catches and prices.

A second reason for the wide interest was the very speculative character of whaling results which attracted speculations in whale products on the commodity exchanges of Amsterdam, Hamburg and smaller ports. The Amsterdam exchange had a special corner for transactions in whale oil and baleen in futures. Therefore, we often find lists of prices of whale oil with rapeseed oil as a competing commodity, and baleen in addition to catch figures.

Whaling ports were not very numerous, owing to the considerable capital required in whaling enterprises. Private persons could keep abreast of ships and catches of other ports and keep records for more than one port.

To help private persons in keeping whaling records, printers in several ports offered blank lists and booklets for sale. They printed the names of ports in the home country and in other countries with columns for the names of shipowners, captains ('Commandeurs') and ships; for catches, ship losses, output of blubber, whale oil and baleen; and prices of whale oil, other oils and baleen. These columns were filled in by interested persons. The lists and booklets were bought and used in Dutch ports, such as Amsterdam, Zaandam and Rotterdam, and possibly in German ports. They were entitled 'Lyst van de Hollandsche, Hamburger en Bremer Groenlandsvaarders, Anno... uitgevaaren'. A considerable number of the booklets full of figures are in the old archives in the Netherlands and possibly also in the local archives of Hamburg, Bremen, Emden and other German towns which maintained intimate business and personal relations with the Netherlands.

The British followed the Dutch example in the eighteenth century when British whaling grew. There is at least one reference to British annual lists of whaleships, shipowners and catch figures. This reference is to 'A List of the ships which sailed for the Greenland and the South Seas Whale-Fisheries from the different ports in England and Scotland in 1780, issued by John Leedley Senior, broker, 4 Cannon Street, London', and is mentioned by Wätjen (1919).

Another useful reference is Sheppard and Suddaby (1906). This is an unpublished manuscript of handwritten tables, kept in the Local History Library in Hull, Great Britain, and contains the following whaling figures:

1772–1825 annual number of ships, tuns of oil and tons of baleen plates ('whale bone' or 'bone');
1814–1841 annual number of ships, tuns of oil and tons of baleen plates for all England (whaling ports combined and apart);
1805–1834 monthly prices of whale oil;
1772–1812 names and catches in tuns of oil of the whaling ships from Hull; and
1813–1842 names and catches (in terms of number of whales and tuns of oil) of ships of the principal or all whaling ports of Great Britain (annual figures, more or less comprehensive statistics of British Arctic whaling, separation of ships and catches east and west of Greenland only for a few years).

The composer of the handwritten tables is one, unknown person.

The next step in collecting whaling statistics by contemporaries was the publication of figures for a series of seasons covering a certain period. The best known compilations of Dutch historical statistics are the annexures of the book by commandeur Cornelis G. Zorgdrager (1720) and the voluminous statistical handbook composed by the Zaandam broker Gerret van Sante (1770). Van Sante gives records of nearly all Dutch whaling captains from 1700 to 1769. His book contained many blank pages for later notes. After 1770 a few now-preserved copies were kept up to date by persons who filled in figures for subsequent years. A complete copy is in the archives of the city of Amsterdam.

There are several other historical whaling statistics published in Dutch journals and books in the nineteenth century after the end of Dutch whaling (Appendix 1). Their original sources are seldom mentioned, but presumably the sources were the booklets, of annual whaling statistics and compilations thereof, such as Van Sante's work.

Though our knowledge of available Dutch statistics is extensive, this is not the case with statistics for other countries. It has been discovered that the State Archive of the Hansa town of Hamburg owns an unpublished manuscript by Gottlieb H. F. Grube dated 1846 which includes statistics of Arctic whaling from Hamburg, and for a few years from other German ports, from 1669 to 1801 (Appendix 2). The State Archive of the Hansa town of Bremen has annual statistics from 1695 to 1806. Two articles in the *Bremisches Jahrbuch* of 1965 and 1975 contain whaling figures for this port.

Statistics of German and Dutch whaling have been collected and condensed by Lindeman (1869) in his well known publication. It is a pity that he did not publish more detailed and annual statistics and indicate his sources, but the author presumes that the two extensive documents in the archives of Hamburg and Bremen mentioned above were his principal sources for German whaling figures. In any case, not all his figures are exact and they can probably be improved. This is evident from comparison between his figures of Dutch whaling and the figures published by Wätjen (1919).

As old whaling statistics were collected by private persons, many of them more or less on their own, it is no wonder that there are often differences between figures which ought to be equal and uniform, as well as inaccuracies and calculation errors, in this medley of statistics. Therefore, we should have sympathy for Hermann Wätjen who struggled with Dutch whaling statistics and who sighs in the introduction to his 1919 publication: 'Generally the economic historian has a thirst for figures. When however they emerge during research in archives in such a multitude, he blesses the moment when a document without figures comes into his hands.' He published two series of figures for the same years, which differ slightly in the early years – one series compiled from the annual lists and booklets, and one from Van Sante's work.

We should, however, not exaggerate the defects of Dutch whaling statistics. Recently, van der Woude (1972), an economic historian who worked with them, wrote that Wätjen had no reason to complain bitterly about their quality because the recorded differences remain within very reasonable limits. Van der Woude calculated that in two cases for the years 1700–1749, the differences between the two series of figures listed by Wätjen were no more than 2.1% and 2.7% respectively. Many statistics in our time contain larger errors. We may assume that the Dutch and German whaling statistics are reasonably reliable and offer an acceptable source for scientific conclusions.

Dutch economic historians have been remarkably hesitant to use the abundant figures of van Sante (1770) and Wätjen (1919), who published them as early as 1919. Only van Braam (1943) condensed their figures and published the result with some general and acceptable conclusions. The first, and so far, only historian who worked extensively with them and analyzed them was van der Woude (1972). It is to be regretted that he did not publish detailed tables and that his many graphs are difficult to read. I have drawn up detailed tables of Dutch Greenland whaling and have analyzed them in this paper. To understand and interpret these tables, I think it is desirable to give a sketch of the migrations of the Greenland whale and of the history of the hunt for this animal because this history ceased long ago and relevant information is now scattered over several rare books and half-forgotten articles.

THE MIGRATIONS OF THE GREENLAND WHALE AND ITS INFLUENCE ON THE CATCH

The Greenland whale, or 'bowhead' (*Balaena mysticetus*), is at present very scarce because of the extensive hunt of this animal from the seventeenth to the nineteenth century, and the slow tempo of recovery of its stock after the prohibition of its catch by an international convention in 1937. One seldom reads in our century of a Greenland whale being sighted in the seas adjacent to Greenland, and more than once it is uncertain whether the observed animal was another species of whale. It is somewhat more numerous in the seas adjacent to the Bering Strait.

To obtain an insight into the migrations of the Greenland whale, one has to resort to statements of long deceased authors because recent reports are virtually non-existent, and one has to compile a literature study from nineteenth century and older publications. Even these publications are far from numerous, although the whale was hunted for three centuries, and they must be very critically judged and used. Masters' journals dating from the seventeenth and eighteenth centuries are scarce and contain little useful information, as has been seen in several Dutch logbooks. A considerable number of logbooks which enable the charting of catches of the bowhead with sufficient accuracy are only preserved from North American whaleships south and north of the Bering Strait in the nineteenth century. This charting has been performed by Townsend (1935).

Statements by members of crews in whaleships have the inevitable defect that they observed whales only during the hunting season, which lasted at most four months of the year, and they do not shed light on the movements of the whales during off-season. Therefore, information from persons who wintered on Arctic islands is very interesting because they observed whales out of season. This kind of information was supplied by three groups of seven Dutch sailors who wintered on Spitsbergen in 1633–34 and 1634–35, and on Jan Mayen in 1633–34, and by Danish colonists who lived on the west coast of Greenland. Their statements were analyzed by the Danish cetologists D. F. Eschricht and J. Reinhardt (1866).

The main source of my knowledge of the migrations of the Greenland whale are the German surgeon Friedrich Martens (1675), the Dutch captain C. G. Zorgdrager (1720), the anonymous author of the Dutch book *De Walvischvangst* (1784–86), the British whaling captain William Scoresby, Jr. (1820), the Danish cetologists

D. F. Eschricht and J. Reinhardt (1866), the U.S. whaling and sealing captain Charles M. Scammon (1874), the British zoologists Robert Brown (1868), Thomas Southwell (1898) and Robert W. Gray (1932), the British whaling captain David Gray (1894), the Russian cetologist A. G. Tomilin (1967) and the Danish zoologist Christian Vibe (1966).

Life cycle and habits of the Greenland whale

According to Slijper (1962), the mating season of this animal is in February and March, in the late winter, and the gestation period lasts nine to ten months. This would mean that the young are born in November to January, the coldest months with the least food. Deviating from Slijper, Vervoort (1949) writes: 'The gestation time is about one year and as most calves are born in the spring, mating takes place in spring and summer.' This supposition appears to be more acceptable, as the experienced captain David Gray (1894) stated: '...I have seen them with very young whales early in May and late in July.' Nursing lasts about one year, according to Slijper and Vervoort; the duration is unknown according to Tomilin (1967).

The whale's length at birth is 3–4 meters (9–12 feet). It matures at a length of 15.5 meters (46 feet) and its maximum length is 18–20 meters (55–60 feet). Its average life span is about 40 years.

The Greenland whale lives in the Arctic Sea around the North Pole which is in fact an inland sea with some wide and other narrow straits to the Atlantic and Pacific Oceans. The Norwegian handbook of natural history, *Speculum Regale* (*circa* 1250), Martens (1675) and Zorgdrager (1720) stated clearly that this whale was only found in Arctic waters. Between about 1750 and 1850, sometimes even later, it was maintained that previously it had a much larger living space. This error is to be attributed to confusion with the so-called 'right whale' (*Eubalaena glacialis*), called 'Noordkaper' by the Dutch after the North Cape of Norway where they hunted it regularly in the seventeenth century. Its Latin name signifies 'ice whale' and is incorrect because this animal evades the ice floes where the Greenland whale prefers to live. Both whales are often called right whales in English.

The whalers knew the difference between the two species of Balaenidae very well, but in the eighteenth century the right whale seems to have become so rare in the Northern Atlantic Ocean that the experienced captain W. Scoresby, Jr. (1820) did not describe and apparently did not know it. It was later confused with the Greenland whale until Eschricht and Reinhardt (1866) again pointed out the evident differences between the two species.

Martens (1675) and Zorgdrager (1720) supposed that the Greenland whale as a typical glacial animal winters somewhere in the Arctic Sea. Zorgdrager suggested that in autumn it retreated to the Tartarian Sea north of Siberia and from there returns to Spitsbergen in spring. He did not know that in winter this sea is entirely frozen over so that whales cannot hibernate there.

In prehistoric time the living space of the Greenland whale was probably larger, as Arctic ice fields reached much farther southward than at present. Once the southern border of the drift ice lay near northern Great Britain and southern Norway, and in 1914 a fossilized Greenland whale was found near Larvik in Norway. (It is now preserved in the cellar of the whaling museum in Sandefjord.) When the ice retreated in the direction of the North Pole, the whales followed the edge of the drift ice and abandoned the Northern Atlantic Ocean.

It is well known that the Greenland whale generally sticks to the drift ice that surrounds the solid ice around the North Pole, with the exception of the whales in the Sea of Okhotsk where the ice disappears in the late summer, and of old whales which are found far from the ice. The whale prefers the proximity of drift ice because there its food – small crustaceans ('brit') – abounds in the short summer and probably also because the ice fields provide shelter for this clumsy, slow animal against attacks of its only enemies, the killer whale and humans.

In winter the Arctic Sea freezes into solid ice. No whale can breathe and live there and all species of whales migrate southward: Balaenopteridae (fin whales) to tropical waters, right whales to seas near the Tropic of Cancer. The Greenland whale, however, remains near the border of the solid ice, though it probably finds little or no food there in winter. Southwell (1898) presumes that it winters in the sea off Labrador, West Greenland, North Iceland (Denmark Strait) and possibly between Spitsbergen and Bear Island. Scammon states (1874) that it winters in the Bering Sea and the Sea of Okhotsk where these are ice free. The Arctic Sea was and is seldom visited by men in winter so that reports regarding Greenland whales in their winter resorts are scarce. But there are reliable statements about the whale's presence in winter off the west coast of Greenland between 60° and 66.5° N (Eschricht and Reinhardt, 1866) and near North Iceland.

In spring (April and May) the solid ice cap melts at its edge and ice fields and flows are driven southward by frequent northern winds from the Pole so that relatively ice-free water opens between the belt of drift ice and the solid ice. There plankton and crustaceans multiply in masses at a high tempo and there the whale finds much food and prospers in summer.

After severe winters, the solid ice cap reaches relatively far southward. Its edge fragments only gradually and late, and open water between the ice floes is scarce. Whaleships under sail had much difficulty in passing the belt of drifting ice. Zorgdrager calls the season after such a winter a 'South ice year' because the whalers met the loose ice at low latitudes. Scoresby calls it a 'close season' because the ice floes were so close. The rosy side of such a season was that the whales were more than usually concentrated in small areas of open water and were numerous and near at hand for those whalers who succeeded in passing the dense ice belt. They expected a good catch after a severe winter. Zorgdrager (1720) wrote: 'Much South ice (means) much (whale) fish' and called a fleet fully laden with whale blubber a 'South ice fleet'. Scoresby (1820) also associated a close season with good catches and wrote: 'The fishery in open seasons is more uncertain than that of close seasons.'

When the solid ice melted earlier in spring and the loose ice drifted southward in larger masses than usual, leaving large open spaces of water, the whalers spoke of a 'general ice year' according to Zorgdrager (1720) and of an 'open season' according to Scoresby (1820). The whales could then scatter between the ice floes earlier and hide under the ice fields in higher latitudes, nearer to the solid ice cap. The whaleships could not follow them there, for the deeper they bored into the drifting ice and the more northward they sailed, the more capricious and stormier the weather became and the greater the difficulties of hunting, towing and flensing whales and the risk that the way to ice-free water would be closed and the ship beset and crushed. In such a season the expectations for a good catch were less hopeful than in a 'South ice year' or 'close season'.

The whalers would say, generalizing, that the biggest whales would move farthest south and away from the drift ice, often in open sea, while females with sucking calves and immature animals remained rather in the dense drift ice.

According to Nansen (1924) and Tomilin (1967) there were at least three tribes (stocks) of Greenland whales, each with its own territory and seasonal migrations, which probably intermingled very little, if at all.

Stock I, the Spitsbergen stock, migrates from its winter resorts near Iceland and possibly Bear Island to the sea around Spitsbergen and perhaps farther to Franz Joseph Land and Nova Zembla.

Stock II, the West Greenland stock, migrates from Labrador to Davis Strait, Baffin Bay and adjacent sounds in the northern Canadian archipelago.

Stock III, the Bering Sea stock in the Sea of Okhotsk and Bering Sea, migrates through Bering Strait to the Beaufort Sea and Chukchi Sea.

The remaining part of the Arctic Sea from Franz Joseph Land and Nova Zembla eastward to Cape Schelagsky and Wrangel Island at 71° N, 180° E was probably never the home of large numbers of whales. Eschricht and Reinhardt (1866) and Southwell (1898) do not know of any reliable reports of sightings of Greenland whales in this sea north of Siberia. Tomilin (1967), however, mentions some finds of dead Greenland whales on this coast, but it is possible that they perished there just because living conditions were too unfavorable. Whales are known to have perished in solidly frozen ice. Possible causes of the whales' absence north of Siberia are the shallowness of the sea, particularly the Barents Sea, scarcity of food and the freezing of the entire Arctic Sea along the long coast of Siberia in winter. No whale could live there in that season.

Stock I – the Spitsbergen stock

The southern edge of the drift ice extends from the east coast of Greenland to the sea northwest and north of Spitsbergen and farther southeast to Nova Zembla. A cold sea current moves along the east coast of Greenland. From March to May it carries ice, plankton and whale food with it. The Greenland whale migrates from its winter resort off Iceland in the direction of Spitsbergen. During this migration it was seldom sighted in spite of the presence of many sealing vessels near Jan Mayen, presumably because they remained within the densest parts of the drift ice belt. They were observed by the seven Dutchmen who wintered on Jan Mayen in 1633–34. Their diary mentions the first whale which appeared near this island on 27 March 1634 and thereafter, whales were seen almost daily until, at the end of April, the pen dropped from the hand of the last man to die.

In the second half of May the whalers found whales in the fjords and near the coasts of West and Northwest Spitsbergen, that is near Prince Charles Foreland and Hakluyt's Headland, seen initially in large shoals. Their numbers decreased in the subsequent years owing to the continuous hunt. After the middle of June the growth of phytoplankton and whale food declined. Southwell (1898) and Gray (1932) state that the fishing between 79° and 80° N off Northwest Spitsbergen terminated largely towards the end of June. This may have been the case in the second half of the nineteenth century when the whale was scarce and on its guard against its hunters so that it withdrew early from the Spitsbergen coast into the receding drift ice. But, in the seventeenth century until *circa* 1670, the catch near West and Northwest Spitsbergen and Jan Mayen lasted until the end of August and took place in the ice-free bays where there was much food.

Two significant segments of the Greenland whale population – adult males and females without calves – swam from Spitsbergen with the East Greenland current to the southwest in the course of the Arctic summer, in pursuit of the shoals or 'banks' of whale food. The whaleships too sailed to the southwest, parallel with the edge of the drift ice in pursuit of the whales. When the whales found too little 'brit' they returned to the northwest to meet fresh shoals of food. And when the whalers saw too few whales they left the belt of ice floes and sailed across open water to the northeast and moved again into the ice belt in higher latitude, according to Zorgdrager (1720), Anon. (1784–86), and Scoresby (1820). Towards the end of the season, in August, most whaleships were found between Jan Mayen and Iceland, from where they set sail for home.

Another large number of whales did not migrate to the southwest, but to the northwest, north and northeast into the drift ice when this opened nearer to the Pole up to 80° N. Bold whalers followed them deeper into the ice belt or awaited their return off the north coast of Spitsbergen at the end of August when autumn approached and the animals had to migrate southward. The Dutch called this late fishing 'the fishing in the east'; there they faced the dangers of autumn storms and of being closed in by the advancing solid ice.

Further, there was an important group consisting of pregnant females and nursing animals with calves called 'suckers' or 'nursery whales' and possibly immature animals of one and two years old. They resorted earlier than the other whales to the drift ice as soon as it opened in April. They disappeared conspicuously to the north and northwest out of reach of the whalers, probably looking for safety from attacks by killer whales and whalers. This group probably migrated southward in autumn, unobserved by whalers, and along the east coast of Greenland, where whaleships could seldom penetrate the drift ice within sight of land.

These are the general seasonal migrations of Stock I apart from frequent local movements in all directions in search of food. Southwell's (1898) theory regarding these migrations is an extension of Scoresby's (1820) statements, complemented with information by Brown (1868) and Gray (1894). The separation of the sexes and age groups corresponding with different latitudes and density of the drift ice, noticed by Southwell (1898) was confirmed by Robert W. Gray (1932). He received information from his father, David, and his uncle John who were both whaling captains from Peterhead in Scotland. He confirmed that females with 'suckers' were seen only for a brief time at the edge of the drift ice and in spring moved deeper into this ice, to remain there unobserved until autumn frost compelled them to return to winter resorts.

Stock II – the West Greenland stock

The drift ice west of Greenland has a similar irregular southern edge as that east of this island. It descends on the west side of Davis Strait much farther southward than on the east side under the influence of ocean currents. This ice reaches its largest extension in March, then it extends from 50° N on the north coast of Newfoundland to 60° N off the south cape of Greenland, Cape Farewell. The solid ice then extends from the north cape of Newfoundland at 52° N along the meridian of 55° W to 66° N on the west coast of Greenland.

From March to September the drift ice recedes far to the north, and in the first days of September, Davis Strait and part of Baffin Bay are largely free from ice, except for the east coast of Baffin Land and the northern regions of Baffin Bay, the notorious Melville Bay. In summer, the west coast of Greenland is largely ice free from Cape Farewell to 76° N, contrary to its east coast which remains entirely icebound in most years.

More information is available regarding the migrations of the Greenland whale west of Greenland than east of it because whaling was practiced off West Greenland for more years and because scientific observations were recorded from the middle of the nineteenth century by the Britishers Robert Brown (1868) and Captain A. H. Markham (1873) and by Danish officials in Greenland colonies during 1799–1830, whose reports were used by Eschricht and Reinhardt (1866). Our main source is Southwell (1898) who based his work on the statements of the above mentioned authors. He distinguishes the areas on the west side of Davis Strait and Baffin Bay, the latter dominated by the south-going Baffin Current, and on the east side, off Greenland which is dominated by the East Greenland Current that rounds Cape Farewell. As he does for Stock I, he distinguishes between the migrations of mature animals and immature whales, among them, females with 'suckers'.

On the American side of the area the whales presumably winter in 57° to 58° N off Labrador. When the solid ice opens there in spring, they migrate to the north. In April and May, early whalers met them before the entrance of Hudson Strait and near Resolution Island. Before 1743 they fished only on the east side of Davis Strait from the end of May. In 1743 the first British whalers sailed to the west side to start fishing there as early as April. This was the beginning of the so-called 'sou' west fishing' (Lubbock, 1937). In 1804 a whaleship from Hull started the hunt even more southward, off Labrador, in the first days of April, but this fishing never became popular because of the short days, frequent storms and heavy ice (Lubbock, 1937).

The females and young weaned animals migrated northward as much as possible within the dense drift ice on the west side. The other whales wandered along the border of the ice to the east side near Disco. From there they moved to the west in June and reunited with the females and young in Baffin Bay. As soon as the ice in Lancaster Sound opened – usually in July – most animals entered this strait and spread into Prince Regent's Inlet and adjacent channels and passed the brief summer there. In September they turned gradually east and southward. The adult whales chose the way along the east coast of Baffin Land, the females and young through the straits west of Baffin Land (Southwell, 1898).

Brown (1868) states that the calves are born in Hudson Strait in winter (which is doubted because this strait is frozen in winter) and off Labrador. Southwell (1898) does not confirm this and states only that the whales winter off Labrador.

Then we move to the east side of Davis Strait which was regularly visited by whalers from about 1700. According to Eschricht and Reinhardt (1866) the whale seldom frequents the west coast of Greenland south of the Danish colony of Sukkertoppen at 65° 25′ N and north of Upernavik at 72° 42′ N. In Disco Bay, at 69° N and off Holsteinborg at 66° 56′ N, the whales appear in the first half of December, fleeing before the advance of the solid ice. Off Sukkertoppen they appear later in December, in January and February, and enter the fjords in varying numbers more numerous as the winter becomes severer and the ice in the Strait more extensive. Part of the whale stock winters near the west coast of Greenland south of Disco. They remain near this coast at Holsteinborg at 66° 56′ N until March; in Disco Bay until the middle of June; and in Umanak Sound at 71° N until the first days of July. Thereafter, they move to the northwest and many cross Baffin Bay to arrive in Lancaster Sound. Eschricht and Reinhardt (1866) concluded that since the establishment of the first Danish colony on Greenland in 1721, the number of whales had decreased considerably because of the rigorous hunt, but that the timing and routes of their migrations had not changed.

One might query how far northward the whales migrate in Baffin Bay. In 1616 the British discoverer Baffin saw many of them at the entrance of Smith Sound – the strait between Baffin Bay and the Pole – at 78° N. James Ross met them in 1818 between 75° and 76° N in July and August when they were not sighted near the southern Danish colonies of Sukkertoppen and Godthaab. Southwell (1898), however, holds that these observations were unusually far northward and that the whale seldom moves farther north than 75° N because Smith Sound is usually inaccessible because of packed drift ice.

After 100 years of hunting in Davis Strait the whale became more scarce there also and the whalers looked for new grounds. In 1817 a new chapter in the history of Stock II commenced when some British whaleships penetrated for the first time into the drift ice of the northeastern part of Baffin Bay; that is Melville Bay, in spite of the serious dangers of storms and ice. Later, the whalers left Disco behind them, saying, 'Dusky (Disco) dipping whalefish skipping', according to Lubbock (1937). In the following years they would arrive in Baffin Bay in June in pursuit of the whale before it crossed over to Lancaster Sound, Eclipse Sound and Pond's Inlet. About 15 September they could be expected at Home Bay and Cape Hooper of Baffin Land and tarried off this coast until heavy frost and the advancing solid ice drove them to Labrador and Southwest Greenland (Southwell, 1898).

The whalers noticed that the Greenland whale caught in Davis Strait and Baffin Bay was on the average much bigger than the whale caught between Greenland and Spitsbergen (Lubbock, 1937). Scoresby (1820) states that the whale killed east of Greenland in four seasons preceding 1820 yielded on the average 9.5 tuns of oil, compared with the whale west of Greenland delivering 14 tuns. Two explanations for this difference are suggested. The first is that the whale of Stock II found much more food than Stock I and grew bigger and fatter. The second, perhaps more acceptable explanation is that the young, slender animals and the milked out, meager nursing females – both with little blubber on them – escaped west of Greenland into the dense drift ice in greater numbers than east of Greenland, at least annually before 1817, because the North Canadian archipelago afforded them an extensive hiding place.

Stock III – the Bering Sea stock

The living space of this stock lies between 53° and 73° N and between 120° and 135° W in the Arctic Sea, the space between Cape Schelagsky in the west and Point Barrow in Alaska in the east, with small outlets to Mackenzie Bay and the entrance of Amundsen Gulf. In winter the Beaufort Sea north of Bering Strait, this strait, and the northern regions of the Bering Sea and the Sea of Okhotsk are frozen over. We owe information on Stock III to the numerous North American whalers in the nineteenth century. They noted many catches in their logbooks and marked place and time. Townsend did good work by charting the catches from many logbooks on a map which he published in 1935.

Another North American, Captain Charles M. Scammon, described the whale species in the Pacific, among them the bowhead, in his book in 1874. The North Americans started the catch in the northern Pacific shortly after 1830. It is told that they caught the first right whale in this ocean off Kodiak. In 1838 they opened the fishing on the northwest coast whaling grounds in the Bering Sea and in 1840 they discovered the Greenland whale there, which they called the bowhead, to distinguish it from the right whale. They preferred the bowhead because it yielded much more blubber and longer, more precious baleen plates than the right whale.

Townsend (1935) has recorded 5,114 catches of bowheads on a map published with brief comment. In winter there was no whaling. In April the whalers started the catch near the west coast and to a lesser extent the east coast of the Sea of Okhotsk and in the Bering Sea. The bowhead follows the receding ice to the north and the whalers pursued it. In August the ice disappears in the Sea of Okhotsk and the largest catches occurred in August and September. In the Bering Sea, the best catch was from April to July and decreased thereafter because the whale migrates through Bering Strait to the Arctic Sea and spreads there up to 73° N.

In July, 1848, Captain Thomas Roys from Sag Harbor was the first whaler who sailed through Bering Strait into the Arctic Sea. As he was very successful, many ships followed him in the ensuing years. The best catches in the Arctic Sea were in August and September. The full season there included September, whereas fishing in the area of Stocks I and II ended generally in August because it took place in higher latitudes. In September the bowhead migrates to Bering Strait and passes it to hibernate in the northern Pacific.

According to Scammon (1874), no bowhead was ever seen migrating from the Sea of Okhotsk to the Bering Sea or the reverse, but the whalers' observations are only valid for the summer. Townsend (1935) thinks it probable that in winter the whales which winter in low latitudes often pass the peninsula of Kamchatka on their way to the Sea of Okhotsk or in the reverse direction.

Migrations of the Greenland whale between the areas of its respective stocks

There were many stories in circulation among whalers regarding Greenland whales which were sighted or harpooned in one area and later appeared in another area, sometimes after an improbable brief time. Whalers liked the assumption that there was regular traffic of the whale between the three areas of Stocks I, II, and III. For when the catch in one of the areas was bad, they could foster the hope that the whale had fled to another area to escape its hunters, had not become scarce, and would return after a time of sanctuary. Usually they referred to exterior and sometimes doubtful characteristics of specific whales which were recognized in other areas far away, and they found old harpoons in dead whales, planted far away or long ago. Tomilin (1967) mentions some of these cases without expressing doubt.

It is true that many harpoons bore initials or full names of whaleships or ship owners, but whalers were often too eager to recognize in them the irons of known ships and men. Even less trust should be put in the recognition of harpoons belonging to Inuit (Eskimos) and Siberians because most whalers were not expert anthropologists and lacked the knowledge to ascertain the origin of these harpoons of bone or stone. Southwell (1898) maintains a healthy skepticism with regard to statments about far wanderings of Greenland whales from one area to another around the North Pole.

It is possible that in winter, when the whales have to stay in lower latitudes south of Cape Farewell and Kamchatka, they occasionally migrate from Denmark Strait near Iceland to Labrador and from the Bering Sea to the Sea of Okhotsk and in reverse direction. But Southwell (1898) writes that generally, the whales do not penetrate far enough into the North Canadian archipelago in summer to meet members of the other stock to mingle with them. He and cetologists after him are of the opinion that the three stocks of the Greenland whale do not meet and mix and do not migrate between their respective home areas.

THE GREAT SLAUGHTER OF THE GREENLAND WHALE

The history of the Greenland whale has a dramatic course of its own and it is fairly well documented. Originally, it was numerous near the coasts of all Arctic islands. It was discovered by William Barendsz and Henry Hudson off Spitsbergen, *circa* 1600. It is dubious whether the whale found by the Basques as far south as St. Lawrence Bay was the Greenland whale. The catch near Spitsbergen was started by the British in 1610 and soon shared by the Basques, Dutch and Danes.

After a few years the Dutch dominated. Shore whaling was carried on from land stations on Spitsbergen and Jan Mayen. For twenty years the catch was in the hands of chartered British, Dutch and Danish companies which restricted the catch for the maintenance of a market monopoly of whaling products. But between 1640 and 1650 these companies lost their influence and faded away or were liquidated. The trade was opened to all private persons and all nations. Land stations grew in numbers but by 1670 they had all closed down because the whale had largely disappeared from the Arctic coasts. Nevertheless it is an exaggeration, found in Tomilin (1967), that

Stock I was decimated in the seventeenth century. The whales evaded the coasts but there were many left in the drift ice between Spitsbergen and Greenland.

A few years before 1670 the Dutch had commenced the ice fishery around Spitsbergen and in the west ice between this island and East Greenland. The catch per whaleship was much smaller there than in the heyday of shore whaling, but it was profitable and the whaling fleets of the Dutch and Germans grew rapidly in spite of ship losses in the ice and of frequent interruptions of whaling by wars with Britain and France. In the 1670s and '80s catches were large and profits attractive. The British and Danes ceased shore whaling and did not participate in the ice fishery. The pioneering nation of European whaling, the Basques from France and Spain, struggled on under severe competition from the Dutch and Germans and introduced the trying out of whale blubber in furnaces on board.

The catch of the Greenland whale was always extremely variable owing to the varying and severe weather conditions in the Arctic Sea. It became more and more uncertain as it continued decade after decade. Between 1690 and 1710 small catches and heavy financial losses became so frequent after the first prosperous decades of the ice fishery that Dutch whalers looked for new fishing grounds. They found them in Davis Strait where Dutch traders had been bartering annually with Greenlanders since about 1670 and showed their fellow countrymen the way. The voyage to the Strait was much longer, so costs were higher. But the Strait fishery was attractive because the whale of Stock II yielded on the average 25–40% more blubber than Stock I, as was stated above. The Strait fishery started shortly after 1700 by traders and became so important that private statisticians in the Netherlands distinguished between whaling east and west of Greenland or between 'Greenland fishery' and 'Davis Strait fishery' from 1719.

Between 1725 and 1735 the catches east of Greenland were very small, probably in large part owing to climatological factors. In these years most Dutch and German whalers moved to the new grounds in Davis Strait. When the fishery in the Strait proved to be as capricious, and when catches east of Greenland rose again after 1735, many whalers returned to the hunt for Stock I because the voyage was shorter and expenditure lower. However, a group of Dutch and German whalers remained faithful to the Strait fishery.

In the course of the eighteenth century a slow and gradual decline in Stock I and probably Stock II occurred, judging from the figures of the catches and the blubber yield per whale. As the size of the Dutch and German whaling fleets changed little between 1740 and 1770, the main reason must be the participation by the Britishers, Danes and Swedes. While the British fleet grew rapidly after 1750, the Dutch fleet decreased after 1770. The principal reason for the waning of the Dutch and the German Hansa towns was not in the first place the decrease in the catches, which was not yet disastrous, but the growing severe competition of foreign whalers, abundantly supported by their governments with bounties, subsidies and protectionist duties on imports of foreign whaling products in correspondence with the mercantilist ideas of the eighteenth century.

About 1790 a decisive turn in Arctic whaling occurred. Dutch whaling had then greatly declined and from 1795 to 1813 the Netherlands ports were blockaded by the British navy. Except for brief interludes in 1796–97 and 1802, Dutch whaling was stopped. The turn in whaling was caused by the British. When catches fell gradually they rationalized the trade. They applied new methods and intensified whaling by increasing their input of production factors. The steep rise in whale oil prices in wartime after 1793 made this change profitable.

The English whaling captain, William Scoresby, Jr., described the change thus (1820):

> The Dutch, from indulging a habit of coolness, became inactive, and the British too closely copied their example. About the close, however, of the eighteenth century, two or three of the captains of the (British) whalefishing ships, men of abilities, commenced a system of activity and perseverance which was followed by the most brilliant result. Instead of being contented with two or three large fish, and considering five or six a great cargo (like the Dutch and Germans), they set the example of doubling or trebling the latter quantity and were only contented, so far as to relax their exertions, when their ships could contain no more. Thus arose a striking epoch in the history of the fishery.

One of those two or three captains who acted as pioneers was William Scoresby, Sr., from Whitby. One of the British innovations which was important for the considerable increase of the catch was the extra fortifying and shielding of whaleships against the pressure of the ice so that they could sail earlier in the year and bore through the dense drift ice south of Spitsbergen in April and early May instead of June, for the purpose of reaching the whales near Spitsbergen earlier – in spite of the greater dangers and cold of the Arctic spring.

With these innovations 'a striking epoch' started, as Scoresby (1820) states, but with fateful consequences for the whale stock. The greatest disadvantage of the opening of the catch earlier in the year was that the nursing females, 'suckers' and immature animals had not yet hidden themselves in the drift ice in the north and were within reach of the whalers. They were slaughtered in great numbers. Other disadvantages were that in spring the whales are meager and produce little blubber and whale oil, and that the baleen plates of young animals are short, undersized and low-priced.

Because Scoresby Senior was one of the innovators in British whaling and because he and his famous author-son participated in the wholesale slaughter, the son is silent in his publications on the predatory traits which whaling assumed after 1790. The catch of the nursing females and the young was relatively easy because (1) there was little open water in the early season; (2) the young were a little shy; (3) they could not dive as long as adult whales and were soon exhausted; (4) their head was sufficiently light, after cutting off the lower jaw, lips and tongue, to be separated from the trunk and hoisted upon the deck where the baleen could be more easily taken out; and (5) the nursing females would stay close to their young and were, in many cases, killed shortly after the calves.

Scoresby (1820), Harmer (1928) and Lubbock (1937) mention several ships which killed 10–15 whales in one fall, that is, in one lowering of the boats, and inevitably most of them were small. The record seems to be the catch of the *Resolution* under Captain Souter of Peterhead in 1814, which was 44 whales, 299 tuns of oil, evidently mostly small animals. 'Suckers' yielded five to ten tuns of blubber, compared with 30 to 40 per adult whale.

The results of British whaling can not be investigated in detail because so far, no comprehensive figures of this industry are available and Dutch and German whaling which can boast of detailed statistics, declined after 1800.

Table 9 contains one of the scarce published series of British local figures, those of whaling from Hull in 1772–1833. The increase in tuns of blubber per ship after 1795 (the turn in whaling) is conspicuous in many seasons. The years concerned do not show a clear fall in tuns of blubber per ship as this fall occurred later. The figures of tuns of blubber per whale flensed for 1814–33 are too few to show the decline in the average size of the whales killed, and separate figures for catches by Hull ships east and west of Greenland are essential because the decline in catches east of Greenland was compensated by the move of ships from east to west of Greenland over the years 1772–1833. However, these are not available.

A rapid decline in the Spitsbergen stock followed the massive killing. As a result, the whalers shifted their activity gradually to the area of the west Greenland stock. From 1817 onwards they pursued this stock into remote corners of the Canadian archipelago. After a few decades Stock II also was on the brink of extermination. It seems that the hunt by North Americans of the bowhead of the Bering Sea stock, which ended in 1908, ceased before its decline was fatal so that a remnant maintained its strength and has to date perhaps grown to a modest extent.

Gray (1894), Gray (1932), Lubbock (1937) and other authors point out that whaling methods after 1790 were, in the long run, disastrous for the whale stocks. Lubbock mentions several seasons in which large numbers of nursing females and immature whales were killed. Commenting on the catches on the new grounds in Baffin Bay in 1826–28 he wrote: '...if rewards were great, the risks were even greater, owing to the discovery of huge quantities of Greenland whales on the west side of Baffin Bay, a locality, however, which could only be reached in favourable seasons'. For the year 1819 he records 'the tremendous slaughter of whales on that fishing ground, which was bounded by what were known as the Northeast and Southwest Bays (in Baffin Bay)'.

British whaleships with doubly reinforced hulls and, after 1860, with steam power, pushed on in Baffin Bay and Lancaster Sound in June and July, hit upon nursing females and 'suckers' and performed the same drama as some years before east of Greenland. Captain James Fairweather wrote in his book *With the Scottish Whalers*:

> During the last 25 years of the fishing in the Arctic large quantities of young whales and their mothers were killed by the whalers in Lancaster Sound and it was this killing of the female and the young which eventually made the Greenland whale practically extinct, and brought the trade to a standstill (Lubbock, 1937).

Lubbock (1937) quotes the logbook of the British whaleship *Cumbrian* which gives a lurid picture of whaling in Lancaster Sound in 1823, one of the most successful years. On 27 July 1823 the logbook records:

> We were turning south along the land floes in hopes of fish. Here and there along the floe edge lay the dead bodies of hundreds of flenched whales, and the air for miles around was tainted with the faetor which arose from such masses of putridity. Towards evening, the numbers come across were even increasing, and the effluvia which then assailed our olfactories became almost intolerable.

The rapid decline of Stocks I and II of the Greenland whale is evident from the following tables supplied by Gray (1932). The figures refer to whaleships from Peterhead in Scotland:

Decade	Average number of whales processed per voyage
1800–09	16.8
1810–19	11.3
1820–29	7.2
1830–39	3.5
1840–49*	2.1

Period	1807–18	1840–51*
Average no. of trips per year	68	92
Average no. of whales flensed per year	993.0	213.0
Average no. of whales per trip	14.6	2.2
Total no. of tuns oil	8,635	1,723
Average no. of tuns oil per trip	127.0	18.7
Average no. of tuns blubber per trip	169.3	24.9
Average no. of tuns blubber per whale	11.5	12.3

* In these years seal hunting had become the main activity of Arctic shipping. As sealers usually unloaded their catches in home ports before they went whaling the number of trips of the ships per year was doubled.

Towards 1900 the hunt of the Greenland whale and bowhead failed in all these areas. Whales of Stock I had been scarce for several decades and sealing became the principal, though soon declining, activity of British ships in the Arctic Sea. 1908 was the last year of Bering Sea fishing by North Americans. The last two British whaleships returned empty from Baffin Bay to Dundee in 1913.

Recently, a Danish zoologist, Vibe (1967), criticized the general opinion that the Greenland whale was decimated or almost exterminated by excessive hunting. He directed his criticism particularly at the Norwegian, Nansen (1924). This zoologist had stated that the Greenland whale population consisted of several geographically separated tribes (stocks) which were exterminated one after the other from east moving to west. Vibe writes: 'This hypothesis is hardly valid.' He attributes the decline of the Greenland whale mainly to changes in natural circumstances in the Arctic Sea, to the long term movements of the drift ice north and southward. Continued advance of this ice destroys the biotopes, forcing the whale away from its best feeding grounds in the Northern Atlantic areas (he means in the Arctic Sea) and made it difficult for it to escape the whalers. He discerns a secular cycle of advance and retreat of the drift ice, and in connection with it, an alternation of scarcity and abundance of whale food and of whales. Scarcity of food caused starvation and infertility among the whales and the advance of the ice exposed them to a larger extent to whalers who caught them in larger numbers. According to Vibe, large catches were consequently no cause of a decline in the whale stock, though they contributed to this decline.

He has found little support for this reasoning. For example, Jonsgård (1972) supports Nansen against Vibe's criticism and thinks that man bears the greatest responsibility for the decimation of the Greenland whale.

Several whaling captains, among them James Fairweather and David Gray, admitted that the killing of breeding and nursing females, of 'suckers' and other immature whales, would lead to the extermination of the Greenland whale and to the end of their trade. Nevertheless, the general attitude of the whalers, the public and the authorities with regard to this deplorable development was remarkably complacent and resigned, as if it was inevitable. Lubbock (1937) sums up this attitude as follows: 'The killing of females and suckers, owing to their great value, could not be avoided, though it was fatal for the future of the fishing.'

DISCUSSION OF THE HISTORICAL DATA REGARDING WHALING AND WHALE CATCHES

The comprehensive Dutch and German whaling statistics, of which the sources are mentioned in Appendix 1, contain the following annual figures:

- number of ships sailing;
- number of ships lost owing to natural disasters (storm, ice, fire);
- number of ships captured by enemies;
- number of whales caught and processed; and
- number of tuns of blubber flensed (cut) from caught whales.

Some lists drawn up for German ports contain the additional figures:

- number of quarters ('quarteelen') of whale oil produced near home ports;
- weight of baleen plates cut from the whales;
- dates of return of whaleships from the Arctic Sea; and
- number of whales processed in ships which were afterwards lost or captured.

The Dutch neglected sealing, but the Germans equipped a considerable number of ships specifically for sealing in the Arctic from 1716 and an increasing number of German whaleships combined sealing with whaling. The statistics for German ports, such as Hamburg, Bremen, Altona and Glückstadt, also contain figures of sealing ships, tuns of seal blubber, quarters of oil boiled from seal blubber in the home country, and seal skins brought home. The main quarries of European hunters were the harp seal (*Phoca groenlandica*), hooded seal (*Cystophora cristata*) and walrus (*Odobenus rosmarus*); the harp seal was the most important game. The student of Arctic sealing will find interesting figures in German whaling statistics of the eighteenth century.

Figures of whale catches before 1661 are not available. DeJong (1972) estimated that the Dutch chartered whaling company, Noordsche of Groenlandsche Compagnie (1614–42), annually processed 350 to 450 whales on its Arctic land stations. The catch of its competitors – Britishers, Danes, Basques and Dutch interlopers – is even more difficult to estimate, but probably did not exceed half of the catch by the Dutch company, which was the strongest participant. It is not true that the whale catch from land stations fell considerably after 1640 and that this compelled the Dutch company to liquidate. After its termination, shore whaling expanded until *circa* 1660; thereafter it declined and ended about 1670.

The Dutch and German figures of annual catches account for 95–98% of Greenland whales and for the remainder of other whale species. These were in the following sequence of importance: the sperm whale ('cachelot'); the right whale ('Noordkaper'); the humpback ('combaars'); and the bottlenose ('Butskop'). Narwhals and belugas were very seldom mentioned. The number of these whales caught is so small that it is not worthwhile to deduct their estimated blubber and oil from the total figures of the output of blubber and whale oil.

(continued on p. 97)

Table 1

Physical input of Dutch whaling[1, 2]

Year	Ships sailed	Ships wrecked	Ships raided	Number of sailors (average 42 men per ship)
1661	133	—	—	5,586
1662	149	—	—	6,258
1663	202	—	—	8,484
1664	193	8	—	8,106
1665	—	—	—	—
1666	—	—	—	—
1667	—	—	—	—
1668	155	11	—	6,510
1669	138	—	—	5,796
1670	148	4	—	6,216
1671	158	11	—	6,636
1672	—	—	—	—
1673	—	—	—	—
1674	—	—	—	—
1675	149	14	—	6,258
1676	145	8	1	6,090
1677	149	5	20	6,258
1678	110	18	—	4,620
1679	126	3	—	5,292
1680	151	12	—	6,342
1681	176	6	—	7,392
1682	195	10	—	8,190
1683	242	11	—	10,164
1684	246	11	—	10,332
1685	212	23	—	8,904
1686	189	11	—	7,938
1687	194	6	—	8,148
1688	214	7	—	8,988
1689	163	11	—	6,846
1690	117	5	—	4,914
1691	2	—	—	84
1692	32	—	—	1,344
1693	89	8	26	3,738
1694	63	6	—	2,646
1695	97	4	3	4,074
1696	121	6	2	5,082
1697	131	8	2	5,502
1698	141	6	—	5,922
1699	151	3	—	6,342
1700	173	1	—	7,266
1701	207	12	—	8,694
1702	225	5	3	9,450
1703	208	7	16	8,736
1704	130	1	—	5,460
1705	157	4	4	6,594
1706	151	1	2	6,342
1707	131	1	—	5,502
1708	122	3	—	5,124
1709	127	1	—	5,334
1710	137	2	3	5,754
1711	117	5	—	4,914
1712	108	5	7	4,536
1713	94	3	—	3,948
1714	108	3	—	4,536
1715	134	5	—	5,628
1716	153	—	—	6,426
1717	179	6	—	7,518
1718	194	8	—	8,148
1719	211	3	—	8,862

[1] From 1661 to 1718 only Dutch whaling ships sailing to Arctic waters east of Greenland were accounted for.

[2] Source: Wätjen (1919) publishes two series of figures for the same years with small differences, the first calculated by him from the annual 'Lijsten van de Hollandchsche, Hamburger en Bremer Groenlands-vaarders' in the municipal archives in Amsterdam and some other Dutch towns, the second series derived from van Sante (1770). Of the two series of figures, the higher of the two annual figures was used. During the 17th century Dutch whale ships and crews were generally smaller than during the 18th century. These crews were of 35–42 men thus the personnel figures above are somewhat too high for the 17th century.

Table 1 (*continued*)

Year	Ships sailed	Ships wrecked	Ships raided	Number of sailors (average 42 men per ship)
1720	233	5	—	9,786
1721	258	8	—	10,836
1722	252	5	—	10,584
1723	235	8	—	9,870
1724	232	8	—	9,744
1725	226	5	—	9,492
1726	219	3	—	9,198
1727	204	6	—	8,568
1728	194	7	—	8,148
1729	186	2	—	7,812
1730	169	3	—	7,098
1731	165	4	—	6,930
1732	176	1	—	7,392
1733	184	2	—	7,728
1734	191	4	—	8,022
1735	185	3	—	7,770
1736	192	1	—	8,064
1737	196	4	1	8,232
1738	198	3	4	8,316
1739	191	5	—	8,022
1740	204	3	—	8,568
1741	178	6	—	7,476
1742	174	1	—	7,308
1743	188	5	—	7,896
1744	187	—	—	7,854
1745	184	—	—	7,728
1746	180	11	—	7,560
1747	165	1	—	6,930
1748	95	—	1	3,990
1749	157	1	—	6,594
1750	160	6	—	6,720
1751	162	2	—	6,678
1752	159	3	—	6,678
1753	166	2	—	6,972
1754	172	2	—	7,224
1755	181	4	—	7,602
1756	186	7	—	7,812
1757	180	1	1	7,560
1758	159	6	—	6,678
1759	155	3	—	6,510
1760	154	3	—	6,468
1761	161	3	—	6,762
1762	166	4	—	6,972
1763	163	4	—	6,846
1764	165	2	—	6,930
1765	165	3	—	6,930
1766	168	1	—	7,056
1767	165	1	—	6,930
1768	160	5	—	6,720
1769	153	4	—	6,426
1770	150	1	—	6,300
1771	151	5	—	6,342
1772	131	2	—	5,502
1773	134	6	—	5,628
1774	130	2	—	5,460
1775	135	5	—	5,670
1776	123	2	—	5,166
1777	120	8	—	5,040
1778	111	3	—	4,662
1779	104	3	—	4,368
1780	82	—	—	3,444
1781	—	—	—	—
1782	—	—	—	—
1783	56	3	—	2,352
1784	64	1	—	2,688
1785	66	—	—	2,772
1786	69	—	—	2,898
1787	68	—	—	2,856
1788	69	—	—	2,898
1789	67	1	—	2,814
1790	66	—	—	2,772
1791	62	2	—	2,604
1792	60	—	—	2,520
1793	32	—	—	1,344
1794	58	—	—	2,436
1795	—	—	—	—
1796	16	—	—	672
1797	35	—	—	1,470
1798	31	—	29	1,302
1799	—	—	—	—
1800	—	—	—	—
1801	—	—	—	—
1802	16	—	—	672
1803	10	—	4	420
1804	—	—	—	—
1805	—	—	—	—
1806	—	—	—	—
1807	—	—	—	—
1808	—	—	—	—
1809	—	—	—	—
1810	—	—	—	—
1811	—	—	—	—
1812	—	—	—	—
1813	—	—	—	—
1814	—	—	—	—
1815	1	—	—	42
1816	1	—	—	42
1817	1	—	—	42
1818	1	—	—	42
1819	1	—	—	42
1820	1	—	—	42
1821	1	—		42
1822	2	—		84
1823	2	—		84
1824	1	—	—	42
1825	—	—	—	—
1826	—	—	—	—

Table 2

Physical input of Dutch whaling East and West of Greenland

Year	Number of ships sailed		Number of ships lost	
	East	West	East	West
1719	182	29	3	—
1720	169	64	4	1
1721	151	107	4	4
1722	185	67	3	2
1723	190	45	5	3
1724	172	60	6	2
1725	145	81	4	1
1726	108	111	1	2
1727	103	101	3	3
1728	104	90	6	1
1729	95	91	1	1
1730	86	83	2	1
1731	67	98	4	—
1732	39	137	—	1
1733	66	118	1	1
1734	98	93	2	2
1735	84	101	—	3
1736	100	92	1	—
1737	108	88	—	4
1738	124	74	2	1
1739	133	58	4	1
1740	171	33	2	1
1741	144	34	6	—
1742	126	48	1	—
1743	138	50	3	2
1744	148	39	—	—

Table 2 (*continued*)

Year	Number of ships sailed		Number of ships lost	
	East	West	East	West
1745	153	31	—	—
1746	140	40	11	—
1747	128	37	1	—
1748	94	1	—	—
1749	116	41	1	—
1750	116	44	3	3
1751	117	45	1	1
1752	117	42	3	—
1753	118	48	2	—
1754	135	37	2	—
1755	152	29	4	—
1756	160	26	7	—
1757	159	21	1	—
1758	151	8	6	—
1759	133	22	3	—
1760	139	15	3	—
1761	138	23	3	—
1762	139	27	4	—
1763	128	35	4	—
1764	127	38	1	—
1765	130	35	—	2
1766	136	32	1	2
1767	132	33	1	—
1768	124	36	5	—
1769	111	42	4	—
1770	105	45	—	1
1771	111	40	5	—
1772	93	38	2	—
1773	91	43	5	1
1774	82	48	—	2
1775	88	47	5	—
1776	84	39	2	—
1777	75	45	7	—
1778	64	47	—	3
1779	59	45	3	—
1780	46	36	—	—
1781	—	—	—	—
1782	—	—	—	—
1783	46	10	1	2
1784	58	6	—	—
1785	65	1	—	—
1786	62	7	—	—
1787	61	7	—	—
1788	58	11	—	1
1789	59	8	1	—
1790	52	14	—	—
1791	49	13	2	—
1792	47	13	—	—
1793	31	1	—	—
1794	55	3	—	—
1795	—	—	—	—
1796	16	—	—	—
1797	34	1	—	—
1798	31	—	29	—
1799	—	—	—	—
1800	—	—	—	—
1801	—	—	—	—
1802	16	—	—	—
1803	10	—	4	—
1804	—	—	—	—
1805	—	—	—	—
1806	—	—	—	—
1807	—	—	—	—
1808	—	—	—	—
1809	—	—	—	—
1810	—	—	—	—
1811	—	—	—	—
1812	—	—	—	—
1813	—	—	—	—
1814	—	—	—	—
1815	1	—	—	—
1816	1	—	—	—
1817	1	—	—	—
1818	1	—	—	—
1819	1	—	—	—
1820	1	—	—	—
1821	1	—	—	—
1822	2	—	—	—
1823	2	—	—	—
1824	1	—	—	—
1825	—	—	—	—
1826	—	—	—	—

Table 3

Physical output of Dutch whaling[1]

Year	Number of whales caught[2]		Supplied number of tuns of blubber[3]	
	Whole fleet	Per ship sailed	Whole fleet	Per ship sailed
1661[4]	452$\frac{1}{4}$	3.4	*ca.* 20,261	*ca.* 152.3
1662	862	5.8	*ca.* 38,618	*ca.* 259.2
1663	932$\frac{1}{2}$	4.6	49,786	246.5
1664	982	5.1	*ca.* 43,994	*ca.* 227.9
1665	—	—	—	—
1666	—	—	—	—
1667	—	—	—	—
1668	573	3.7	*ca.* 25,670	*ca.* 165.6
1669	1,013$\frac{1}{2}$	7.3	53,236	385.8
1670	794$\frac{1}{2}$	5.4	32,574	220.1
1671	1,083$\frac{1}{2}$	6.9	45,386	287.3
1672	—	—	—	—
1673	—	—	—	—
1674	—	—	—	—
1675	900$\frac{1}{2}$	6.0	38,721	259.9
1676	812$\frac{1}{6}$	5.6	34,916	240.8
1677	784$\frac{11}{12}$	5.3	34,702	232.9
1678	1,118$\frac{3}{4}$	10.2	49,148	446.8
1679	831	6.6	39,857	316.3
1680	1,377$\frac{1}{2}$	9.1	52,631	348.5
1681	889	5.1	30,609	173.9
1682	1,470	7.5	62,960	322.9
1683	1,349$\frac{5}{6}$	5.6	43,540	179.9
1684	1,185	4.8	44,770	182.0
1685	1,383$\frac{1}{4}$	6.5	55,960	264.0
1686	664$\frac{5}{6}$	3.5	30,532	161.5
1687	621$\frac{1}{2}$	3.2	24,398	125.8
1688	345	1.6	14,670	68.6
1689	243$\frac{1}{6}$	1.5	10,120	62.1
1690	825$\frac{1}{2}$	7.1	34,960	298.8
1691	—	—	—	—
1692	62	1.9	2,748	85.9
1693	175	2.0	8,480	95.3
1694	164$\frac{5}{12}$	2.6	7,821	124.1
1695	281	2.9	9,111	93.9
1696	428	3.5	17,251	142.6
1697	1,274$\frac{1}{2}$	9.7	42,281	322.8
1698	1,488$\frac{1}{2}$	10.6	56,485	400.6
1699	775$\frac{1}{2}$	5.1	30,845	204.3

[1] See footnote 2 Table 1.

[2] Most of the captured animals were Greenland whales (bowheads). However, a small number (probably seldom more than 5% of the total number) of sperm whales, right whales, humpbacks and bottlenoses in this order of importance were caught.

[3] The addition '*ca.*' (ie. *circa*) indicates an estimate for a year when the real number is not mentioned in the original statistics.

[4] From 1661 to 1718 only Dutch ships sailing to Arctic waters east of Greenland were accounted for.

Table 3 (*continued*)

	Number of whales caught[2]		Supplied number of tuns of blubber[3]	
Year	Whole fleet	Per ship sailed	Whole fleet	Per ship sailed
1700	914	5.3	36,721	212.3
1701	2,071¾	10.0	67,471	325.9
1702	697 5/12	3.1	24,104	107.1
1703	646	3.1	24,537	118.0
1704	653½	5.0	23,899	183.8
1705	1,678	10.7	52,144	332.1
1706	466	3.1	15,630	103.5
1707	128½	1.0	5,615	42.9
1708	534⅙	4.4	21,081	172.8
1709	192¾	1.5	8,237	64.9
1710	62	0.5	3,427	25.0
1711	631	5.4	20,589	176.0
1712	370 5/12	3.4	14,170	131.2
1713	255	2.7	12,854	136.7
1714	1,282½	11.9	37,819	350.2
1715	705	5.3	26,800	200.0
1716	535	3.5	20,648	135.0
1717	394	2.2	14,463	80.8
1718	284¾	1.5	13,111	67.6
1719	345½	1.6	12,393	58.7
1720	463½	2.0	21,254	91.2
1721	732⅓	2.8	26,923	104.4
1722	1,112	4.4	39,178	155.5
1723	314	1.3	15,267	64.9
1724	358½	1.5	17,143	73.9
1725	530½	2.3	23,760	105.1
1726	246½	1.1	13,323	60.8
1727	404⅞	2.0	19,799	97.1
1728	364	1.9	18,245	94.0
1729	236⅔	1.3	12,545	67.4
1730	250¾	1.5	14,229	84.2
1731	306	1.9	18,003	109.1
1732	319¼	1.8	16,392	93.1
1733	362⅔	2.0	17,395	94.5
1734	332¼	1.7	17,484	91.5
1735	496¾	2.7	23,896	129.2
1736	857½	4.5	38,820	202.2
1737	505½	2.6	23,010	117.4
1738	476⅝	2.4	21,960	110.9
1739	729¾	3.8	25,645	134.3
1740	720⅝	3.5	30,178	147.9
1741	312¾	1.8	13,565	76.2
1742	567	3.3	21,516	123.7
1743	937½	5.0	28,775	153.1
1744	1,494	8.0	46,080	246.4
1745	569	3.1	22,807	124.0
1746	1,037	5.8	35,122	195.1
1747	776¾	4.7	27,500	166.7
1748	278⅙	2.9	6,889	72.5
1749	618¼	3.9	24,419	155.5
1750	591	3.7	18,004	112.5
1751	331⅙	2.1	10,570	65.2
1752	547¾	3.4	19,336	121.6
1753	641⅙	3.9	17,950	108.1
1754	673	3.9	19,003	111.0
1755	720½	4.0	18,672	103.2
1756	569½	3.1	13,541	72.8
1757	424½	2.4	14,205	78.9
1758	371½	2.3	13,417	84.4
1759	466	3.0	16,211	104.6
1760	455	3.0	17,440	113.3
1761	357½	2.2	14,760	91.7
1762	189¾	1.1	7,550	45.5
1763	697	4.3	20,246	124.2
1764	224	1.4	9,532	57.8
1765	476	2.9	16,689	101.1
1766	190½	1.1	6,718	40.0
1767	179⅙	1.1	7,626	46.2
1768	600⅓	3.8	18,157	113.5
1769	1,131	7.4	25,783	168.5
1770	525	3.5	15,259½	101.7
1771	143⅔	1.0	5,160	34.1
1772	786	6.0	25,816	197.1
1773	445½	3.3	18,932	141.3
1774	460	3.5	16,987	130.7
1775	105	0.8	4,033	29.9
1776	509½	4.1	14,848	120.7
1777	428¼	3.6	14,458	120.5
1778	307½	2.8	7,576	68.3
1779	168¼	1.6	6,706	64.5
1780	475½	5.8	12,875	157.0
1781	—	—	—	—
1782	—	—	—	—
1783	328½	5.9	6,606	118.0
1784	171½	2.7	5,390	84.2
1785	333	5.0	8,039	121.8
1786	457	6.6	11,366	164.7
1787	239½	3.5	7,469	109.8
1788	188	2.7	3,847	55.8
1789	504¾	7.5	8,187	122.2
1790	114½	1.7	3,272	49.6
1791	79⅓	1.3	3,157	50.9
1792	200	3.3	4,317	72.0
1793	72	2.3	2,473	77.3
1794	113	1.9	4,030	69.5
1795	—	—	—	—
1796	85	5.3	1,890	118.1
1797	142½	4.1	3,484	99.5
1798	9	0.3	225	7.3
1799	—	—	—	—
1800	—	—	—	—
1801	—	—	—	—
1802	63	3.9	1,031	64.4
1803	13	1.3	210	21.0
1804	—	—	—	—
1805	—	—	—	—
1806	—	—	—	—
1807	—	—	—	—
1808	—	—	—	—
1809	—	—	—	—
1810	—	—	—	—
1811	—	—	—	—
1812	—	—	—	—
1813	—	—	—	—
1814	—	—	—	—
1815	—	—	—	—
1816	2	2.0	40	40.0
1817	—	—	—	—
1818	—	—	—	—
1819	2	2.0	60	60.0
1820	—	—	—	—
1821	6	6.0	90	90.0
1822	2	1.0	110	55.0
1823	11	5.5	207	103.5

Table 4

Physical output of Dutch whaling East and West of Greenland: number of whales caught[1]

	Number of whales caught by the whole fleet		Number of whales caught per ship sailed	
Year	East	West	East	West
1719	302½	43	1.7	1.5
1720	319	144½	1.9	2.3
1721	667⅚	64½	4.4	0.6
1722	976½	125½	5.3	1.9
1723	201	113	1.1	2.5
1724	223½	135	1.3	2.3
1725	279½	251	1.9	3.1
1726	133	113½	1.2	1.0
1727	226¼	178⅝	2.2	1.8
1728	165½	198½	1.6	2.2
1729	115⅓	121⅓	1.2	1.3
1730	37	213¾	0.4	2.6
1731	51	255	0.7	2.6
1732	100⅔	$218\frac{7}{12}$	2.6	1.6
1733	227½	135⅙	3.4	1.1
1734	102½	229¾	1.0	2.5
1735	271	225¾	3.2	2.2
1736	588½	269	5.9	2.9
1737	355	150½	3.3	1.7
1738	362½	114⅛	2.9	1.5
1739	678	51¾	5.1	0.9
1740	607	113⅝	3.5	3.4
1741	176	136¾	1.2	4.0
1742	517	50	4.1	1.0
1743	862	75½	6.2	1.5
1744	1,311½	182½	8.9	4.7
1745	362½	206½	2.4	6.7
1746	820	217	5.9	5.4
1747	645	131¾	5.0	3.6
1748	278⅙	—	3.0	—
1749	412¼	206	3.6	5.0
1750	533	58	4.6	1.3
1751	265	66⅙	2.3	1.5
1752	440¼	107½	3.8	2.6
1753	541⅙	100	4.6	2.1
1754	655	18	4.9	0.5
1755	679½	41	4.5	1.4
1756	529½	40	3.3	1.5
1757	414½	10	2.6	0.5
1758	305½	66	2.0	8.3
1759	427	39	3.2	1.8
1760	377	78	2.7	5.2
1761	287½	70	2.1	3.0
1762	124	65¾	0.9	2.4
1763	565	132	4.4	3.8
1764	193	31	1.5	0.8
1765	394	82	3.0	2.3
1766	157½	33	1.2	1.0
1767	99⅙	80	0.8	2.4
1768	392⅚	207½	3.2	5.8
1769	972½	158½	8.8	3.8
1770	439½	85½	4.2	1.9
1771	105⅔	38	1.0	1.0
1772	546½	239½	5.9	6.3
1773	196	249½	2.2	5.8
1774	281	179	3.4	3.7
1775	86	19	1.0	0.4
1776	365	144½	4.3	3.7
1777	250¼	178	3.3	4.0
1778	253	54½	4.0	1.2
1779	132¼	36	2.2	0.8
1780	385	90½	8.0	2.5
1781	—	—	—	—
1782	—	—	—	—
1783	326½	2	7.1	0.2
1784	163½	8	2.8	1.3
1785	328	5	5.0	5.0
1786	418	39	6.7	5.6
1787	198½	41	3.3	5.9
1788	167	21	2.9	1.9
1789	481¾	23	8.1	2.9
1790	104½	10	2.0	0.7
1791	61⅚	17½	1.3	1.3
1792	198	2	4.2	0.2
1793	72	—	2.3	—
1794	99½	13½	1.8	4.5
1795	—	—	—	—
1796	85	—	5.3	—
1797	141½	1	4.2	1.0
1798	9	—	0.3	—
1799	—	—	—	—
1800	—	—	—	—
1801	—	—	—	—
1802	63	—	3.9	—
1803	13	—	1.3	—
1804	—	—	—	—
1805	—	—	—	—
1806	—	—	—	—
1807	—	—	—	—
1808	—	—	—	—
1809	—	—	—	—
1810	—	—	—	—
1811	—	—	—	—
1812	—	—	—	—
1813	—	—	—	—
1814	—	—	—	—
1815	—	—	—	—
1816	2	—	2.0	—
1818	—	—	—	—
1819	2	—	2.0	—
1820	—	—	—	—
1821	—	6	—	6.0
1822	—	2	—	1.0
1823	—	11	—	5.5
1824	—	—	—	—

[1] See footnote 2 Table 1.

Table 5

Physical output of Dutch whaling East and West of Greenland: supplied number of tuns of blubber[1]

	Supplied number of tuns of blubber of the whole fleet		Supplied number of tuns of blubber per ship sailed	
Year	East	West	East	West
1719	9,973	2,420	54.8	83.4
1720	13,986	7,268	82.8	113.6
1721	23,155	3,768	153.3	35.2
1722	32,538	6,640	175.9	99.1
1723	8,991	6,276	47.3	139.5
1724	9,496	7,647	55.2	127.5
1725	10,495	13,265	72.4	163.8
1726	6,234	7,089	57.7	63.9
1727	9,920	9,879	96.3	97.8
1728	7,225	11,020	69.5	122.4
1729	5,155	7,390	54.3	81.2
1730	2,024	12,205	23.5	147.0
1731	2,863	15,140	42.7	154.5
1732	3,977	12,415	102.0	90.6
1733	9,665	7,730	146.4	65.5
1734	4,950	12,534	50.5	134.8

[1] See footnote 2 Table 1.

Table 5 (*continued*)

Year	Supplied number of tuns of blubber of the whole fleet		Supplied number of tuns of blubber per ship called	
	East	West	East	West
1735	12,185	11,711	145.1	116.0
1736	23,320	15,500	233.2	168.5
1737	15,110	7,900	139.9	89.8
1738	15,740	6,220	126.9	84.1
1739	22,760	2,885	171.1	49.7
1740	25,575	4,603	149.6	139.5
1741	6,455	7,110	44.8	209.1
1742	18,831	2,685	149.5	55.9
1743	24,920	3,855	180.6	77.1
1744	37,850	8,230	255.7	211.0
1745	13,707	9,100	89.6	293.5
1746	25,870	9,252	184.8	231.3
1747	21,540	5,960	168.3	161.1
1748	6,889	—	73.3	—
1749	14,580	9,839	125.7	240.0
1750	15,330	2,674	132.2	60.8
1751	7,111	3,459	60.8	76.9
1752	14,865	4,471	127.1	106.5
1753	13,546	4,404	114.8	91.8
1754	17,987	1,016	133.2	27.5
1755	16,763	1,909	110.3	65.8
1756	11,578	1,963	72.4	75.5
1757	13,730	475	86.4	22.6
1758	10,539	2,878	69.8	359.8[2]
1759	14,414	1,797	108.4	81.7
1760	13,805	3,635	99.3	242.3
1761	11,609	3,151	84.1	137.0
1762	4,772	2,778	34.3	102.9
1763	14,531	5,715	113.5	163.3
1764	7,900	1,632	62.2	42.9
1765	12,816	3,873	98.6	110.7
1766	5,242	1,476	38.5	46.1
1767	4,164	3,462	31.6	104.9
1768	9,428	8,729	76.0	242.5
1769	18,784	6,999	169.2	166.6
1770	11,420½	3,839	108.8	85.3
1771	3,352	1,808	30.2	45.2
1772	15,442	10,374	166.0	273.0
1773	8,456	10,476	92.9	243.6
1774	9,166	7,821	111.8	162.9
1775	3,072	961	34.9	20.5
1776	8,490	6,358	101.1	163.0
1777	6,451	8,007	86.0	177.9
1778	4,960	2,616	77.5	55.7
1779	4,573	2,133	77.5	47.4
1780	8,690	4,185	188.9	116.3
1781	—	—	—	—
1782	—	—	—	—
1783	6,530	76	142.0	7.6
1784	5,024	366	86.6	61.0
1785	7,839	200	120.6	200.0
1786	9,667	1,699	155.9	242.7
1787	5,744	1,725	94.2	246.4
1788	2,944	903	50.8	82.1
1789	7,227	960	122.5	120.0
1790	2,817	456	54.2	32.6
1791	2,441	716	49.8	55.1
1792	4,227	90	89.9	6.9
1793	2,473	—	79.8	—
1794	3,468	562	63.1	187.3
1795	—	—	—	—
1796	1,890	—	118.1	—
1797	3,439	45	101.1	45.0
1798	225	—	7.5	—
1799	—	—	—	—
1800	—	—	—	—
1801	—	—	—	—
1802	1,031	—	64.4	—
1803	210	—	21.0	—
1804	—	—	—	—
1805	—	—	—	—
1806	—	—	—	—
1807	—	—	—	—
1808	—	—	—	—
1809	—	—	—	—
1810	—	—	—	—
1811	—	—	—	—
1812	—	—	—	—
1813	—	—	—	—
1814	—	—	—	—
1815	—	—	—	—
1816	40	—	40.0	—
1817	—	—	—	—
1818	—	—	—	—
1819	60	—	60.0	—
1820	—	—	—	—
1821	—	90	—	90.0
1822	—	110	—	55.0
1823	—	207	—	103.5
1824	—	—	—	—

[2] This figure seems to be remarkably high and raises the question whether the number of tuns of blubber obtained by the whaling fleet in Davis Strait west of Greenland, that is 2,878, is put too high in Wätjen's (1919) sources. Wätjen has recalculated the figure carefully, as stated in his note 3, p. 289.

Table 6

Average size of whales caught by the Dutch (tuns of blubber flensed per whale)

Year	East of Greenland	West of Greenland	Year	East of Greenland	West of Greenland
1661[1]	*ca.* 44.8	—	1690	42.4	—
1662	*ca.* 44.8	—	1691	—	—
1663	53.7	—	1692	44.3	—
1664	*ca.* 44.8	—	1693	48.5	—
1665	—	—	1694	47.6	—
1666	—	—	1695	32.4	—
1667	—	—	1696	40.3	—
1668	*ca.* 44.8	—	1697	33.2	—
1669	52.5	—	1698	37.9	—
			1699	39.8	—
1670	41.0	—			
1671	41.9	—	1700	40.2	—
1672	—	—	1701	32.6	—
1673	—	—	1702	34.6	—
1674	—	—	1703	38.4	—
1675	43.0	—	1704	36.6	—
1676	43.0	—	1705	31.1	—
1677	44.2	—	1706	33.5	—
1678	43.9	—	1707	43.7	—
1679	48.0	—	1708	39.5	—
			1709	42.7	—
1680	38.2	—			
1681	34.4	—	1710	55.3	—
1682	42.8	—	1711	32.6	—
1683	32.3	—	1712	38.3	—
1684	37.8	—	1713	50.4	—
1685	40.5	—	1714	29.5	—
1686	45.9	—	1715	38.0	—
1687	39.3	—	1716	38.6	—
1688	42.5	—	1717	36.7	—
1689	41.3	—	1718	46.0	—

[1] From 1661 to 1718 only Dutch whaling ships sailing to Arctic waters east of Greenland were accounted for.

Table 6 (*continued*)

Year	East of Greenland	West of Greenland	Year	East of Greenland	West of Greenland
1719	33.0	56.3	1767	41.9	43.3
1720	43.8	50.3	1768	24.0	42.1
1721	34.7	58.4	1769	19.3	44.2
1722	33.3	52.9	1770	26.0	44.9
1723	44.7	55.5	1771	31.7	47.6
1724	42.5	56.6	1772	28.3	43.3
1725	37.5	52.8	1773	43.1	42.0
1726	46.9	62.5	1774	32.6	43.7
1727	43.8	55.3	1775	35.7	50.6
1728	43.7	55.5	1776	23.3	44.0
1729	44.7	60.9	1777	25.7	45.0
1730	54.7	57.1	1778	19.6	48.0
1731	59.6	59.4	1779	34.5	59.3
1732	39.5	56.8	1780	22.6	46.2
1733	42.5	57.2	1781	—	—
1734	48.3	54.6	1782	—	—
1735	45.0	51.9	1783	20.0	38.0
1736	39.6	57.6	1784	30.7	45.8
1737	42.6	52.5	1785	23.9	40.0
1738	43.4	54.5	1786	23.1	43.6
1739	33.6	55.7	1787	28.9	42.1
1740	42.1	40.5	1788	17.6	43.0
1741	36.7	52.0	1789	15.0	41.7
1742	36.4	53.7	1790	27.0	45.6
1743	28.9	51.1	1791	29.3	40.9
1744	28.9	45.1	1792	29.1	45.0
1745	37.8	44.1	1793	34.3	—
1746	31.5	42.6	1794	34.9	41.6
1747	33.4	45.2	1795	—	—
1748	24.7	—	1796	22.2	—
1749	35.0	47.8	1797	24.3	45.0
1750	28.8	46.1	1798	25.0	—
1751	26.8	52.3	1799	—	—
1752	33.7	41.6	1800	—	—
1753	25.0	44.0	1801	—	—
1754	26.2	56.4	1802	16.4	—
1755	24.7	46.6	1803	16.2	—
1756	21.9	49.1	....		
1757	33.1	47.5	1815	—	—
1758	34.5	43.6	1816	20.0	—
1759	33.8	46.1	1817	—	—
1760	36.6	46.6	1818	—	—
1761	40.4	45.0	1819	30.0	—
1762	38.5	42.3	1820	—	—
1763	25.7	43.3	1821	—	15.0
1764	40.9	52.0	1822	—	55.0
1765	32.5	47.2	1823	—	18.8
1766	33.3	44.7			

When we added numbers of caught whales to arrive at total catches over a series of years we have to take into consideration that whales were lost in ships which sank or were captured by raiders. The number of these whales is known for some years. Sometimes it was considerable. More important was the annual loss of whales killed in the Arctic Sea but lost due to natural circumstances, such as mist, storm and ice.

The harvest was smaller than the killing. Small (1971) estimates the percentage of whales lost in the early years of modern whaling in the Antarctic from 1909 to 1925 at 20% of all killed whales, in the 1960s at 5–10%. The old whalers in the Arctic lacked mechanical propulsion of ships and the wireless radio and radar which help modern whalers to retrace and salvage lost whales. Therefore it is thought that annual losses of whales killed in the Arctic in percentage were not less than in the Antarctic and that we must add at least 20% to the number of caught Greenland whales to estimate the number of killed animals.

Table 7

The pressure of Dutch whaling on the Greenland whale

	Whales caught per sailed ship		Tuns of blubber cut per whale	
Decade	East	West	East	West
1661–1670	5.0	—	49.1	—
1671–1680	7.1	—	43.2	—
1681–1690	4.6	—	39.9	—
1691–1700	4.8	—	40.5	—
1701–1710	4.2	—	38.8	—
1711–1720	4.0	1.9	38.7	53.3
1721–1730	2.1	1.9	42.7	56.8
1731–1740	3.2	2.1	43.6	53.9
1741–1750	4.5	3.7	32.2	47.5
1751–1760	3.4	2.5	29.6	47.4
1761–1770	3.0	2.4	32.3	45.0
1771–1780	3.6	2.9	29.7	47.0
1781–1790	4.8	2.9	23.3	42.6
1791–1800[1]	3.2	1.7	31.3	43.1
1801–1810	2.6	—	16.3	—
1811–1820	0.8	—	25.0	—
1821–1830	—	2.1	—	29.6

[1] The year 1798 has been omitted, as 29 of 31 Dutch ships which sailed were captured.

Table 1 shows the inputs, that is the number of ships and sailors in Dutch Arctic whaling, with peaks in 1683 (242 ships) and 1721 (258 ships), and the decline after 1771. Table 2 shows the rise of whaling in Davis Strait and the moves of ships and whaling activities between the old fishing grounds east of Greenland and the new ones west of this island.

Tables 3, 4 and 5 show the outputs of Dutch whaling, that is the number of whales caught and flensed and of supplied tuns of blubber. Peaks are the seasons of 1682 (1,470 whales) and in 1701 (2,071 whales). There is an unmistakable falling trend in the yield of the catch, that is in the number of whales per ship and more clearly in the number of tuns of blubber per ship, particularly when one compares the second half of the eighteenth century with the second half of the seventeenth.

Table 6 shows the average size of the whales caught, as measured by the average number of tuns of blubber per whale. The average catch per whaleship could to a certain extent be maintained by catching more of the smaller animals, but Table 6 demonstrates that the size of the whales caught decreased gradually and that the stock was affected. One observes further that the whales of the West Greenland stock caught were on the average bigger than those of the Spitsbergen stock and that the number of whales caught west of Greenland was on the average smaller than the number caught per ship east of Greenland. Table 7 repeats Table 6 in a condensed form to show the trend in the number of whales per ship and in the average size of whales caught more clearly.

The average number of tuns of blubber flensed per whale in Table 6 is too high, especially for the catch in Davis Strait but also in some years for the catch east of

(continued on p. 99)

Table 8

Whaling from Hull, Great Britain, in the Arctic Sea[1]

	Ships sailed[2]			Ships wrecked or captured	Whales caught		Supplied weight of baleen plates	
Year	East	West	Total		whole fleet	per ship	tons	cwt
1772	—	—	9	—	—	—	—	—
1773	—	—	9	—	—	—	—	—
1774	—	—	9	1	—	—	—	—
1775	—	—	12	2	—	—	—	—
1776	—	—	10	1	—	—	—	—
1777	—	—	9	—	—	—	—	—
1778	—	—	8	—	—	—	—	—
1779	—	—	4	1	—	—	—	—
1780	—	—	4	—	—	—	—	—
1781	—	—	3	—	—	—	—	—
1782	—	—	3	—	—	—	—	—
1783	—	—	4	—	—	—	—	—
1784	—	—	9	—	—	—	—	—
1785	—	—	15	—	—	—	—	—
1786	—	—	20	1	—	—	—	—
1787	—	—	30	1	—	—	—	—
1788	—	—	34	—	—	—	—	—
1789	—	—	29	2	57	2	(800 lb.)	
1790	—	—	24	1	—	—	—	—
1791	—	—	21	3	—	—	—	—
1792	—	—	19	—	—	—	—	—
1793	—	—	18	—	—	—	—	—
1794	—	—	17	—	—	—	—	—
1795	—	—	14	—	—	—	—	—
1796	—	—	18	1	—	—	—	—
1797	—	—	22	1	—	—	—	—
1798	—	—	23	—	—	—	—	—
1799	—	—	28	2	—	—	—	—
1800	—	—	23	—	—	—	—	—
1801	—	—	25	—	—	—	—	—
1802	—	—	34	—	—	—	—	—
1803	—	—	41	—	—	—	—	—
1804	—	—	43	3	—	—	—	—
1805	—	—	40	2	—	—	—	—
1806	—	—	42	3	—	—	—	—
1807	—	—	37	2	—	—	—	—
1808	—	—	32	5	—	—	—	—
1809	—	—	29	3	—	—	—	—
1810	—	—	34	—	—	—	—	—
1811	—	—	43	1	—	—	—	—
1812	—	—	50	1	—	—	—	—
1813	—	—	55	1	—	—	—	—
1814	23	35	58	1	697	12.0	291	10
1815	32	26	58	1	291	5.0	188	11
1816	32	23	55	—	464	8.4	263	18
1817	29	29	58	1	333	5.7	245	10
1818	31	33	64	1	489	7.6	304	13
1819	33	32	65	4	424	6.5	254	5
1820	38	23	62[3]	2	688	11.1	402	13
1821	32	29	61	9	498	8.2	322	7
1822	24	16	40	—	228	5.7	154	4
1823	24	17	41	3	636	15.5	297	6
1824	13	23	36	—	275	7.6	196	12
1825	7	29	36	—	219	6.1	131	17
1826	2	30	32	1	172	5.4	147	17
1827	6	24	30	1	370	12.3	261	15
1828	1	29	30	1	438	14.6	306	19
1829	—	*33*	*33*	*1*	*336*	*10.2*	*220*	*0*
1830	—	33	33	6	85	2.6	70	6
1831	5	27	32	—	168	5.3	102	14
1832	6	24	30	2	539	18.0	252	11
1833	—	27	27	1	589	21.8	284	17

[1] Source: Sheppard and Suddaby (1906). For the year 1789, second part, p. 26: '25 ships of Hull brought 57 whales which supplied 2,674 tuns of whale oil and 800 pounds of baleen plates.'

[2] East means east of Greenland, west means west of Greenland, ie., Davis Strait and Baffin's Bay.

[3] This total of 62 differs slightly from the separate figures east and west of Greenland in the above mentioned source.

Table 9

Comparison of whaling from Hull and the Netherlands[1]

	Whale oil supplied by the fleet of Hull		Number of tuns of blubber per ship		Number of tuns of blubber per whale	
Year	English tuns[2]	Dutch quarters	Hull[3]	Netherlands	Hull	Netherlands
1772	391	1,919.8	142.2	197.1	—	32.8
1773	265	1,301.2	96.4	141.3	—	42.5
1774	466	2,288.1	169.5	130.7	—	36.9
1775	668	333.9	18.5	29.9	—	38.4
1776	275	1,350.3	90.0	120.7	—	29.1
1777	339	1,664.5	123.3	120.5	—	33.7
1778	171	839.6	70.0	68.8	—	24.6
1779	232	1,139.1	189.9	64.5	—	39.9
1780	309	1,517.2	252.9	147.3	—	27.1
1781	263	1,291.3	286.9	—	—	—
1782	217	1,065.5	236.8	—	—	—
1783	290	1,423.9	237.3	118.0	—	20.1
1784	392	1,924.7	142.6	84.2	—	31.4
1785	722	3,545.0	157.5	121.8	—	24.1
1786	856	4,203.0	140.1	164.7	—	24.9
1787	1,132	5,558.1	123.5	109.8	—	31.2
1788	956	4,694.0	130.4	55.8	—	20.5
1789	854	4,193.1	96.4	122.2	—	16.2
1790	832	4,085.1	113.5	49.6	—	28.6
1791	345	1,694.0	53.8	50.9	—	39.8
1792	896	4,399.4	154.3	72.0	—	21.6
1793	835	4,100.0	151.9	77.3	—	34.3
1794	709	3,481.2	136.5	69.5	—	40.5
1795	1,148	5,636.7	268.4	—	—	—.
1796	1,678	8,239.0	305.1	118.1	—	22.2
1797	1,741	8,548.3	259.1	99.5	—	24.4
1798	2,162	10,615.4	307.7	7.3	—	25.0
1799	2,234	10,968.9	261.1	—	—	—
1800	1,818	8,926.4	258.7	—	—	—
1801	2,149	10,551.6	281.4	—	—	—
1802	2,955	14,509.1	284.5	64.4	—	16.4
1803	2,332	11,450.1	186.2	21.0	—	16.2
1804	4,018	19,728.4	305.9	—	—	—
1805	5,175	25,409.3	423.5	—	—	—
1806	3,528	17,322.5	274.9	—	—	—
1807	4,485	22,021.4	396.8	—	—	—
1808	4,465	21,923.2	456.7	—	—	—
1809	4,322	21,221.0	487.9	—	—	—
1810	5,009	24,594.2	482.3	—	—	—
1811	5,398	26,504.2	410.9	—	—	—
1812	6,502	31,924.8	425.7	—	—	—
1813	3,500	17,185.0	208.3	—	—	—
1814	7,326	35,970.7	413.5	—	34.4	—
1815	3,746	18,392.9	211.4	—	42.1	—
1816	5,155	25,311.1	306.8	40.0	36.4	20.0
1817	4,711	23,131.0	265.9	—	46.3	—
1818	6,199	30,437.1	317.1	—	41.5	—
1819	5,183	25,488.5	261.0	60.0	46.0	30.0
1820	8,086	39,702.3	426.9	—	53.0	—
1821	5,888	28,910.1	315.9	90.0	38.7	15.0
1822	3,112	15,279.9	254.7	110.0	44.7	55.0
1823	5,490	26,955.9	438.3	103.5	28.3	18.8
1824	3,500	17,185.0	318.3	—	41.7	—
1825	2,873	14,106.4	261.2	—	42.9	—
1826	2,674	13,129.3	273.5	—	50.9	—
1827	4,579	22,482.9	499.6	—	40.5	—
1828	*5,297*	*26,008.3*	*577.9*	—	39.6	—
1829	3,976	19,522.2	394.4	—	38.7	—
1830	1,271	6,240.6	126.1	—	48.9	—
1831	1,797	8,823.3	183.8	—	35.0	—
1832	4,503	22,109.7	491.3	—	27.3	—
1833	5,024	24,667.8	609.1	—	27.9	—

[1] Source of Hull data: Sheppard and Suddaby (1906).

[2] An English tun is 4.92 Dutch quarters (quarteelen). Scoresby (1820, vol. 2, p. 91, note 3) calculates that one English tun is 252 imperial gallons, equal to 252 × 4.545 liters = 1,145.34 liters. One quarter is 232.8 liters, so one English tun is 4.92 quarters. Scoresby's quotation on p. 94, note 2, loc. cit., that one Dutch quarter is 60.27 imperial gallons equal to 274 liters is too high.

[3] Calculated as $\frac{3}{8}$ of the average number of quarters of whale oil brought in per ship of Hull.

Table 10

Comparison of German and Dutch Arctic whaling: ships, whales and blubber[1]

A. Number of ships sailed and ships lost by nature or enemies

Decade	Ships sailed: Germany	Ships sailed: Netherlands	Ships lost: Germany	Ships lost: Netherlands
1661–69	?	970	?	19
1670–79	561	985	19	80
1680–89	553	1,922	26	114
1690–99	492	944	36	79
1700–09	544	1,631	44	61
1710–19	573	1,435	15	55
1720–29	427	2,239	17	57
1730–39	401	1,847	10	34
1740–49	222	1,712	3	28
1750–59	215	1,677	9	36
1760–69	273	1,620	3	26
1770–79	302	1,289	10	37
1780–89	376	541	6	5
1790–99	?	360	?	31
1800–09	?	26	?	4

B. Number of whales caught and tuns of blubber supplied

Decade	Whales caught: Germany	Whales caught: Netherlands	Tuns of blubber: Germany	Tuns of blubber: Netherlands
1661–69	?	4,815.25	?	231,565
1670–79	3,747.50	6,325.29	186,084	275,304
1680–89	2,376.75	9,529.01	101,295	370,190
1690–99	1,129.50	5,474.40	48,569[2]	209,982
1700–09	2,343.50	7,982.06	81,164	279,439
1710–19	1,431.00	4,822.15	52,175	176,274
1720–29	1,077.90	4,762.84	44,719	207,427
1730–39	544.60	4,386.26	25,792	216,834
1740–49	563.50	8,011.01	24,598	256,851
1750–59	503.25	5,336.07	16,573	160,909
1760–69	589.50	4,500.24	21,862	144,501
1770–79	889.80	3,878.66	43,584	129,776
1780–89	1,306.75	2,697.75	46,805	63,779
1790–99	?	792.83	?	22,849
1800–09	?	76.00	?	1,241

[1] The source of the figures of German whaling is Annexure A3, p. 111, in Lindeman (1869). The figures refer to the German ports of Bremen, Hamburg, Altona and Glückstadt. Lindeman's data are presumably liable to corrections and one of his figures has been revised as indicated by a note. Lindeman's figures of Dutch whaling are inexact and therefore not used.

[2] Corrected figure.

Table 11

Comparison of German and Dutch Arctic whaling: oil and production figures[1]

A. Number of quarters of whale oil produced and of tuns of blubber cut per whale

Decade	Quarters of whale oil: Germany	Quarters of whale oil: Netherlands	Tuns of blubber cut per whale: Germany	Tuns of blubber cut per whale: Netherlands
1661–69	?	347,348	?	48.1
1670–79	279,126	412,956	49.7	43.5
1680–89	151,943	555,285	42.6	38.8
1690–99	72,854[2]	314,973	43.0[2]	38.4
1700–09	121,746	419,159	34.6	35.0
1710–19	78,263	264,411	36.5	36.6
1720–29	67,079	311,141	41.5	43.6
1730–39	38,688	325,251	47.4	49.4
1740–49	36,897	385,277	43.7	32.1
1750–59	24,860	241,364	32.9	30.2
1760–69	32,793	216,752	37.1	32.1
1770–79	65,376	194,664	49.0	33.5
1780–89	70,208	95,669	35.8	23.6
1790–99	?	34,274	?	28.8
1800–09	?	1,862	?	16.3

B. Number of whales per ship and tuns of blubber per ship

Decade	Whales per ship sailed: Germany	Whales per ship sailed: Netherlands	Tuns of blubber per ship sailed: Germany	Tuns of blubber per ship sailed: Netherlands
1661–69	?	5.0	?	238.7
1670–79	6.7	6.4	331.7	279.5
1680–89	4.3	5.0	183.2	192.6
1690–99	2.3	5.8	98.7[2]	222.4
1700–09	4.3	4.9	149.2	171.3
1710–19	2.5	3.4	91.1	122.8
1720–29	2.5	2.1	104.7	92.6
1730–39	1.4	2.4	64.3	117.4
1740–49	2.5	4.7	110.8	150.0
1750–59	2.3	3.2	77.1	96.0
1760–69	2.2	2.8	80.1	89.2
1770–79	1.8	2.2	86.8	100.7
1780–89	3.5	5.0	104.5	117.9
1790–99	?	2.2	?	63.5
1800–09	?	2.9	?	47.7

[1] The source of the figures of German whaling is Annexure A3, p. 111, in Lindeman (1869).

[2] Corrected figure.

Greenland, because the average number does not take into account:

(1) the blubber obtained by barter from the Greenlanders in Davis Strait;
(2) the catch of seals and walruses; and
(3) the blubber cut from whales which were not Greenland whales (bowheads).

This means that the difference in size between the Greenland whales flensed east and west of Greenland respectively, as derived from the number of tuns of blubber flensed per whale, is less than appears from Table 6, especially during the years 1719–40 when barter trade in Davis Strait was important. When this trade was reduced to decreasing significance after 1740, whaleships continued to take goods with them for occasional barter (then termed smuggling with the Greenlanders). The blubber which whaleships obtained in this way is not registered separately from the blubber flensed from whales by the Dutch and it remains an unknown component in the statistics of whaling in Davis Strait.

Mr P. Dekker in the Netherlands has drawn attention to the necessity of making the stated subtractions under (1), (2) and (3) from the number of tuns of blubber brought from Davis Strait. Though the catch of seals, walruses and whales other than Greenland whales was occasionally important, the figures for this catch give the impression that in many years it was of minor importance and less substantial than the blubber obtained by barter in Davis Strait. Dekker has published an improved version of Table 6 in Mededelingen, December 1978 (see references).

Table 8 shows figures for whaling from one of the leading British whaling ports, ie. Hull in 1772–1833, from a little known source. Table 9 compares the results of whaling from Hull and from the Netherlands. Basis of the comparison is the number of tuns of blubber per ship sailed. Until *circa* 1790 the results do not show superiority of one nation over the other. This relation changed thoroughly after 1790. From that year the Hull whalers achieved better results in most years than before

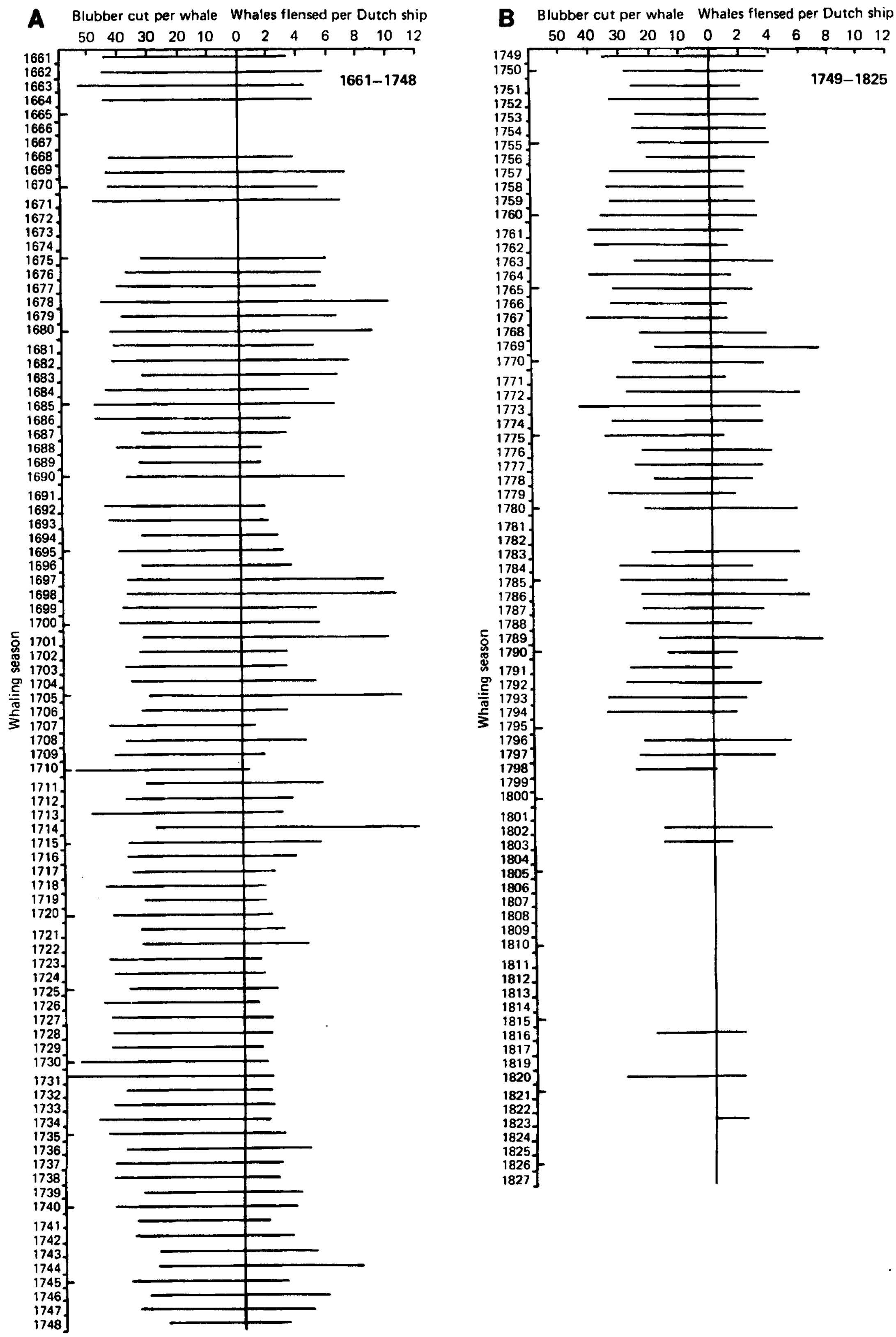

Fig. 1. Comparison of the number of Greenland whales flensed per ship with the number of tuns of blubber cut per whale, 1661–1825.

1790 and passed the Dutch. The change in the relation reflects the new development ushered in by British whaling after 1790. The decline of whale stocks I and II is not yet evident from the Hull figures.

Tables 10 and 11 compare German and Dutch Arctic whaling results in a condensed form. The German figures are borrowed from Lindeman (1869). Apparently the Dutch had a slight superiority over the Germans in the relevant period 1669–1789 in number of whales per ship of tuns of blubber per ship. So far annual and more detailed figures for old German whaling have not been published.

Fig. 1 compares the number of whales flensed per ship with the number of tuns of blubber cut per whale. We may assume that over periods of several decades the number of tuns of blubber per whale is a measure of the size and age of the animal, because over long periods feast and famine in food which determine the number of tuns cancel out. If this is true, there seems to be a correlation between the two series of figures portrayed, in which the larger is the number of whales per ship, the smaller is the number of tuns of blubber per whale. The correlation seems to be greater for the eighteenth century than for the seventeenth when whales were more abundant. Obviously when whales were scarce whalers caught more of the smaller-sized animals.

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Appendix 1

STATISTICAL TABLES AS ORIGINAL SOURCES

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Appendix 2

STATISTICS OF WHALING FROM HAMBURG

The main source for statistics of the Arctic whale-fishery of Hamburg is the unpublished manuscript compiled by Gottlieb Henrich Friederick Grube (see Appendix 1 for citation of original source material). Grube is mentioned on the first page. The manuscript has been written by two persons in succession – the first using German, the second Dutch. This work is in the State Archive of the Hansa town of Hamburg. It was probably used by Moritz Lindeman (1869) and certainly by Ludwig Brinner (1913) who mentions Grube's work as an anonymous unpublished source. It is not mentioned by Wanda Oesau (1955).

Grube's work contains data for the years 1669–1801, namely annual ships' lists, names of commandeurs and their individual catches, dates of their returns and annual figures of whale and seal catches by ships of Hamburg and from 1780 also Altona, Glückstadt, Vogesak and Bremen. The annual figures comprise numbers of whale-ships, whaling and sealing ships, ships lost, whales flensed, whales in lost ships, tuns of whale blubber and seal blubber flensed, quarters of oil processed in the home country from whale and seal blubber, seal skins and pounds of baleen (whalebone). Several of these series cover only part of the period 1669–1801. In the course of the eighteenth century an increasing number of ships practiced both whaling and sealing, initially specialized and separated crafts, and the distinction between the two kinds of hunters became blurred. Consequently figures for whale catches and seal catches were mixed up in the neatly written tables. They have to be regrouped and resummarized.

The annexed Tables 1A to 6A are based on Grube's manuscript, and concern Hamburg only.

Table 1A

Whale-fishery of Hamburg, East of Greenland

Year	Ships sailed	Whales flensed	Tuns of blubber cut	Quarters of whale-oil tryed-out[1]
1669[2]	37	260	14,602	21,903
1670	40	155½	8,642	12,963
1671	40	351	16,837	25,256
1672	47	516½	23,365	35,048
1673	53	589½	29,128	43,692
1674	74	520⅚	30,135	45,203
1675	83	484⅔	25,706	38,559
1676	53	103½	4,833	7,250
1677	72	295⅚	14,685	22,028
1678	55	513½	20,827	31,241
1679	44	217⅚	11,906	17,859
1680	49	470	19,128	28,692
1681	51	280⅔	10,193½	15,290
1682	51	414½	18,577½	27,866
1683	54	307½	10,859½	16,289
1684	57	227½	11,383	17,075
1685	56	335½	14,857	22,286
1686	54	126½	6,840½	10,261
1687	54	135	5,696	8,544
1688	54	41	1,855	2,783
1689	43	38¼	1,860	2,790
1690	35	180½	8,752	13,128
1691	43	20	919	1,379
1692	33	105	5,000	7,500
1693	52	83½	3,873	5,810
1694	54	75½	4,221	6,332
1695	45	51⅚	2,732	4,098
1696	52	135½	6,295	9,443
1697	57	515	18,344	27,516
1698	54	471½	20,041	30,062
1699	52	111	5,057	7,586
1700	53	189½	8,341	12,512
1701	54	544½	21,952	32,928
1702	57	109⅚	4,141	6,212
1703	54	102	5,266	7,899
1704	8	33	1,298	1,947
1705	32	175	6,511	9,767
1706	34	33	1,500	2,250
1707	25	35½	1,470	2,205
1708	21	39½	1,810	2,715
1709	23	71	2,682	4,023
1710	32	8	427	641
1711	27	152½	4,352	6,528

[1] Estimates based on the relation that one tun of whale-blubber yields on the average 1.5 quarters of whale-oil. The weight of one tun of whale-blubber is between 700 and 800 Dutch and English pounds. The contents of one quarter are 12 steekan, each 16 mingles, and are equal to 232.8 litres. One English tun of whale-oil is 4.92 quarters. Scoresby (1820, Vol. 2, p. 91, Note 3) states that one English tun equals 252 imperial gallons, that is 252 × 4.545 litres = 1,145.34 litres. One quarter is 232.8 litres, so one English tun is 4.92 quarters.

[2] From 1669 to 1718 only whaling east of Greenland was recorded, but whaling west of Greenland in Davis Strait probably started some years before 1719, the first year in which whaling in Davis Strait was recorded.

Table 1A (*continued*)

Year	Ships sailed	Whales flensed	Tuns of blubber cut	Quarters of whale-oil tryed-out[1]
1712	19	41	1,821	2,732
1713	18	27	1,465	2,198
1714	32	205	5,809	8,714
1715	39	125	5,247	7,871
1716	41	79½	3,306	4,959
1717	47	60	2,854	4,281
1718	40	41½	2,044	3,066

Table 2A

Number of Whaling Ships of Hamburg

	East of Greenland				
Year	Whaleships	Whaling and sealing ships	Total	West of Greenland	Grand total
1719	41	—	41	4	45
1720	44	1	45	5	50
1721	40	—	40	14	54
1722	52	—	52	6	58
1723	59	—	59	4	63
1724	57	—	57	2	59
1725	45	—	45	7	52
1726	41	—	41	9	50
1727	27	—	27	17	44
1728	24	—	24	8	32
1729	24	—	24	6	30
1730	23	—	23	8	31
1731	20	—	20	9	29
1732	13	—	13	12	25
1733	25	—	25	6	31
1734	23	—	23	3	26
1735	19	—	19	—	19
1736	21	3	24	1	25
1737	22	—	22	1	23
1738	22	—	22	—	22
1739	20	—	20	—	20
1740	19	—	19	—	19
1741	18	—	18	1	19
1742	17	1	18	—	18
1743	18	—	18	—	18
1744	19	—	19	—	19
1745	22	—	22	—	22
1746	21	—	21	—	21
1747	19	—	19	—	19
1748	22	—	22	—	22
1749	19	2	21	4	25
1750	17	1	18	4	22
1751	16	1	17	5	22
1752	14	—	14	5	19
1753	16	—	16	3	19
1754	19	—	19	1	20
1755	19	1	20	—	20
1756	20	—	20	—	20
1757	21	1	22	—	22
1758	19	—	19	—	19
1759	15	1	16	2	18
1760	15	—	15	3	18
1761	17	3	20	3	23
1762	16	1	17	3	20
1763	17	2	19	2	21
1764	19	—	19	2	21
1765	20	2	22	3	25
1766	22	3	25	4	29
1767	24	4	28	3	31
1768	25	5	30	3	33
1769	27	17	44	4	48
1770	19	14	33	4	37
1771	29	14	43	1	44
1772	20	—	20	2	22
1773	20	—	20	2	22
1774	24	14	38	3	41
1775	17	5	22	3	25
1776	34	3	37	3	40
1777	31	12	43	3	46
1778	13	16	29	3	32
1779	11	13	24	2	26
1780	12	5	17	1	18
1781	11	7	18	1	19
1782	10	8	18	1	19
1783	11	8	19	1	20
1784	11	7	18	—	18
1785	14	7	21	—	21
1786	11	5	16	—	16
1787	11	12	23	—	23
1788	13	13	26	—	26
1789	10	13	23	—	23
1790	8	24	32	—	32
1791	9	26	35	—	35
1792	6	29	35	—	35
1793	16	17	33	—	33
1794	12	14	26	—	26
1795	4	16	20	—	20
1796	3	16	19	—	19
1797	3	11	14	—	14
1798	8	10	18	—	18
1799	5	13	18	—	18
1800	2	14	16	—	16
1801	10	7	17	—	17

Table 3A

Number of whales flensed by Hamburg ships

	East of Greenland				
Year	Whaleships	Whaling and sealing ships	Total	West of Greenland	Grand total
1719	32	—	32	1	33
1720	50½	2	52½	7½	60
1721	135½	—	135½	7¼	142¾
1722	155¾	—	155¾	10½	166¼
1723	15½	—	15½	5	20½
1724	31¼	—	31¼	6	37¼
1725	47	—	47	24	71
1726	15½	—	15½	8	23½
1727	35½	—	35½	12	47½
1728	21	—	21	12	33
1729	26	—	26	5	31
1730	2	—	2	8	10
1731	8	—	8	5	13
1732	15⅚	—	15⅚	8½	24⅓
1733	22	—	22	1	23
1734	19	—	19	1	20
1735	28	—	28	—	28
1736	68	2	70	1	71
1737	44½	—	44½	—	44½
1738	27	—	27	—	27
1739	77	—	77	—	77
1740	50	—	50	—	50
1741	13	—	13	1	14
1742	32½	½	33	—	33
1743	66½	—	66½	—	66½
1744	93	—	93	—	93
1745	33½	1	34½	—	34½
1746	87	—	87	—	87

Table 3A (*continued*)

	East of Greenland				
Year	Whaleships	Whaling and sealing ships	Total	West of Greenland	Grand total
1747	67	—	67	—	67
1748	50⅚	—	50⅚	—	50⅚
1749	38⅙	1	39⅙	15½	55⅔
1750	26	1	27	2½	29½
1751	42⅔	1	43⅔	5	48⅔
1752	49¾	—	49¾	8½	58¼
1753	54	—	54	3	57
1754	61½	—	61½	1	62½
1755	60	1	61	—	61
1756	49½	—	49½	—	49½
1757	51	1	52	—	52
1758	28½	—	28½	—	28½
1759	19	1	20	2	22
1760	28½	—	28½	10	38½
1761	25	2	27	7	34
1762	21	1	22	4	26
1763	79¾	1½	81¼	8	89¼
1764	29	—	29	1	30
1765	50	1	51	11	62
1766	17⅔	3	20⅔	—	20⅔
1767	9½	4	13½	3	16½
1768	30½	23	53½	9	62½
1769	195½	28	223½	6½	230
1770	41	30	71	6	77
1771	44	25	69	—	69
1772	70½	—	70½	12	82½
1773	30½	—	30½	9	39½
1774	86	12½	98½	5	103½
1775	18	4	22	1	23
1776	142½	8	150½	7	157½
1777	54½	17	71½	5	76½
1778	28½	42	70½	1	71½
1779	8½	15	23½	—	23½
1780	69½	19	88½	2	90½
1781	84	55	139	1	140
1782	105	71½	176½	3	179½
1783	58½	45½	104	—	104
1784	21	17	38	—	38
1785	47	26½	73½	—	73½
1786	82	21	103	—	103
1787	33	42½	75½	—	75½
1788	22½	19	41½	—	41½
1789	53	77½	130½	—	130½
1790	10½	19½	30	—	30
1791	5½	12	17½	—	17½
1792	21	83¼	104¼	—	104¼
1793	25½	15	40½	—	40½
1794	21	12	33	—	33
1795	30	91	121	—	121
1796	27	72½	99½	—	99½
1797	56½	59½	116	—	116
1798	102	57½	159½	—	159½
1799	4	36	40	—	40
1800	1	21	22	—	22
1801	46	16	62	—	62

Table 4A

Number of tuns of whale-blubber flensed by Hamburg ships

	East of Greenland				
Year	Whaleships	Whaling and sealing ships	Total	West of Greenland	Grand total
1719	1,380	—	1,380	50	1,430
1720	2,394	46	2,440	348	2,788
1721	5,410	—	5,410	438	5,848
1722	6,023	—	6,023	548	6,571
1723	865	—	865	270	1,135
1724	1,448	—	1,448	393	1,841
1725	1,874	—	1,874	1,420	3,294
1726	678	—	678	564	1,242
1727	1,605	—	1,605	690	2,295
1728	1,135	—	1,135	759	1,894
1729	1,373	—	1,373	359	1,732
1730	122	—	122	391	513
1731	430	—	430	208	638
1732	748	—	748	482	1,230
1733	1,245	—	1,245	55	1,300
1734	1,032	—	1,032	57	1,089
1735	1,380	—	1,380	—	1,380
1736	2,971	(100)[1]	3,071	50	3,121
1737	2,126	—	2,126	—	2,126
1738	1,361	—	1,361	—	1,361
1739	2,705	—	2,705	—	2,705
1740	2,035	—	2,035	—	2,035
1741	570	—	570	70	640
1742	1,697	(25)	1,722	—	1,722
1743	2,502	—	2,502	—	2,502
1744	3,791	—	3,791	—	3,791
1745	2,039	20	2,059	—	2,059
1746	3,380	—	3,380	—	3,380
1747	3,373	—	3,373	—	3,373
1748	1,103½	—	1,103½	—	1,103½
1749	1,816	92½	1,908½	827	2,735½
1750	1,197	(50)	1,247	116	1,363
1751	1,418	15	1,433	344	1,777
1752	2,275	—	2,275	340	2,615
1753	1,952	—	1,952	177	2,129
1754	2,115	—	2,115	—	2,115
1755	2,185½	48	2,233½	—	2,233½
1756	1,538½	—	1,538½	—	1,538½
1757	2,259	40	2,299	—	2,299
1758	1,415½	—	1,145½	—	1,145½
1759	832½	20	852½	93½	945½
1760	1,553	—	1,553	634	2,187
1761	1,461½	(100)	1,561½	390½	1,952
1762	1,052	(50)	1,102	222	1,324
1763[2]	(1,982)	(50)	(2,032)	556	(2,588)
1764	(985)	46	(1,031)	—	(1,031)
1765	(1,447)	—	(1,447)	—	(1,447)
1766	(391)	75	(466)	—	(466)
1767	(382)	—	(382)	—	(382)
1768	(1,475)	—	(1,475)	—	(1,475)
1769	(3,633)	—	(3,633)	—	(3,633)
1770	(1,211)	—	(1,211)	—	(1,211)
1771	(962)	—	(962)		(962)
1772	(2,285)	—	(2,285)	—	(2,285)
1773	(1,035)	—	(1,035)	—	(1,035)
1774	(1,927)	—	(1,927)	220	(2,147)
1775	619	(200)	(819)	50	(869)
1776	3,576	(400)	(3,976)	300	(4,276)
1777	1,201	(850)	(2,051)	245	(2,296)
1778	545	(2,100)	(2,645)	60	(2,705)
1779	367	(750)	(1,117)	0	(1,117)

[1] Figures between parentheses indicate estimates by C. de Jong and are necessary for years for which figures of tuns of blubber are lacking and have to be derived from figures of quarters of whale-oil supplied by Grube (see Appendix 1).

[2] For an indefinite series of years in the 18th century before 1763 it is uncertain whether the compiler means by 'Quardeelen' (quarters) either whale and seal blubber or oil cooked from this blubber. Previously he states quarters of blubber explicitly, from 1763 he states quarters by oil, from 1775 he states both quarters of blubber and quarters of oil.

Table 4A (*continued*)

Year	East of Greenland: Whaleships	East of Greenland: Whaling and sealing ships	East of Greenland: Total	West of Greenland	Grand total
1780	1,213	(950)	(2,163)	100	(2,263)
1781	1,914	(1,375)	(3,289)	40	(3,329)
1782	1,435	(1,788)	(3,223)	130	(3,353)
1783	1,065	826	1,891	0	1,891
1784	570	545	1,115	—	1,115
1785	860	446	1,306	—	1,306
1786	1,508	434	1,942	—	1,942
1787	716	1,019	1,735	—	1,735
1788	490	453	943	—	943
1789	1,045	1,148	2,193	—	2,193
1790	287	540	827	—	827
1791	193	449	642	—	642
1792	530	1,771	2,301	—	2,301
1793	765	1,059	1,824	—	1,824
1794	814	452	1,266	—	1,266
1795	570	1,416	1,986	—	1,986
1796	590	1,333	1,923	—	1,923
1797	1,009	919	1,928	—	1,928
1798	1,510	657	2,167	—	2,167
1799	129	940	1,069	—	1,069
1800	31	628	659	—	659
1801	725	309	1,034	—	1,034

Table 5A

Number of tuns of blubber cut per whale on Hamburg ships East of Greenland, 1669–1718[1]

Year	Tuns of blubber per whale	Year	Tuns of blubber per whale
1669	56.2	1694	55.9
		1695	52.8
1670	55.6	1696	46.1
1671	48.0	1697	35.6
1672	48.0	1698	42.5
1673	49.4	1699	45.6
1674	57.9		
1675	53.0	1700	44.0
1676	46.8	1701	40.3
1677	49.6	1702	37.7
1678	40.6	1703	51.6
1679	54.7	1704	39.3
		1705	37.2
1680	39.9	1706	45.5
1681	36.3	1707	41.4
1682	44.8	1708	45.8
1683	35.3	1709	37.8
1684	50.0		
1685	44.3	1710	53.4
1686	54.1	1711	28.5
1687	42.2	1712	44.4
1688	45.2	1713	54.3
1689	48.0	1714	28.3
		1715	42.0
1690	48.6	1716	41.6
1691	46.0	1717	47.6
1692	47.6	1718	59.2
1693	47.6		

[1] From 1669 to 1718 only whaling east of Greenland was recorded, but whaling west of Greenland in Davis Strait probably started some years before 1719, the first year in which whaling in Davis Strait was recorded. The whales flensed west of Greenland were on the average much bigger than those east of Greenland. This difference possibly explains the unprecedentedly high figure for 1718, when whaling in Davis Strait probably was of importance to Hamburg.

Table 6A

Number of tuns of blubber cut per whale on Hamburg ships

Year	East of Greenland: Whale-ships	East of Greenland: Whaling and sealing ships	West of Greenland Whaleships
1719	43.1	—	50.0
1720	47.4	23.0	46.4
1721	39.9	—	58.4
1722	38.7	—	52.2
1723	56.7	—	54.0
1724	47.1	—	65.5
1725	40.2	—	59.2
1726	43.7	—	70.5
1727	45.2	—	57.5
1728	54.0	—	63.3
1729	52.8	—	71.8
1730	40.7	—	48.9
1731	53.8	—	41.6
1732	47.3	—	56.7
1733	56.6	—	55.0
1734	54.3	—	57.0
1735	49.3	—	—
1736	43.7	—	50.0
1737	47.8	—	—
1738	50.4	—	—
1739	35.1	—	—
1740	40.7	—	—
1741	43.8	—	—
1742	52.2	—	—
1743	37.6	—	—
1744	40.8	—	—
1745	60.9	20.0	—
1746	38.9	—	—
1747	50.3	—	—
1748	35.8	—	—
1749	47.6	93.5(?)	53.4
1750	46.0	—	46.4
1751	33.2	15.0	68.8
1752	45.7	—	40.0
1753	36.1	—	59.0
1754	34.4	—	—
1755	53.1	48.0	—
1756	31.1	—	—
1757	44.3	40.0	—
1758	49.7	—	—
1759	43.8	20.0	46.8
1760	54.5	—	63.4
1761	58.5	—	23.2
1762	50.1	—	55.5
1763	(24.8)[1]	—	69.5
1764	(34.0)	46.0	—
1765	(28.9)	—	—
1766	(22.1)	25.0	0
1767	(40.2)	—	(39.7)
1768	(48.4)	—	(41.0)
1769	(18.6)	—	(48.8)
1770	(29.5)	—	(39.0)
1771	(21.9)	—	—
1772	(32.4)	—	(39.2)
1773	(33.9)	—	(28.7)
1774	(22.4)	—	(44.0)
1775	34.4	—	50.0
1776	25.1	—	42.9
1777	22.0	—	49.0
1778	19.1	—	60.0
1779	43.1	—	—
1780	17.5	—	50.0
1781	22.8	—	40.0

[1] Figures between parentheses indicate estimates by C. de Jong, necessary for years for which figures of tuns of blubber are lacking and have to be derived from figures of quarters of whale-oil supplied by Grube (see Appendix 1).

Table 6A (*continued*)

	East of Greenland		West of Greenland
Year	Whaleships	Whaling and sealing ships	Whaleships
1782	13.7	—	43.3
1783	18.2	18.2	0
1784	27.1	32.1	—
1785	18.3	16.8	—
1786	19.5	20.7	—
1787	21.7	24.0	—
1788	22.0	23.8	—
1789	19.7	14.8	
1790	27.3	27.7	—
1791	35.1	37.4	—
1792	25.2	21.3	—
1793	30.0	29.3	—
1794	38.8	37.7	—
1795	19.0	15.6	—
1796	21.9	18.4	—
1797	17.9	15.4	—
1798	14.8	11.4	—
1799	32.3	26.1	—
1800	31.0	29.9	—
1801	15.8	19.3	—

SC/32/PS16

The Historical Status and Reduction of the Western Arctic Bowhead Whale (*Balaena mysticetus*) Population by the Pelagic Whaling Industry, 1848–1914

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ABSTRACT

From 1848, when the western Arctic whaling grounds were discovered, to 1914, when the whaling industry had collapsed, the bowhead whales of the Bering, Chukchi, and Beaufort Seas were systematically hunted by whaling vessels of several nations. This report attempts to determine the impact of the pelagic whaling industry upon the western Arctic bowhead whale. Data have been drawn from the logbooks and journals of the whaling industry representing 19% of all known whaling cruises made to those waters during the period. From these records we estimate that 18,650 whales were killed and 16,600 were taken by the pelagic whaling industry, an average of about 280 whales killed and 250 whales taken per year. DeLury estimates of the bowhead whale population for 1847 (the year before the beginning of exploitation by the whaling industry) suggest that the population numbered approximately 30,000, and was no less than 20,000 and no more than 40,000. The population appears to have been depleted rapidly: one-third of the total number of kills during the entire period of commercial whaling occurred in the first decade, and two-thirds of them in the first two decades. The ships' records also suggest that the species was rapidly eliminated from major parts of its range.

INTRODUCTION

Today the bowhead whale (*Balaena mysticetus*) population of the Bering, Chukchi, and Beaufort Seas (the western Arctic population) is at the center of a controversy about the effect of the Alaskan Eskimo hunt on its numbers (see Bockstoce, 1980). Although many observers believe the population was greatly reduced by pelagic whaling and has not recovered significantly from the low level at which it probably stood in 1915, hitherto no thorough attempt has been made to estimate the number of bowheads that existed prior to the commencement of commercial hunting or to determine the impact that the pelagic industry had on the population. This report presents the results of the first comprehensive and systematic attempt to answer these questions and is based on the best available data: the daily entries in the logbooks and journals of the whaling industry.

Although a few bowheads may have been taken between 1843 and 1847, these whales were not deliberately sought in the Bering Sea until 1848. In that year Captain Thomas Roys sailed into seas unknown to whalemen and discovered the great whaling grounds near Bering Strait where the bowheads, oil-rich, baleen-laden, and docile, were found in numbers. Roys quickly filled his ship and returned to Honolulu to broadcast his success. Word of these new whaling grounds spread quickly, and in the following year more than forty vessels sailed north and enjoyed equally successful cruises. In succeeding years the news of the 1849 season increasingly lured other vessels, and in 1852 more than 200 whaleships operated in the Bering Strait region.

The whalers quickly established a routine that they would vary only slightly for the next sixty years. Leaving New England in the autumn and rounding Cape Horn in the southern summer, they outfitted at Hawaiian ports or San Francisco, sailing for the Arctic in late March to reach the pack ice of the central Bering Sea a month later. Informal accounts suggest that they took a few whales as they worked their way north toward Bering Strait through the melting floes, but by early June most of the whales had passed them and gone deep into the safety of the ice on the migration to their summer feeding grounds in the Arctic Ocean. As the fishery progressed into its second decade the whalemen generally would not see their quarry again until late July when the ice allowed the ships to approach the north coast of Alaska and intersect the whales traveling from the Beaufort Sea to their autumn feeding grounds near Herald Island in the Chukchi Sea. The ships often cruised near Herald Island until the violent weather and encroaching ice of early October drove them back to ports in the Pacific Ocean.

The whalemen usually repeated these summer voyages once or twice more before returning to their home ports. Some alternated their summer hunts among cruises to the Arctic, the Okhotsk Sea, or the Gulf of Alaska, depending on where the best catches were being made; nevertheless, they rarely visited more than one of these areas per year.

The intensity of the hunting in the early years of the fishery quickly reduced the bowhead population (and it is possible that the whales themselves responded to the threat by fleeing the hunting areas), for the catches of 1853 and 1854 were poor enough in comparison with previous years that the fleet virtually abandoned the Bering Strait region in 1855, 1856, and 1857, and turned its attention to the bowheads of the Okhotsk Sea. It too was soon overhunted, and the whalemen returned to Bering Strait in 1858 to cruise there regularly for the following half century.

In the spring, once the ships reached 54° N, or, in the later years of the fishery, 57° or 58° N, the whalemen began to watch for bowheads; for the next five or six months they generally kept themselves in constant readiness to lower their boats. When they saw whales, if the seas were not too rough or the ice too dense, four or five boats usually went after them. If the men were lucky, a boat got close enough to strike a whale with a harpoon. The whale would then run, towing the line and boat after it, eventually becoming sufficiently exhausted so that it

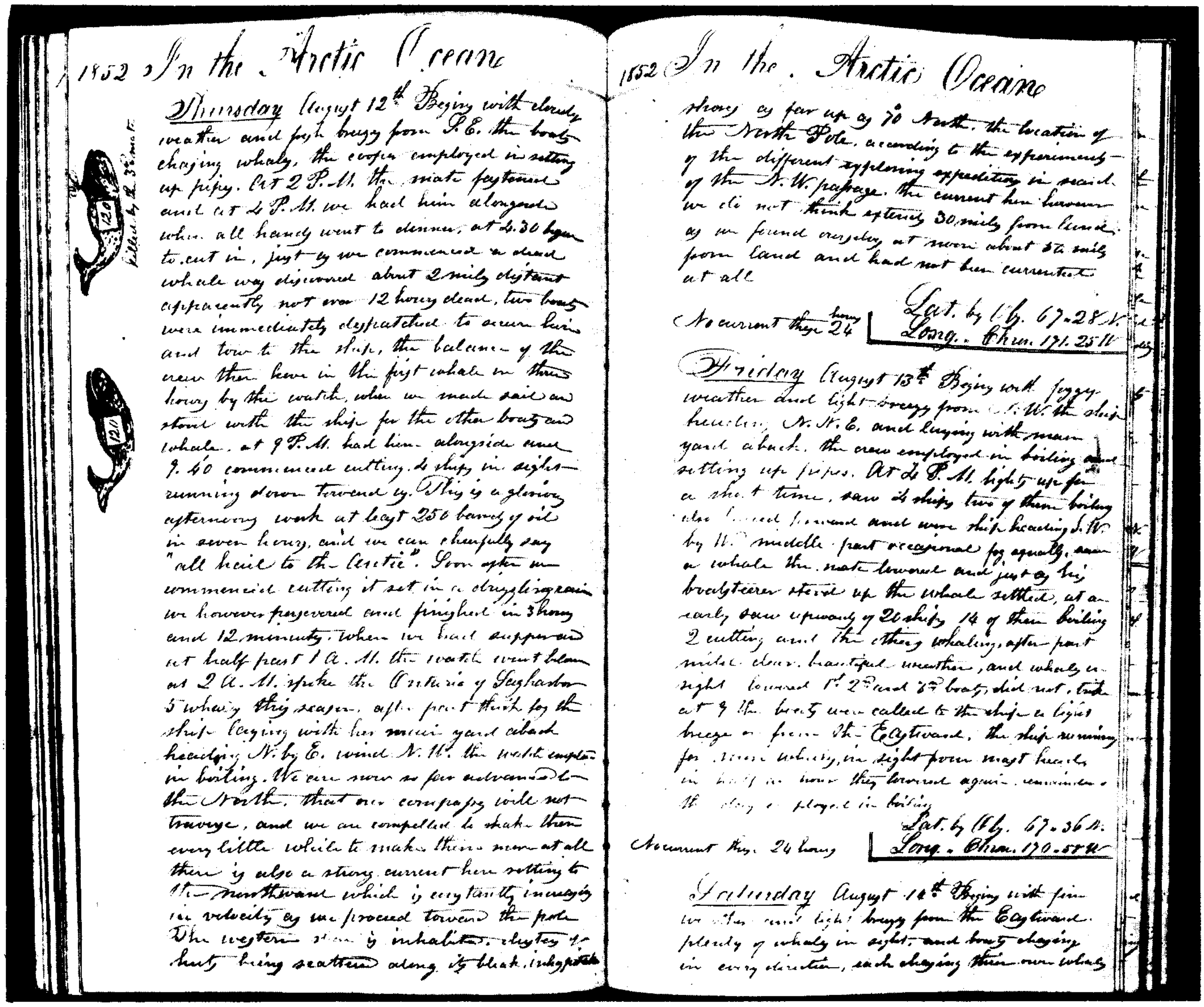


Fig. 1. Entries in journal of *Montreal*'s 1852 cruise (courtesy of the New Bedford Whaling Museum).

could be killed with a lance. But frequently whales escaped into the ice, towing lines and gear. In response to these losses the whalemen, after 1860, increasingly used darting guns (which were fixed to the harpoon shaft and fired a small bomb into the whale at the moment of striking) and shoulder guns (heavy brass smooth bores that fired a similar bomb from a distance and thus generally replaced the lance).

Once the whale was dead, or if a dead whale was found, the carcass was towed to the ship, where the crew took the baleen aboard and stripped off and 'tryed out' (rendered into oil) the blubber. As a rough average, a moderate-sized bowhead yielded 100 barrels of oil (a barrel was 31½ US gallons) and 1,500 pounds of baleen.

Information of this sort was recorded daily (Fig. 1) by the whalemen in their logbooks and journals (a logbook was an official ship's record; a journal, a private document). Usually recorded was information on the ship's position, wind velocity and direction, sea state, visibility, and ice cover. Similarly, if whales were encountered, the whalemen usually noted the species, number seen, and whether the boats chased, struck and lost, captured or found dead a whale. If the whale was processed, its oil and baleen yield were often recorded as well.

By 1866 the hunting pressure had put the bowhead population in steep decline, and to offset poor catches the whalemen began taking walrus (*Odobenus rosmarus*) and gray whales (*Eschrichtius robustus*) in the 'middle season' between their spring and autumn encounters with bowheads. A decline in oil prices soon ended this; by 1880 oil prices were so low that profits could only be made by taking baleen, the great flexible plates that hang from a bowhead's upper jaw and are used to filter food from the water. As the price of oil sank, forced down by petroleum products, the price of baleen began to rise dramatically, driven by the call of the fashion industry for, among its other uses, 'whalebone' corset stays and skirt hoops (Fig. 2).

In 1880 the western Arctic remained the major profitable whaling ground for the American fleet, and the rising price of baleen stimulated the development of steam-auxiliary whaling vessels. These immediately proved successful in pursuing the whales to the least accessible corners of the Arctic Ocean. In 1889 steamers reached the bowheads' summer feeding grounds off the MacKenzie River delta in Canada's Northwest Territories, and from then until 1914 the focus of the industry was concentrated largely on those waters. Changes in fashion and the introduction of flexible spring steel as a

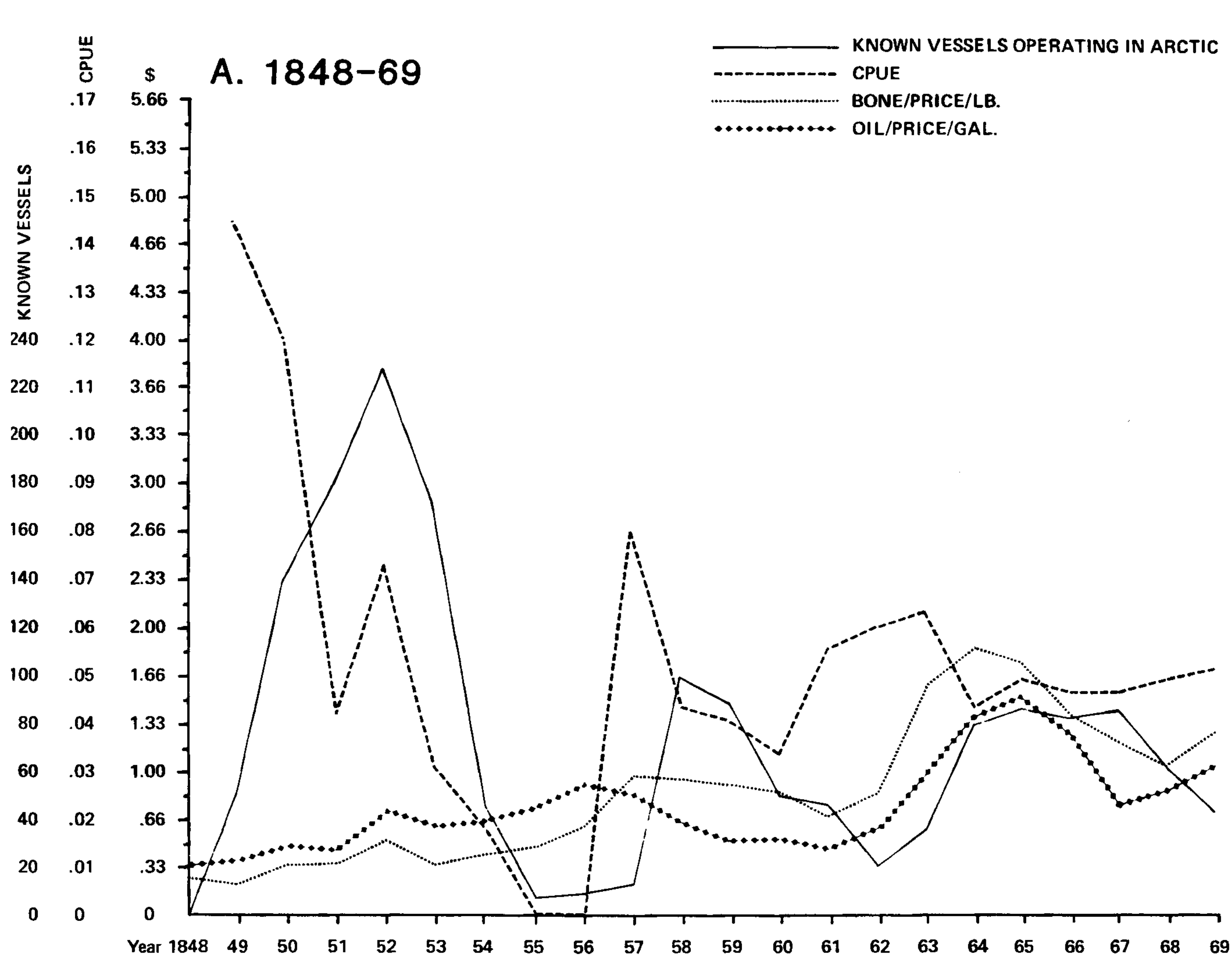


Fig. 2. Yearly variation in vessel numbers, catch per unit effort (CPUE) and product prices.

cheap substitute for baleen caused the market to collapse in 1908, dragging the industry with it. After 1914, although a few vessels cleared port as whaleships, they were in fact primarily on fur trading and freighting voyages, and only a few whales were taken by ships thereafter.

RESOURCES AND METHODS

Although the fundamental resource for this investigation was the information in the daily entries in whaling logbooks and journals, it was necessary to carry out several preliminary procedures before the extraction of the data could begin.

First, we had to identify all vessels that hunted bowheads in the Bering, Chukchi and Beaufort Seas to determine, among other things, both the size of the fleet in each year, and, of course, the names of those vessels for which logbooks or journals might have survived. The basic source for this phase of the study was the *Whalemen's Shipping List and Merchants' Transcript* (Fig. 3). Published in New Bedford from 1843 to 1914, it contains the most comprehensive documentation of the American whaling industry; its weekly issues posted the latest information on all American whaling vessels throughout the world. The *Shipping List* was of particular use to this project because whaling vessels usually touched at a major port to refit, to take on fresh provisions, and to report their cargoes immediately before and after their half-year Arctic cruise; thus, their Arctic catch can usually be determined (expressed in barrels of oil and pounds of baleen) by subtracting the cumulative cargo listed in the spring from that listed in the autumn. Once in the Arctic, ships passing one another frequently reported their 'season's catch' (usually expressed in the number of whales they had taken); this information, carried by ships leaving the Arctic, would also find its way to the pages of the *Shipping List*.

To organize these data we constructed a ledger sheet (Fig. 4) listing the following information from left to right: column 1, the vessel's name, rig, captain, and home port; columns 2 through 4, successive seasonal reports; column 5, the post-season report; column 6, the pre-season report. This information was gathered for each year and subdivided by home port.

The data from the *Shipping List* were augmented and corrected by adding information from other newspapers (principally from Honolulu's *Friend* and the *Pacific Commercial Advertiser* and several San Francisco papers) as well as from scattered data in more than 500 printed books, magazine articles, manuscripts, and government documents. This body of data was then spot-checked for accuracy against information compiled in the 19th century by Dennis Wood, a New Bedford insurance broker. These resources allowed us to expand our purview beyond the American whaling industry to

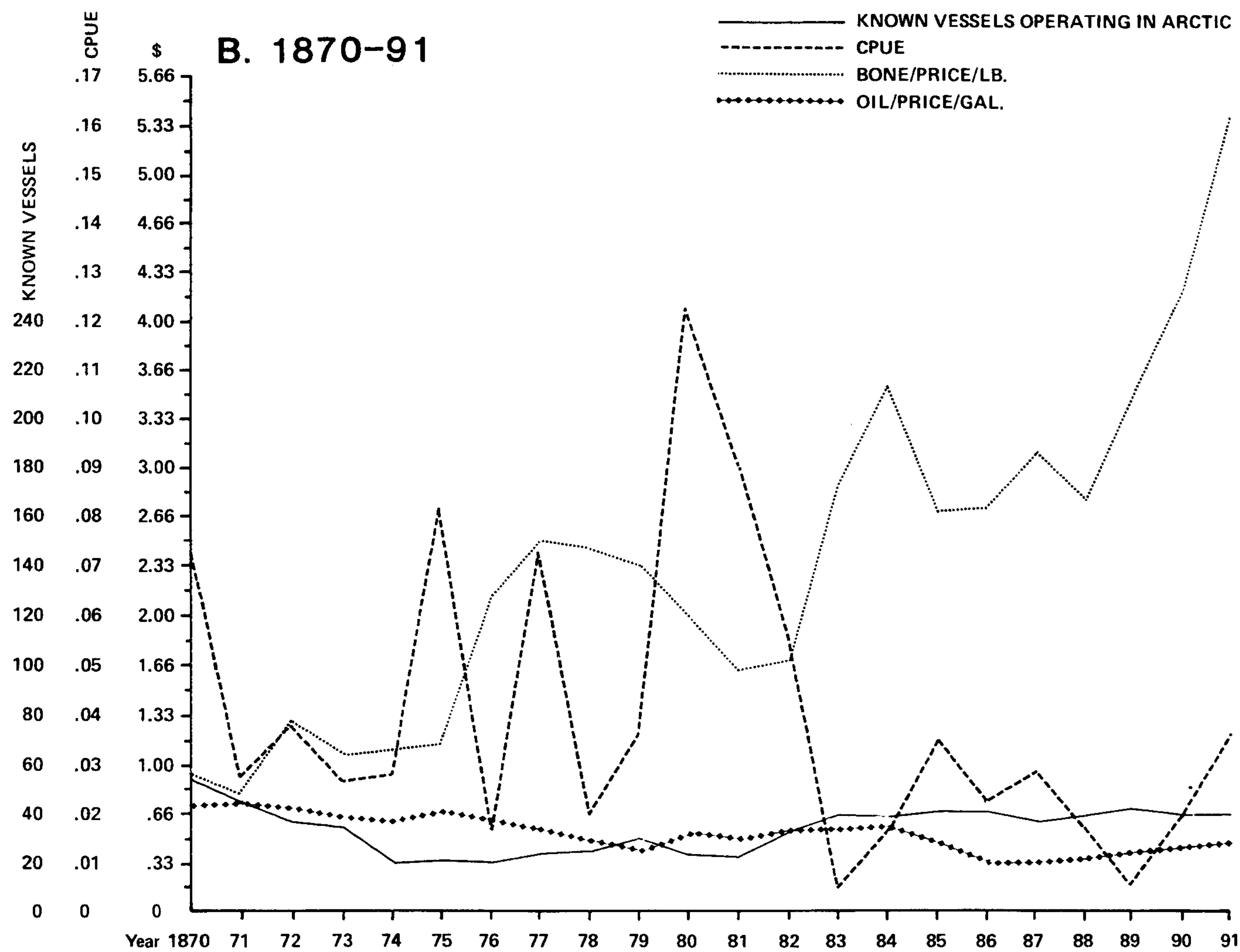


Fig. 2 (*cont.*)

include vessels of the other nations operating in the western Arctic: Hawaii, Germany, France, and Great Britain (Australia).

Later, as we carried out the data extraction, reports in the logbooks and journals of other ships seen on the whaling grounds were checked against the tables and inserted if the information was important. In all, more than 25,000 reports were processed, giving us a record of more than 2,700 annual cruises. Significantly, as the extraction phase wore on, fewer and fewer unreported ships were found to add to our list; in fact the decline was so remarkable that during the extraction of data from the last hundred or so documents no previously unreported vessels were identified. Thus we believe that, if our list of whaling vessels operating in the western Arctic is not now complete, we have certainly identified more than 99% of them.

A note should be made about the sources that we intentionally did not consult. A number of compendia of data about whaling voyages exist, but an examination of each revealed serious deficiencies for our needs. Although Hegarty's (1959) and Starbuck's (1964) important works were based on the information in the *Shipping List*, these authors included only the cumulative results of the entire whaling voyage and hence are of little value for determining the annual bowhead catch; furthermore there are some omissions and errors in each. Townsend (1935) devoted a section of his report to the bowhead whales of the North Pacific, but he segregated them neither geographically nor chronologically; consequently bowheads from the Okhotsk Sea and the western Arctic are listed together under the total number taken on an entire whaling voyage, not for each season. In addition, a spot-check of his data has revealed that occasionally gray whales and right whales were counted as bowheads and that some bowhead captures were overlooked. Although Clark (1887) listed seasonal reports for voyages to the western Arctic from 1868 to 1884, he omitted some vessels known to have operated there and included others that did not; his figures for each vessel's seasonal products frequently included walrus oil, gray whale oil, right whale oil and baleen, or bowhead baleen that was obtained in trade from the natives. Estimates of the bowhead kill that are based on these sources should be treated with skepticism.

Once our list of whaling vessels was well underway, we were able to turn to the published check-lists of the approximately 4,000 whaling logbooks and journals that are held in public collections in the United States, Canada and Australia. (A survey of whaling manuscripts held in other countries revealed no documents useful for our purposes.) Among those we found records for nearly 800 seasonal Arctic cruises; nevertheless it is regrettable that less than 550 were suitable, that is, containing a complete record for the entire seasonal cruise and being sufficiently legible and detailed for our needs. Of those that were

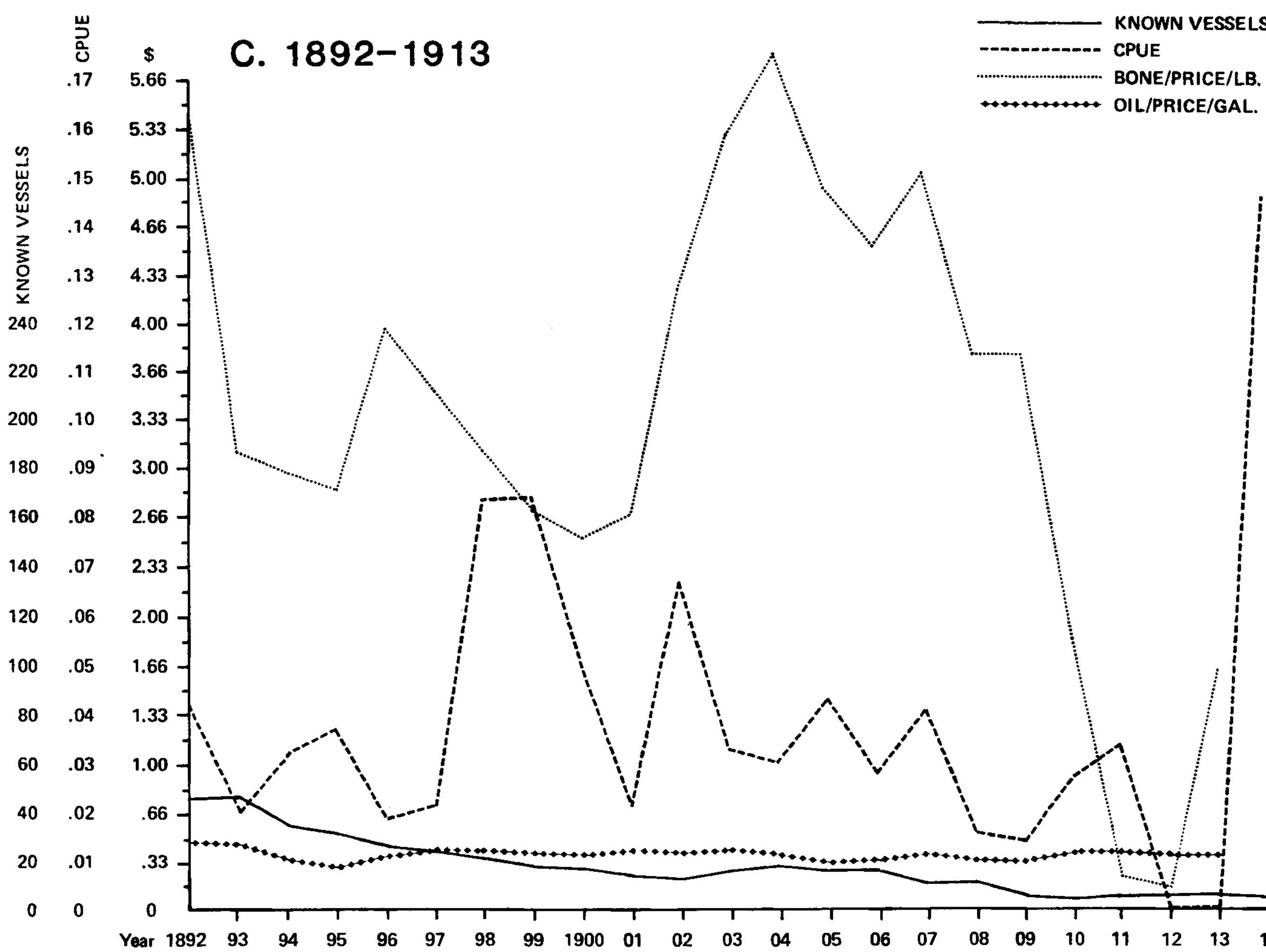


Fig. 2 (*cont.*)

acceptable we were pleasantly surprised to find that they were spread relatively evenly throughout the duration of the fishery, representing about 20% of the voyages to the western Arctic in each year.

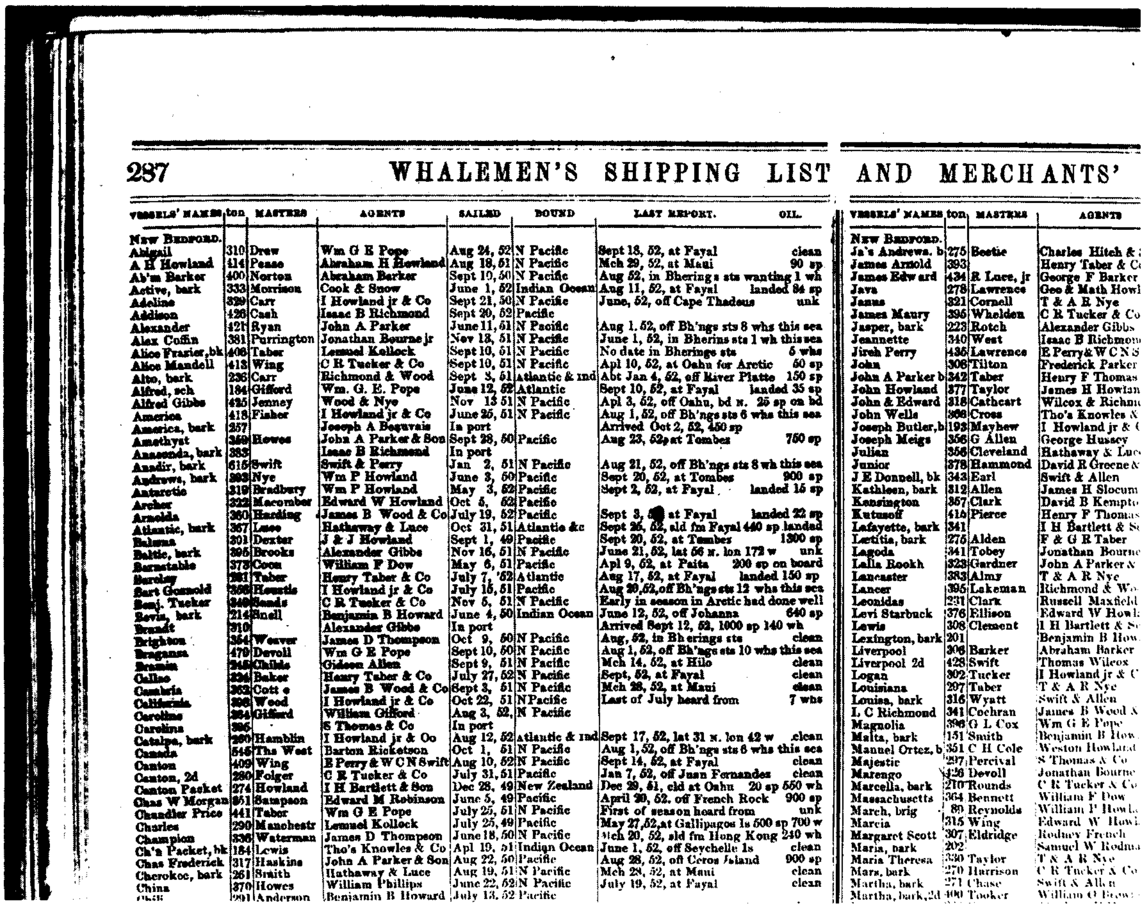
While the work mentioned above was going on we were also at work designing a useful format for the data extraction. Our aim was to extract and store as much information from the documents as possible (bearing in mind the constraints of budget and time) not only including information on the bowhead but also on other fauna that might affect the hunting effort. Fig. 5 gives our format for the 80-line data sheet and computer card.

A team of six spent 36 person-months extracting and encoding more than 66,000 daily observations from documents representing 516 seasonal cruises, which are equal to 19% of the total number of whaling cruises conducted in the western Arctic. For one of the years, 1867, documents from an exceptionally large percentage of the cruises have survived, and we were able to extract data for 28 (33.7%) of the 83 vessels operating in the western Arctic that year.

Because of the necessity of having a large body of reference works and supporting documents available during the actual extraction of data, virtually all of this phase of the project was carried out in the New Bedford Whaling Museum, using either the logbooks and journals directly or microfilm copies of documents held in repositories outside the New Bedford area. To aid speed and accuracy the extractors sat before $1:1 \times 10^6$-scale aeronautical charts of the area (Fig. 6) which, conveniently, were hachured at each minute of latitude (one nautical mile) and at one- or five-minute intervals of longitude. Also provided were hydrographic charts (for depth and bottom composition information), ice charts, current charts, and American, Canadian and British compendia of sailing directions.

These research aids allowed us to overcome a number of problems in data interpretation that arose from the nature of the documents. Principal among these was the practice among whalemen, once within sight of land, to change from recording their daily positions in degrees and minutes of latitude and longitude to their distance and direction from a visible geographical feature. Thus if, for instance, a position was recorded as '20 miles southwest of King Island', it was a comparatively simple matter, upon consulting the aeronautical charts, to convert this information to 64° 44′ N, 168° 34′ W.

A related problem arose when whalers used obsolete or obscure geographical terminology. Because the landforms of the western Arctic had only been rudimentarily charted when the whalers arrived there (in a few cases the whalers were the discoverers), they quickly developed their own nomenclature for the geographical features of the area or adopted or adapted nomenclature from Russian or British charts. The official committees for geographical names in the United States, Canada, and the Soviet Union have not accepted many of these names for standard usage and others have been substantially



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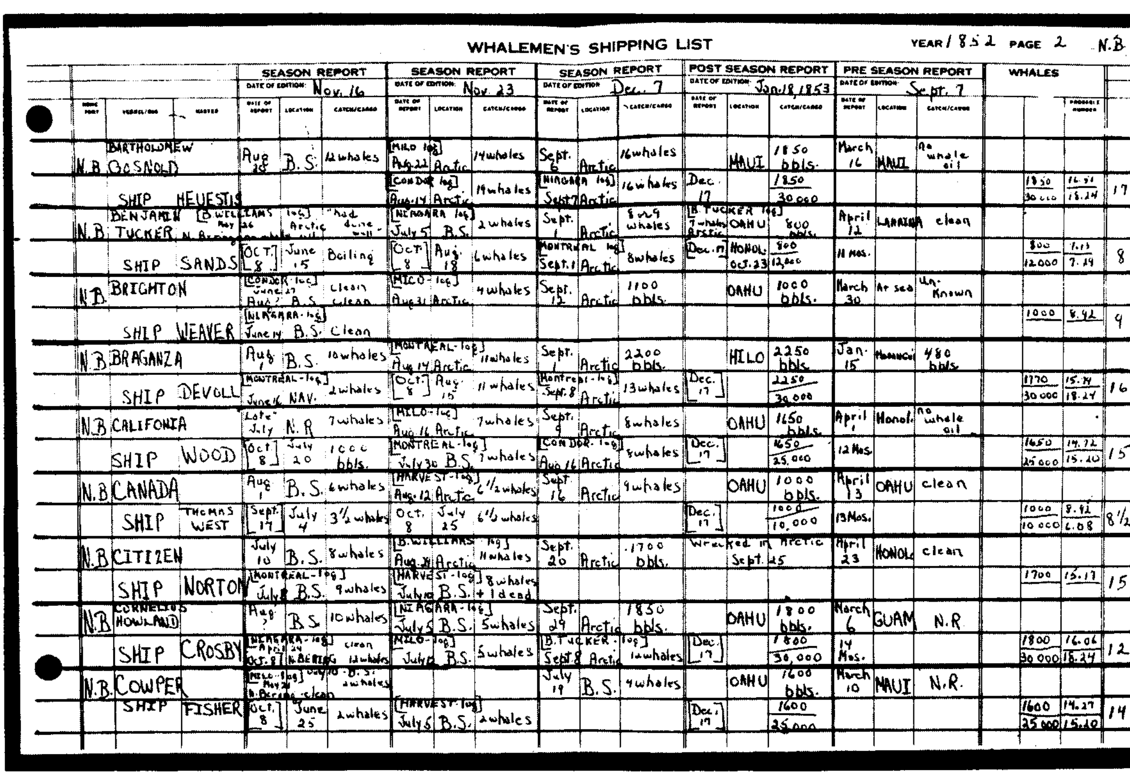
VESSELS' NAMES	ton	MASTERS	AGENTS	SAILED	BOUND	LAST REPORT.	OIL.
NEW BEDFORD.							
Abigail	310	Drew	Wm G E Pope	Aug 24, 52	N Pacific	Sept 18, 52, at Fayal	clean
A H Howland	414	Pease	Abraham H Howland	Aug 18, 51	N Pacific	Mch 29, 52, at Maui	90 sp
Ab'm Barker	400	Norton	Abraham Barker	Sept 10, 50	N Pacific	Aug 52, in Bherings sts wanting 1 wh	
Active, bark	333	Morrison	Cook & Snow	June 1, 52	Indian Ocean	Aug 11, 52, at Fayal	landed 84 sp
Adeline	329	Carr	I Howland jr & Co	Sept 21, 50	N Pacific	June, 52, off Cape Thadeus	unk
Addison	426	Cash	Isaac B Richmond	Sept 20, 52	Pacific		
Alexander	421	Ryan	John A Parker	June 11, 51	N Pacific	Aug 1. 52, off Bh'ngs sts 8 whs this sea	
Alex Coffin	381	Purrington	Jonathan Bourne jr	Nov 13, 51	N Pacific	June 1, 52, in Bherins sts 1 wh this sea	
Alice Frazier, bk	408	Taber	Lemuel Kollock	Sept 10, 51	N Pacific	No date in Bheringe sts	5 whs
Alice Mandell	413	Wing	C R Tucker & Co	Sept 10, 51	N Pacific	Apl 10, 52, at Oahu for Arctic	60 sp
Alto, bark	236	Carr	Richmond & Wood	Sept 3, 51	Atlantic & Ind	Abt Jan 4, 52, off River Platte	150 sp
Alfred, sch	184	Gifford	Wm. G. E. Pope	June 12, 52	Atlantic	Sept 10, 52, at Fayal	landed 35 sp
Alfred Gibbs	425	Jenney	Wood & Nye	Nov 13 51	N Pacific	Apl 3, 52, off Oahu, bd N.	25 sp on bd
America	418	Fisher	I Howland jr & Co	June 25, 51	N Pacific	Aug 1, 52, off Bh'ngs sts 6 whs this sea	
America, bark	257		Joseph A Beauvais	In port		Arrived Oct 2, 52, 450 sp	
Amethyst	359	Howes	John A Parker & Son	Sept 28, 50	Pacific	Aug 23, 52, at Tombez	750 sp
Anaconda, bark	383		Isaac B Richmond	In port			
Anadir, bark	615	Swift	Swift & Perry	Jan 2, 51	N Pacific	Aug 21, 52, off Bh'ngs sts 8 wh this sea	
Andrews, bark	393	Nye	Wm P Howland	June 3, 50	Pacific	Sept 20, 52, at Tombez	900 sp
Antarctic	319	Bradbury	Wm P Howland	May 3, 52	Pacific	Sept 2, 52, at Fayal	landed 15 sp
Archer	322	Macomber	Edward W Howland	Oct 5, 52	Pacific		
Arnolda	360	Harding	James B Wood & Co	July 19, 52	Pacific	Sept 3, 52, at Fayal	landed 22 sp
Atlantic, bark	367	Luce	Hathaway & Luce	Oct 31, 51	Atlantic &c	Sept 26, 52, sld fm Fayal 440 sp landed	
Balaena	301	Dexter	J & J Howland	Sept 1, 49	Pacific	Sept 20, 52, at Tumbez	1300 sp
Baltic, bark	395	Brooks	Alexander Gibbs	Nov 16, 51	N Pacific	June 21, 52, lat 56 N. lon 172 W	unk
Barnstable	373	Coon	William F Dow	May 6, 51	Pacific	Apl 9, 52, at Paita	200 sp on board
Barclay	281	Taber	Henry Taber & Co	July 7, '52	Atlantic	Aug 17, 52, at Fayal	landed 150 sp
Bart Gosnold	358	Heustis	I Howland jr & Co	July 15, 51	Pacific	Aug 20, 52, off Bh'ngs sts 12 whs this sea	
Benj. Tucker	349	Sands	C R Tucker & Co	Nov 5, 51	N Pacific	Early in season in Arctic had done well	
Bevis, bark	214	Snell	Benjamin B Howard	June 4, 50	Indian Ocean	June 12, 52, off Johanna	640 sp
Brandt	310		Alexander Gibbs	In port		Arrived Sept 12, 52, 1000 sp 140 wh	
Brighton	354	Weaver	James D Thompson	Oct 9, 50	N Pacific	Aug, 52, in Bherings sts	clean
Braganza	479	Devoll	Wm G E Pope	Sept 10, 50	N Pacific	Aug 1, 52, off Bh'ngs sts 10 whs this sea	
Bramin	345	Childs	Gideon Allen	Sept 9, 51	N Pacific	Mch 14, 52, at Hilo	clean
Callao	324	Baker	Henry Taber & Co	July 27, 52	N Pacific	Sept, 52, at Fayal	clean
Cambria	362	Cott e	James B Wood & Co	Sept 3, 51	N Pacific	Mch 28, 52, at Maui	clean
California	398	Wood	I Howland jr & Co	Oct 22, 51	N Pacific	Last of July heard from	7 whs
Caroline	384	Gifford	William Gifford	Aug 3, 52,	N Pacific		
Carolina	386		S Thomas & Co	In port			
Catalpa, bark	260	Hamblin	I Howland jr & Co	Aug 12, 52	Atlantic & Ind	Sept 17, 52, lat 31 N. lon 42 W	clean
Canada	545	Tho West	Barton Ricketson	Oct 1, 51	N Pacific	Aug 1, 52, off Bh'ngs sts 6 whs this sea	
Canton	409	Wing	E Perry & W C N Swift	Aug 10, 52	N Pacific	Sept 14, 52, at Fayal	clean
Canton, 2d	280	Folger	C R Tucker & Co	July 31, 51	Pacific	Jan 7, 52, off Juan Fernandez	clean
Canton Packet	274	Howland	I H Bartlett & Son	Dec 28, 49	New Zealand	Dec 29, 51, cld at Oahu	20 sp 550 wh
Chas W Morgan	351	Sampson	Edward M Robinson	June 5, 49	Pacific	April 20, 52. off French Rock	900 sp
Chandler Price	441	Taber	Wm G E Pope	July 25, 51	N Pacific	First of season heard from	unk
Charles	290	Manchestr	Lemuel Kollock	July 25, 49	Pacific	May 27, 52, at Gallipagos Is 500 sp 700 w	
Champion	336	Waterman	James D Thompson	June 18, 50	N Pacific	Mch 20, 52, sld fm Hong Kong 240 wh	
Ch'n Packet, bk	184	Lewis	Tho's Knowles & Co	Apl 19, 51	Indian Ocean	June 1, 52, off Seychelle Is	clean
Chas Frederick	317	Haskins	John A Parker & Son	Aug 22, 50	Pacific	Aug 28, 52, off Ceros Island	900 sp
Cherokee, bark	261	Smith	Hathaway & Luce	Aug 19, 51	N Pacific	Mch 28, 52, at Maui	clean
China	370	Howes	William Phillips	June 22, 52	N Pacific	July 19, 52, at Fayal	clean
[illegible]	291	Anderson	Benjamin B Howard	July 13, 52	Pacific		

VESSELS' NAMES	ton	MASTERS	AGENTS
NEW BEDFORD.			
Ja's Andrews, b	275	Beetle	Charles Hitch & [illegible]
James Arnold	393		Henry Taber & C[illegible]
James Edward	434	R Luce, jr	George F Barker
Java	278	Lawrence	Geo & Math Howl[illegible]
Janus	321	Cornell	T & A R Nye
James Maury	395	Whelden	C R Tucker & Co
Jasper, bark	223	Rotch	Alexander Gibbs
Jeannette	340	West	Isaac B Richmon[illegible]
Jireh Perry	435	Lawrence	E Perry & W C N S[illegible]
John	306	Tilton	Frederick Parker
John A Parker b	342	Taber	Henry F Thomas
John Howland	377	Taylor	James H Howlan[illegible]
John & Edward	318	Cathcart	Wilcox & Richm[illegible]
John Wells	368	Cross	Tho's Knowles & [illegible]
Joseph Butler, b	193	Mayhew	I Howland jr & [illegible]
Joseph Meigs	356	G Allen	George Hussey
Julian	356	Cleveland	Hathaway & Luc[illegible]
Junior	378	Hammond	David R Greene & [illegible]
J E Donnell, bk	343	Earl	Swift & Allen
Kathleen, bark	312	Allen	James H Slocum
Kensington	357	Clark	David B Kempto[illegible]
Kutusoff	416	Pierce	Henry F Thomas
Lafayette, bark	341		I H Bartlett & S[illegible]
Lætitia, bark	275	Alden	F & G R Taber
Lagoda	341	Tobey	Jonathan Bourne
Lalla Rookh	323	Gardner	John A Parker & [illegible]
Lancaster	383	Almy	T & A R Nye
Lancer	395	Lakeman	Richmond & W[illegible]
Leonidas	231	Clark	Russell Maxfield
Levi Starbuck	376	Ellison	Edward W Howl[illegible]
Lewis	308	Clement	I H Bartlett & S[illegible]
Lexington, bark	201		Benjamin B How[illegible]
Liverpool	306	Barker	Abraham Barker
Liverpool 2d	428	Swift	Thomas Wilcox
Logan	302	Tucker	I Howland jr & C[illegible]
Louisiana	297	Taber	T & A R Nye
Louisa, bark	316	Wyatt	Swift & Allen
L C Richmond	341	Cochran	James B Wood & [illegible]
Magnolia	396	G L Cox	Wm G E Pope
Malta, bark	151	Smith	Benjamin B How[illegible]
Manuel Ortez, b	351	C H Cole	Weston Howland
Majestic	297	Percival	S Thomas & Co
Marengo	426	Devoll	Jonathan Bourne
Marcella, bark	210	Rounds	C R Tucker & Co
Massachusetts	364	Bennett	William F Dow
March, brig	89	Reynolds	William P Howl[illegible]
Marcia	315	Wing	Edward W Howl[illegible]
Margaret Scott	307	Eldridge	Rodney French
Maria, bark	202		Samuel W Rodma[illegible]
Maria Theresa	330	Taylor	T & A R Nye
Mars, bark	270	Harrison	C R Tucker & Co
Martha, bark	271	Chase	Swift & Allen
Martha, bark, 2d	400	Tooker	William O Brow[illegible]

Fig. 3. A page from the *Whalemen's Shipping List and Merchant's Transcript* (courtesy of the New Bedford Whaling Museum).



WHALEMEN'S SHIPPING LIST YEAR 1852 PAGE 2 N.B

HOME PORT	VESSEL/RIG	MASTER	SEASON REPORT, Date of edition: Nov. 16 — Date of report	Location	Catch/cargo	SEASON REPORT, Date of edition: Nov. 23 — Date of report	Location	Catch/cargo	SEASON REPORT, Date of edition: Dec. 7 — Date of report	Location	Catch/cargo	POST SEASON REPORT, Date of edition: Jan. 18, 1853 — Date of report	Location	Catch/cargo	PRE SEASON REPORT, Date of edition: Sept. 7 — Date of report	Location	Catch/cargo	WHALES		Probable number
N.B	BARTHOLOMEW GOSNOLD		Aug 28	B.S.	12 whales	[HILO log] Aug. 22	Arctic	14 whales	Sept. 6	Arctic	16 whales		MAUI	1850 bbls.	March 16	MAUI	no whale oil			
	SHIP	HEUESTIS				[CONDOR log] Aug. 14	Arctic	14 whales	[NIAGARA log] Sept 7	Arctic	16 whales	Dec. 17		1850 / 30,000				1850 / 30,000	16.91 / 15.24	17
N.B	BENJAMIN TUCKER		[B. WILLIAMS log] May 26	Arctic	"had done well"	[NIAGARA log] July 5	B.S.	2 whales	Sept. 1	Arctic	8 or 9 whales	[B. TUCKER log] 7 whales Arctic	OAHU	800 bbls.	April 12	LAHAINA	clean			
	SHIP	SANDS	[Oct. 8]	June 15	Boiling	[Oct. 8]	Aug. 18	6 whales	[MONTREAL log] Sept. 1	Arctic	8 whales	[Dec. 17]	HONOL. Oct. 23	800 / 12,000	11 Mos.			800 / 12,000	7.13 / 7.19	8
N.B	BRIGHTON		[CONDOR log] June 27 / Aug ?	B.S.	clean / clean	[HILO log] Aug. 31	Arctic	4 whales	Sept. 12	Arctic	1100 bbls.		OAHU	1000 bbls.	March 30	At sea	Unknown			
	SHIP	WEAVER	[NIAGARA log] June 14	B.S.	Clean													1000	8.42	9
N.B	BRAGANZA		Aug 1	B.S.	10 whales	[MONTREAL log] Aug. 14	Arctic	11 whales	Sept. 1	Arctic	2200 bbls.		HILO	2250 bbls.	Jan. 15	Honolulu	480 bbls.			
	SHIP	DEVOLL	[MONTREAL log] June 16	NAV.	2 whales	[Oct. 8]	Aug. 15	11 whales	[Montreal log] Sept. 8	Arctic	13 whales	[Dec. 17]		2250 / 30,000				1770 / 30 000	15.74 / 18.24	16
N.B	CALIFONIA		"Late" July	N.R	7 whales	[HILO log] Aug. 16	Arctic	7 whales	Sept. 9	Arctic	8 whales		OAHU	1650 bbls.	April 1	Honol.	no whale oil			
	SHIP	WOOD	[Oct. 8]	July 20	1000 bbls.	[MONTREAL log] July 30	B.S.	7 whales	[CONDOR log] Aug. 16	Arctic	8 whales	[Dec. 17]		1650 / 25,000	12 Mos.			1650 / 25 000	14.72 / 15.10	15
N.B	CANADA		Aug 1	B.S.	6 whales	[HARVEST log] Aug. 12	Arctic	6 1/2 whales	Sept. 16	Arctic	9 whales		OAHU	1000 bbls.	April 13	OAHU	clean			
	SHIP	THOMAS WEST	[Sept. 17]	July 4	3 1/2 whales	Oct. 8	July 25	6 1/2 whales				[Dec. 17]		1000 / 10,000	13 Mos.			1000 / 10 000	8.92 / 6.08	8 1/2
N.B	CITIZEN		July 10	B.S.	8 whales	[B. WILLIAMS log] Aug. 31	Arctic	11 whales	Sept. 20	Arctic	1700 bbls.	Wrecked in Arctic Sept. 25			April 23	HONOL.	clean			
	SHIP	NORTON	[MONTREAL log] July 8	B.S.	9 whales	[HARVEST log] July 10	B.S.	8 whales + 1 dead										1700	15.17	15
N.B	CORNELIUS HOWLAND		Aug ?	B.S.	10 whales	[NIAGARA log] July 5	B.S.	5 whales	Sept. 29	Arctic	1850 bbls.		OAHU	1800 bbls.	March 6	GUAM	N.R			
	SHIP	CROSBY	[NIAGARA log] April 24 / Oct. 8	N. BERING	clean / 12 whales	[HILO log] July 10	B.S.	5 whales	[B. TUCKER log] Sept. 8	Arctic	14 whales	[Dec. 17]		1800 / 30,000	14 Mos.			1800 / 30 000	16.06 / 15.24	12
N.B.	COWPER		[HILO log] May 24 / N. Bering / July 10	B.S.	clean / 2 whales				July 19	B.S.	4 whales		OAHU	1600 bbls.	March 10	MAUI	N.R.			
	SHIP	FISHER	[Oct. 8]	June 25	2 whales	[HARVEST log] July 6	B.S.	2 whales				[Dec. 17]		1600 / 25,000				1600 / 25 000	14.27 / 15.10	14

Fig. 4. Ledger sheet for New Bedford vessels, 1852 (courtesy of the New Bedford Whaling Museum).

changed through translation or transliteration; thus, although they were widely used in the 19th century, they remain obscure today. Consequently, it was necessary to compose a gazetteer of the region's more than 350 obsolete place names for the reference of our data extractors (see, for instance, an abridged version: Bockstoce and Batchelder, 1978).

Line number	Description
1	blank
2–4	document repository number
5–8	document identification number
9–12	vessel identification number
13	sail or auxiliary power vessel
14–17	year of observation
18–19	month of observation
20–21	day of observation
22	latitude: extractor's estimate or logbook data
23–27	latitude
28	longitude: extractor's estimate or logbook data
29–34	longitude
35	wind direction
36	wind velocity
37	visibility in miles
38	ice cover
39–40	fauna seen: none, bowhead, gray whale, humpback, 'whale feed', unspecified, etc.
41–43	number of animals seen
44	sex of animal if taken: male, female, calf, unspecified, etc.
45	type of encounter: seen only, lowered and chased only, struck and lost alive, struck and lost dying, captured and processed, found dead and not processed, etc.
46–48	if processed: barrels of oil yielded
49–52	if processed: pounds of baleen yielded
53–66	second encounter of day: repeat of categories in lines 39–52
67–80	third encounter of day: repeat of categories in lines 39–52

Fig. 5. Data reduction sheet format.

Another difficulty which had to be overcome was the logbook entries that were recorded on days when inclement weather made it impossible for the whalemen to determine their position. If, during periods of fog, snow, gales or overcast skies, they recorded their estimated position, we entered this on our data forms, but often they simply recorded no information on their position. In such cases it was necessary for us to interpolate between previous and succeeding positions, making an educated estimate, tempered by information both from our modern charts and sailing directions and from the logbook's data on wind, sea states, ice conditions and – if they were recorded – on depth, current and bottom characteristics.

Lastly it was occasionally necessary for the data extractors to make subjective judgments from the data when the logbook keeper's remarks were particularly opaque. These judgments were required infrequently and in three categories only: to derive an estimate of visibility; to convert remarks on sea ice into an estimate of its sea coverage; and, when a whale was reported as struck and lost, to judge whether it was moribund (struck and lost dying) or likely to live (struck and lost alive). A struck-and-lost-dying whale was considered to be any whale that had been bombed (struck with a shoulder or darting gun), lanced, or severely wounded by one or more harpoon irons.

As the data extraction progressed, the data sheets were transferred to the Marine Biological Laboratory in Woods Hole, Massachusetts where the information was key-punched onto computer cards, converted to nine-track standard computer tape, and stored on discs (Fig. 7).

ANALYSIS AND RESULTS

Analysis of the data was carried out as follows. First, programs were written to reorder the data originally

Fig. 6. Data extractors at work (courtesy of the New Bedford Whaling Museum).

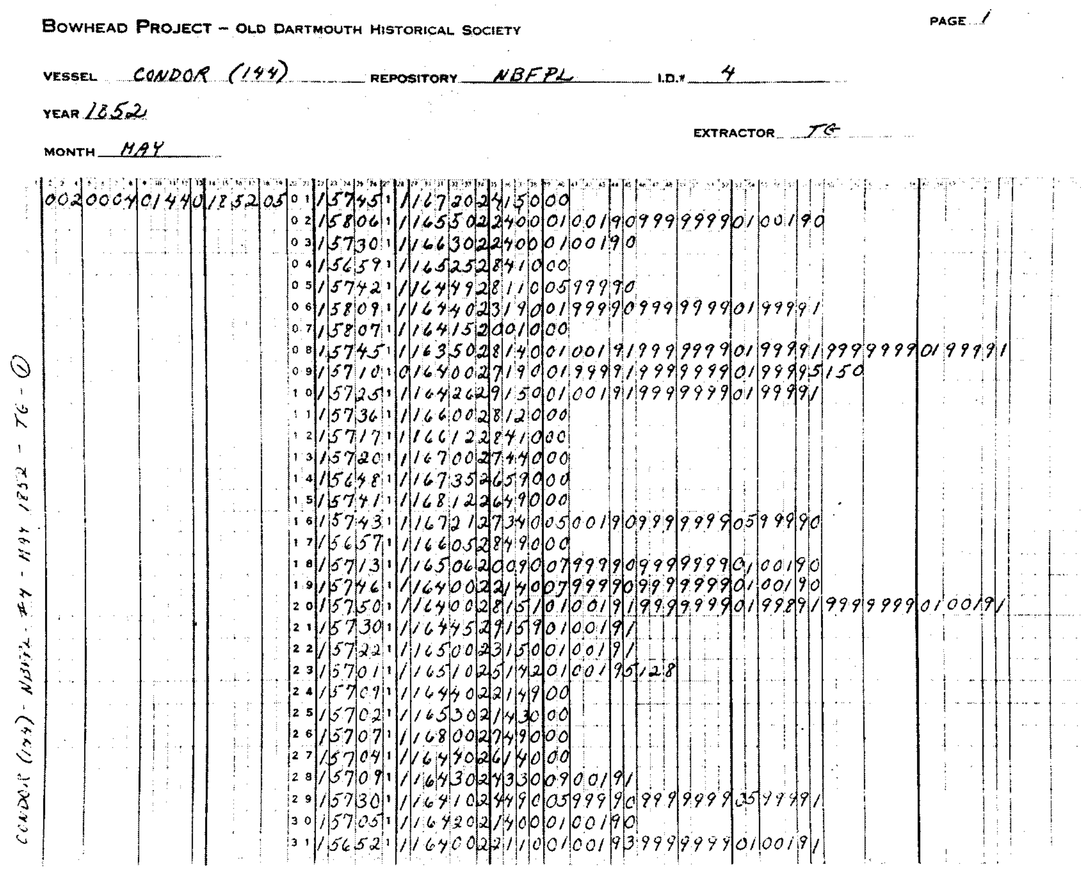


Fig. 7. Sample of data reduction sheet (courtesy of the New Bedford Whaling Museum).

entered onto the computer tapes so that they appeared chronologically. Second, programs were written to provide summaries on an annual or seasonal basis for any information of interest. In September 1979 the data were transferred from the Woods Hole Oceanographic Computer Center to that at the University of California, Santa Barbara. Manipulations of the original data were thenceforth carried out on the Itel AS/6 computer. Summarized data representing annual or seasonal information, were then transcribed onto diskettes and final statistical analyses carried out on an IBM 5110 computer.

Data summaries

Table 1 summarizes the annual whaling activities from 1849 to 1914 (15 whales were taken on the lone voyage in 1848; however, no data on effort were available so this voyage was excluded from our analysis). In the extracted voyages (our data sample), representing approximately 19% of the total voyages, 3,198 whales were caught and 3,573 killed during the entire period. One-third of the total number of whales caught during the entire 66-year period were taken during the first nine years and almost two-thirds during the first 20 years. Even more striking is the observation that one-third of the total number of whales killed were killed during the first six years, and two-thirds during the first 20 years (Fig. 8). These results suggest that the bowhead whale population was rapidly depleted during the first 20 years even though the industry continued to hunt the bowhead in those waters for another 47 years.

Table 2 gives the total catch and kill annually as derived from the logbook records. Annual catches and kills for the entire whaling fleet were calculated by dividing the values in the data sample by the fraction of the voyages those samples represented for that year. From the annual totals we have calculated the weighted cumulative catch and kill. We estimate that during the entire period of commercial pelagic bowhead whaling 16,600 were caught and 18,650 were killed, a figure which accords well with Bockstoce's (1978) preliminary estimate of 19,142 (see also Figs 9 and 10).

Implicit in this analysis is the assumption that the information extracted from logbooks and journals for the 516 cruises that make up our data base is representative of all the cruises to the western Arctic. Although we believe this is a reasonable assumption, a person without an intimate knowledge of these historical documents may believe that their use could lead to bias in our catch and kill estimates. One might suggest, for example, that the logbooks that have survived over this long period of time are a preferred type of record, perhaps being the records of only the most successful voyages or those records that are the most detailed. One might also suggest that there is some connection between the success of the whale hunt and the amount of detail the logkeeper incorporated into the daily entries of the logbook. Contrary to these suggestions, we cannot isolate any reasons for the survival of any one logbook over another (apart from an illustrated logbook, which calls for an artistic judgment on its preservation rather than an historical one), and we have no evidence that a greater number of a specific type of logbook exists. We have logbooks of usually successful whalers who suffered poor voyages; logbooks of unsuccessful whalers who had lucky voyages; highly

(continued on p. 117)

Table 1

Primary data extracted by season, where Kill is the number of whales caught plus those struck and lost dying, Cumcatch and Cumkill are the cumulative values from 1849–1914, Days is the total number of days whaling in all voyages, Docs is the number of documented voyages from which we extracted information and Percent is the proportion of total voyages included in our sample.

Year	Catch	Kill	Cumcatch	Cumkill	Days	Docs	Voyages	Percent
1849	71	80	71	80	499	7	50	14.00
1850	316	380	387	460	2,675	25	136	18.38
1851	142	168	529	628	3,427	33	176	18.75
1852	381	467	910	1,095	5,329	39	224	17.41
1853	101	128	1,011	1,223	3,402	27	168	16.07
1854	21	26	1,032	1,249	1,178	9	45	20.00
1855	0	1	1,032	1,250	232	3	7	42.86
1856	0	0	1,032	1,250	41	1	9	11.11
1857	12	13	1,044	1,263	153	2	12	16.67
1858	83	90	1,127	1,353	1,966	19	97	19.59
1859	78	85	1,205	1,438	1,966	20	86	23.26
1860	43	45	1,248	1,483	1,238	10	49	20.41
1861	65	68	1,313	1,551	1,205	10	45	22.22
1862	45	47	1,358	1,598	766	6	20	30.00
1863	74	78	1,432	1,676	1,194	9	35	25.71
1864	94	103	1,526	1,779	2,148	19	80	23.75
1865	103	133	1,629	1,912	2,137	19	84	22.62
1866	149	160	1,778	2,072	3,307	24	81	29.63
1867	191	202	1,969	2,274	4,172	28	83	33.73
1868	114	129	2,083	2,403	2,367	15	60	25.00
1869	89	97	2,172	2,500	1,765	11	42	26.19
1870	162	169	2,334	2,669	2,224	15	55	27.27
1871	29	31	2,363	2,700	1,093	10	43	23.26
1872	42	50	2,405	2,750	1,118	9	35	25.71
1873	21	21	2,426	2,771	794	5	35	14.29
1874	15	15	2,441	2,786	539	3	19	15.79
1875	30	30	2,471	2,816	367	3	20	15.00
1876	3	4	2,474	2,820	184	1	19	5.26
1877	53	57	2,527	2,877	728	5	23	21.74
1878	9	10	2,536	2,887	460	3	24	12.50
1879	7	9	2,543	2,896	195	1	29	3.45
1880	59	60	2,602	2,956	482	3	23	13.04
1881	17	19	2,619	2,975	189	1	22	4.55
1882	15	15	2,634	2,990	265	2	32	6.25
1883	3	3	2,637	2,993	591	3	39	7.69
1884	6	7	2,643	3,000	354	2	38	5.26
1885	27	28	2,670	3,028	767	4	41	9.76
1886	12	13	2,682	3,041	531	4	41	9.76
1887	15	17	2,697	3,058	523	3	36	8.33
1888	15	17	2,712	3,075	843	5	39	12.82
1889	4	5	2,716	3,080	711	4	42	9.52
1890	13	13	2,729	3,093	668	4	39	10.26
1891	41	42	2,770	3,135	1,133	7	39	17.95
1892	35	36	2,805	3,171	843	5	44	11.36
1893	16	16	2,821	3,187	790	5	44	11.36
1894	30	32	2,851	3,219	958	7	33	21.21
1895	22	22	2,873	3,241	602	7	30	23.33
1896	14	14	2,887	3,255	761	6	25	24.00
1897	19	19	2,906	3,274	904	6	23	26.09
1898	54	57	2,960	3,331	649	5	20	25.00
1899	51	52	3,011	3,383	611	4	16	25.00
1900	28	28	3,039	3,411	567	4	16	25.00
1901	9	9	3,048	3,420	435	4	13	30.77
1902	33	33	3,081	3,453	484	3	12	25.00
1903	19	19	3,100	3,472	580	3	15	20.00
1904	12	13	3,112	3,485	402	3	17	17.65
1905	27	29	3,139	3,514	624	5	16	31.25
1906	9	9	3,148	3,523	324	4	16	25.00
1907	19	19	3,167	3,542	472	3	11	27.27
1908	9	9	3,176	3,551	571	3	11	27.27
1909	2	2	3,178	3,553	142	1	5	20.00
1910	4	4	3,182	3,557	147	1	4	25.00
1911	6	6	3,188	3,563	179	1	5	20.00
1912	0	0	3,188	3,563	84	1	5	20.00
1913	0	0	3,188	3,563	92	1	5	20.00
1914	10	10	3,198	3,573	69	1	4	25.00

Table 2

Estimated catch and kill by season for the entire pelagic whaling fleet, where WCATCH is the weighted catch (Catch × WFACTOR), WKILL is the weighted kill (Kill × WFACTOR), WCUMCAT and WCUMKIL are the cumulative values from 1849–1914 and WFACTOR is the weighting factor derived as the inverse of Percent from Table 1

Year	WCATCH	WKILL	WCUMCAT	WCUMKIL	WFACTOR
1849	507	571	507	571	7.14
1850	1,719	2,067	2,226	2,639	5.44
1851	757	896	2,984	3,535	5.33
1852	2,188	2,682	5,172	6,217	5.74
1853	628	796	5,800	7,013	6.22
1854	105	130	5,905	7,143	5.00
1855	0	2	5,905	7,146	2.33
1856	0	0	5,905	7,146	9.00
1857	72	78	5,977	7,224	6.00
1858	424	459	6,401	7,683	5.11
1859	335	366	6,736	8,049	4.30
1860	211	221	6,947	8,269	4.90
1861	293	306	7,240	8,575	4.50
1862	150	157	7,390	8,732	3.33
1863	288	303	7,677	9,035	3.89
1864	396	434	8,073	9,469	4.21
1865	455	588	8,529	10,057	4.42
1866	503	540	9,031	10,597	3.38
1867	566	599	9,598	11,196	2.96
1868	456	516	10,054	11,712	4.00
1869	340	370	10,393	12,082	3.82
1870	594	620	10,987	12,702	3.67
1871	125	133	11,112	12,835	4.30
1872	163	194	11,275	13,029	3.89
1873	147	147	11,422	13,176	7.00
1874	95	95	11,517	13,271	6.33
1875	200	200	11,717	13,471	6.67
1876	57	76	11,774	13,547	19.00
1877	244	262	12,018	13,810	4.60
1878	72	80	12,090	13,890	8.00
1879	203	261	12,293	14,151	29.00
1880	452	460	12,746	14,611	7.67
1881	374	418	13,120	15,029	22.00
1882	240	240	13,360	15,269	16.00
1883	39	39	13,399	15,308	13.00
1884	114	133	13,513	15,441	19.00
1885	277	287	13,789	15,728	10.25
1886	123	133	13,912	15,861	10.25
1887	180	204	14,092	16,065	12.00
1888	117	133	14,209	16,197	7.80
1889	42	53	14,251	16,250	10.50
1890	127	127	14,378	16,377	9.75
1891	228	234	14,607	16,611	5.57
1892	308	317	14,915	16,927	8.80
1893	141	141	15,055	17,068	8.80
1894	141	151	15,197	17,219	4.71
1895	94	94	15,291	17,313	4.29
1896	58	58	15,349	17,372	4.17
1897	73	73	15,422	17,445	3.83
1898	216	228	15,638	17,673	4.00
1899	204	208	15,842	17,881	4.00
1900	112	112	15,954	17,993	4.00
1901	29	29	15,983	18,022	3.25
1902	132	132	16,115	18,154	4.00
1903	95	95	16,210	18,249	5.00
1904	68	74	16,278	18,323	5.67
1905	86	93	16,365	18,415	3.20
1906	36	36	16,401	18,451	4.00
1907	70	70	16,471	18,521	3.67
1908	33	33	16,504	18,554	3.67
1909	10	10	16,514	18,564	5.00
1910	16	16	16,530	18,580	4.00
1911	30	30	16,560	18,610	5.00
1912	0	0	16,560	18,610	5.00
1913	0	0	16,560	18,610	5.00
1914	40	40	16,600	18,650	4.00

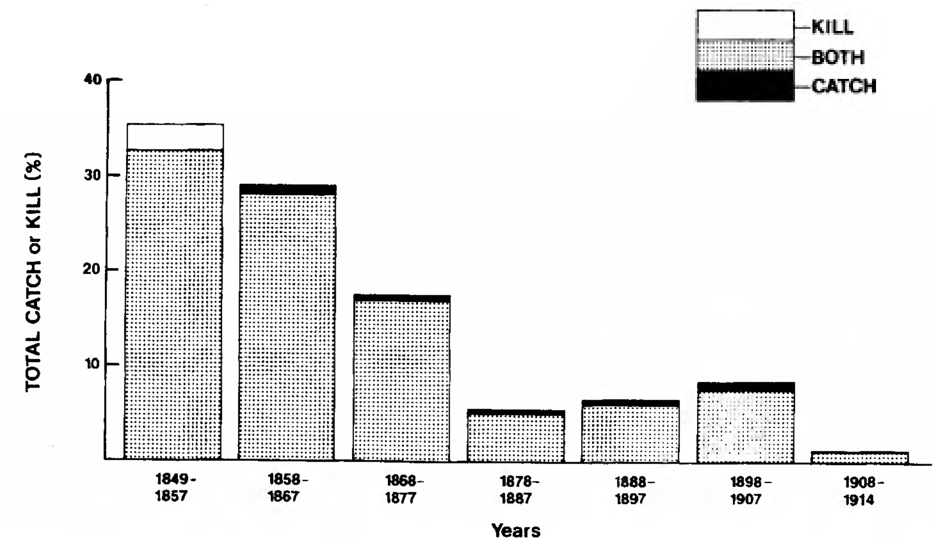


Fig. 8. Percentage of the total catch and kill by periods. The CATCH in each decade is plotted as a percentage of the TOTAL CATCH for the entire period; similarly, the KILL in each decade is shown as a percentage of the TOTAL KILL. (The shaded portion labeled BOTH indicate overlap.) Thus, in the first decade, the percentage of KILL exceeded the percentage CATCH, whereas in all subsequent decades the percentage CATCH is greater than percentage KILL.

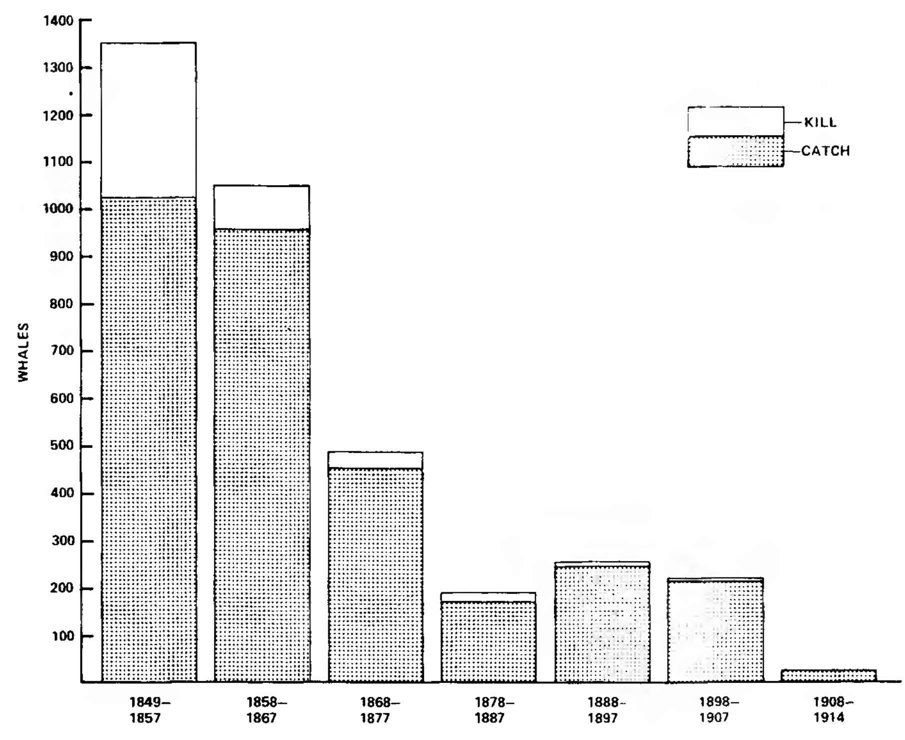


Fig. 9. The catch and kill by period from the primary data, representing 19% of the known voyages from 1849 to 1914.

detailed logbooks of unsuccessful voyages; and poorly detailed logbooks of successful voyages. Furthermore, the relationship between the abilities of a captain and his crew to catch whales and the desire of a single man (usually not the ship's captain) to maintain detailed records is an obscure one at best. But the relationship is even more tenuous because a significant fraction of the data was derived from journals (personal records kept by anyone aboard ship) and not from the official logbooks of the ships. One of our most detailed journals, kept by Captain Frederick A. Barker, was of a particularly unsuccessful voyage. Thus we believe that the information from these historical documents does not bias our estimates and that our data base is a representative one.

Seasonality of effort and catch

Table 3 lists the number of whales caught per month and period as compiled from our data sample, together with a total by month over all years. The logbook records indicate that about 25%, a sizeable fraction of the total whales caught, were taken before July. Most whales, however, were caught during July, August and September (71%). Nevertheless, the percentage taken early in the season declined abruptly after the second decade, reflecting the depletion of the whales in the lower latitudes. In the first decade 33% of the whales were caught before July, in the second decade 28%; in the third, fifth, sixth and seventh decades, 8%, 11%, 9%, and

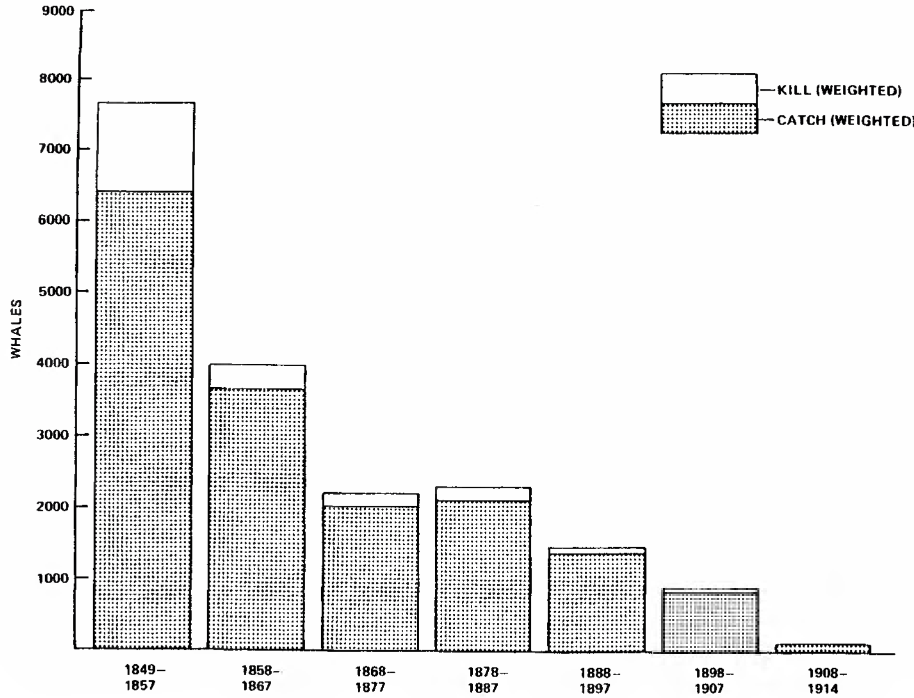


Fig. 10. The weighted catch and kill by period, estimated to be the total catch and total kill from 1849 to 1914.

Table 3

Catch by month and 10-year period

	Period														Total	
	1849–58		1859–68		1869–78		1879–88		1889–98		1899–1908		1909–14		1849–1914	
Month	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
April	1	< 1	3	< 1	2	< 1	4	2	2	1	2	1	—	—	14	< 1
May	81	8	61	6	15	3	25	15	14	7	13	5	1	3	210	7
June	264	25	205	22	30	5	18	11	6	3	7	3	—	—	530	17
July	276	26	100	11	6	1	18	11	5	2	32	12	—	—	437	14
August	338	32	295	32	107	19	37	22	66	32	111	43	12	39	966	30
September	82	8	228	25	332	60	49	29	92	44	74	28	14	45	871	27
October	2	< 1	30	3	65	12	19	11	24	11	22	8	4	12	166	5
November	—	—	2	< 1	—	—	—	—	—	—	—	—	—	—	2	< 1
December	—	—	1	< 1	—	—	—	—	—	—	—	—	—	—	1	< 1
Total	1,044		925		557		170		209		261		31		3,197	

3% respectively, were taken before July. Only the fourth decade's data repeat the early trends, with 28% taken before July (and this probably reflects the introduction of the more maneuverable steam-auxiliary vessels), but this decade had the smallest total catch except for the period after 1909.

Changes in the location of catch and effort

For the purpose of this report we subdivided the Bering, Chukchi and Beaufort Seas into 19 regions which we constructed empirically to segregate areas where the greatest concentrations of whaling activity had occurred.

Figs 11A–H show the distribution of the catch and ship days recorded in the logbooks read for the entire whaling period. Figs 11A–G give this distribution by decade, and Fig. 11H gives the distribution for the entire pelagic whaling era. The distributions indicate that the bowhead population was essentially eliminated from a large part of its original range by 1914. In the first decade (1849–1858), a sizeable number of whales were caught south of 60° N: off the Asian coast, 36 were taken between 54° and 57° N, 38 between 57° and 60° N; 23 were taken in the Abyss area between Asia and North America, and a total of 105 whales were taken below 60° N. During the second decade (1859–1868), only 27 whales were taken there, and most of these in the Abyss area.

During the third decade (after 1868) whales were caught only occasionally below 60° N, and only one was caught below there after 1888. Similarly, after 1878 the whales seem to have been essentially eliminated from the region between 60° and 63° N, few having been caught there even though ships continued to spend a considerable number of days in this region. The whales were also gradually eliminated from the Anadyr and Narrows areas, between 63° and 66° N: although 292 whales were caught in this region in the first decade (1849–1858) and 130 in the second (1859–1868), only 23 were caught there in the third decade (1869–1878), 20 in the fourth (1879–1888), 10 in the fifth (1889–1898), 15 in the sixth (1899–1908) and none in the last period (1909–1914).

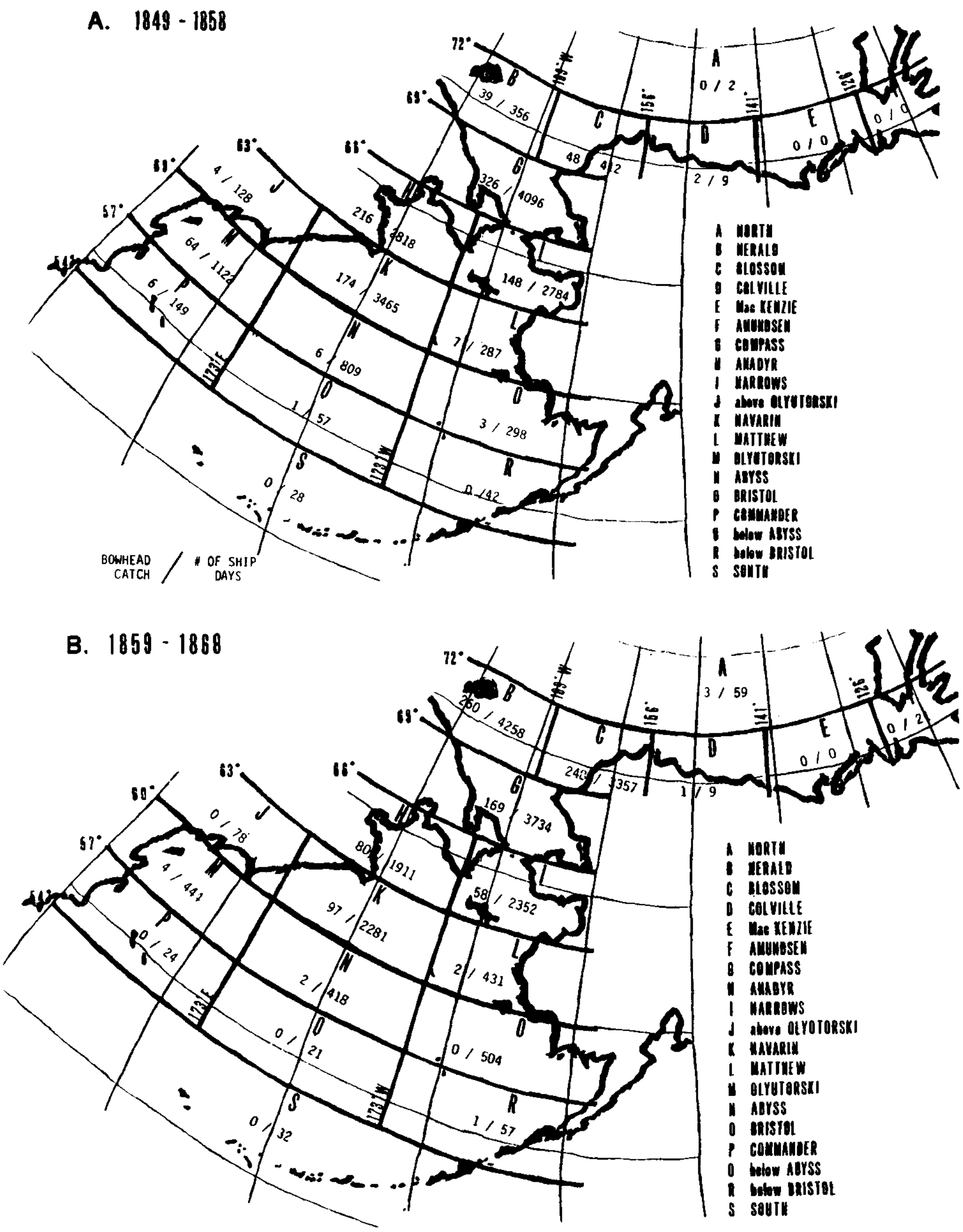


Fig. 11. Distributions of catch and ship-days whaling by period. Values plotted are: bowhead catch/number of ship days.

The catch of bowhead whales during the first period of exploitation (1849–1858) indicates that this species was taken from April through October as far south as 54° N, from the coast of Asia to 173° W, and as far north as 69° N in the southern Chukchi Sea. As the population was reduced, however, the whalers were forced to push farther and farther north and east to maintain their catch levels, finally reaching as far as 73° N and as far east in the Canadian Arctic as 114° W. We take this entire area as the original range of the bowhead: in the southern Bering Sea above 54° N from the coast of Asia to 173° W; throughout the northern Bering Sea above 60° N; throughout the Chukchi and Beaufort Seas; and perhaps scattered in contiguous waters.

Because in the first period of commercial exploitation the whalers successfully caught bowheads in the north and southwest Bering Sea throughout the spring, summer and fall, it seems reasonable to assume that the bowheads in these areas were on feeding grounds and not merely in a migratory phase. We believe therefore, that the records we have analyzed suggest that the pre-exploitation feeding areas were vastly larger than contemporary ones, and that the bowhead seems to have been eliminated, for reasons not completely understood, from the use of large parts of its once greater range.

It is possible that the western Arctic bowhead population was originally made up of several discrete subpopulations, each with its own feeding area. This is consistent with the observation that the whales appear to have been eliminated from large parts of the original feeding grounds. It is equally possible, however, that the bowheads were a single population that responded rapidly to the presence and activities of the whaling ships, and fled areas of intensive hunting, receding farther and farther north and east to the comparatively safer areas either near the ice or where exploitation had not yet occurred. By the end of the 19th century the whaling fleet, through the use of auxiliary power and Arctic wintering sites (such as Herschel Island), had reached all known areas where the bowheads traveled and fed.

The whales' only refugium then remained amid the pack ice (where during their spring migration they were

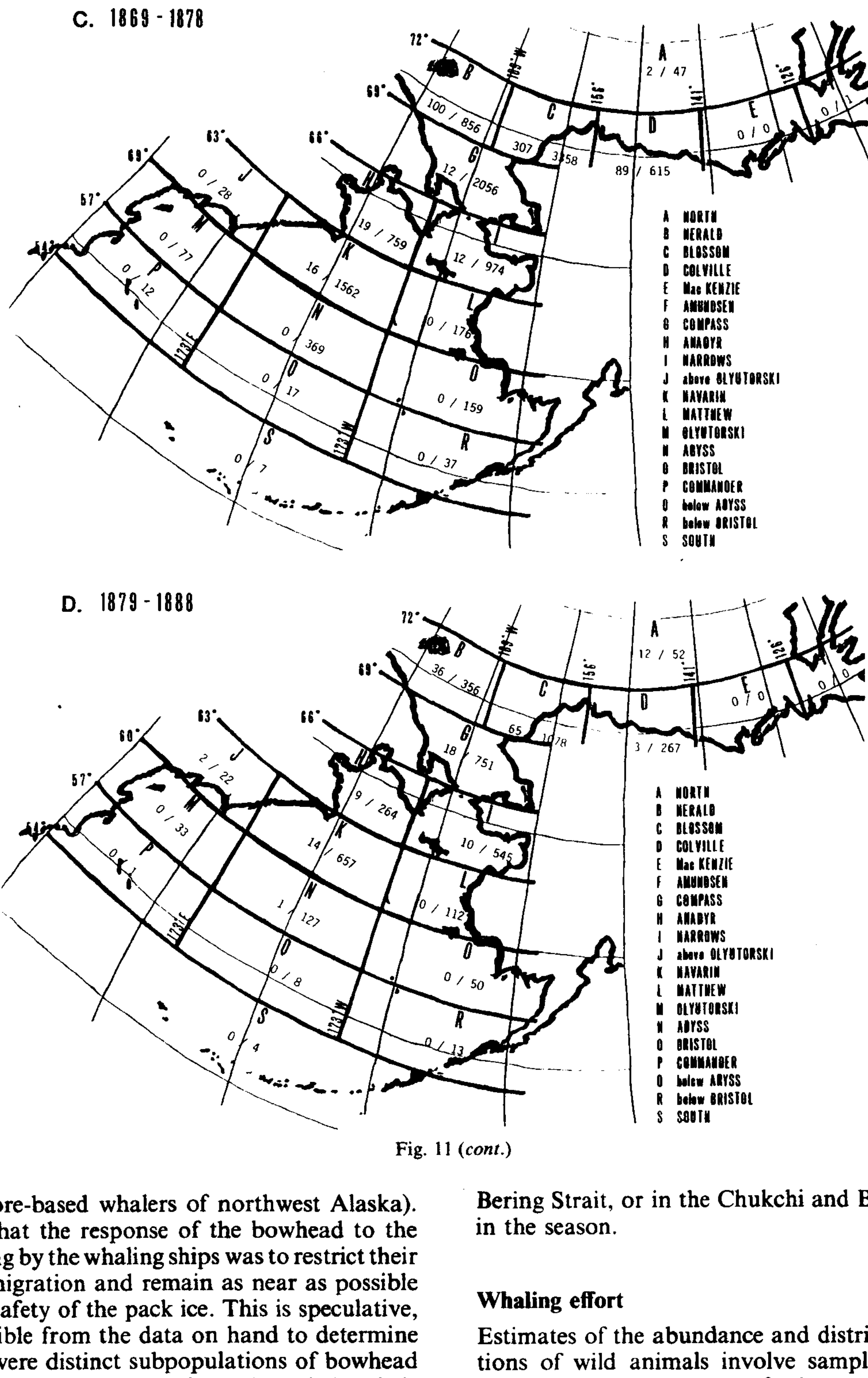


Fig. 11 (*cont.*)

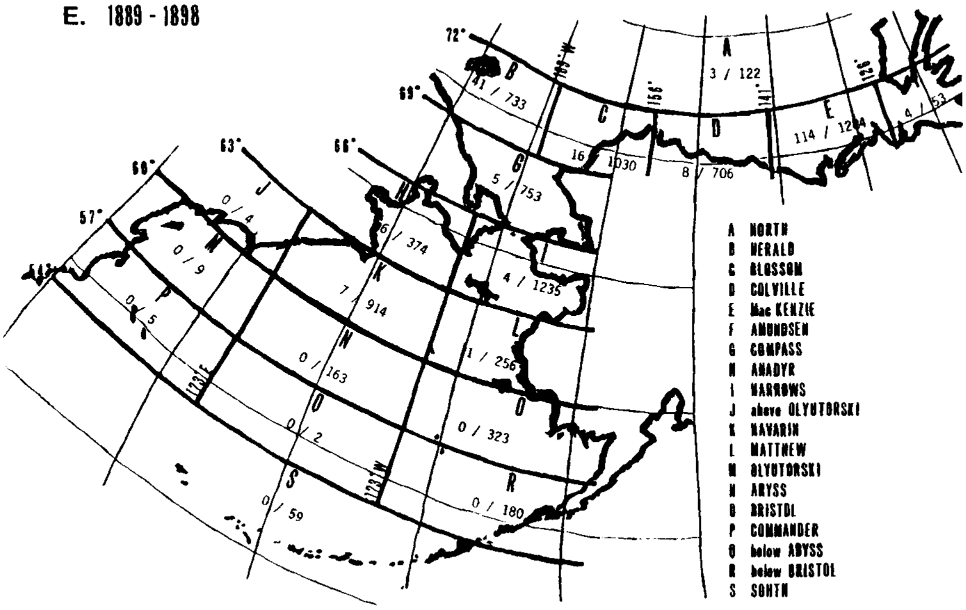
prey to the shore-based whalers of northwest Alaska). This suggests that the response of the bowhead to the intensive hunting by the whaling ships was to restrict their entire annual migration and remain as near as possible to the relative safety of the pack ice. This is speculative, for it is impossible from the data on hand to determine whether there were distinct subpopulations of bowhead or one single well-mixed population. Nevertheless it is possible that the great contraction in the feeding areas of the modern population (in comparison to the 1847 population's feeding area), coupled with the modern Eskimo shore-based hunt may be important factors in the failure of the species to have increased significantly more than six decades after the last whaling ships hunted in the western Arctic.

In summary, after ten years of pelagic whaling, the bowhead was apparently eliminated from its habitats along the Asian coast; few whales were caught below 60° N after 20 years; few below 63° N after 30 years, and few below 66° N after 40 years. After 40 years, bowheads were caught almost exclusively either as they passed near Bering Strait, or in the Chukchi and Beaufort Seas later in the season.

Whaling effort

Estimates of the abundance and distribution of populations of wild animals involve sampling methods that require some measure of the searching effort, a requirement which has been a primary limitation of the reliability of the estimates of populations of marine mammals and marine fishes. Where direct measurements are lacking, scientists have attempted to determine long-term time series for animal populations by analyzing the records of commercial hunting. The longest historical documentation of any wildlife population is the Hudson Bay Company's fur trade records. First analyzed by Elton (1942), they chronicle more than 100 years of the catch of several terrestrial mammals. Although the Hudson Bay fur trading records are of great interest, they contain no direct measure of hunting effort. Elton and others have assumed that the effort of the hunters (and numbers of

E. 1889 - 1898



F. 1899 - 1908

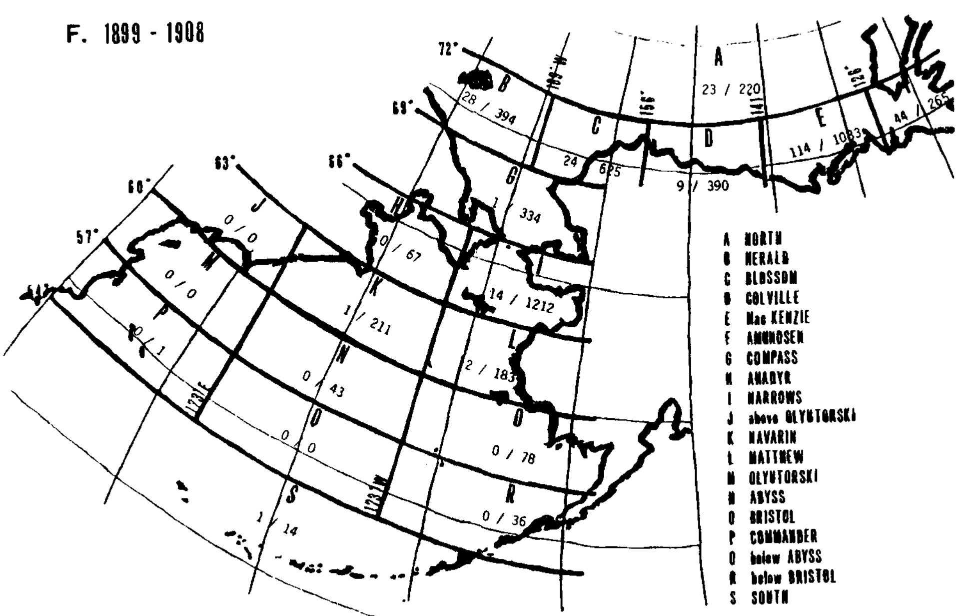


Fig. 11 (*cont.*)

their traps) always greatly exceeded the numbers of prey that might be caught, so that effort could be viewed as large and constant and could be ignored as a factor in the observed temporal patterns of catch. That is, they assumed, with little basis in fact, that changes in catch were totally due to changes in population abundance.

In previous attempts to reconstruct population histories of marine mammals from historical records, the measure of effort has been imprecise (the number of ships hunting in an area per year has, for instance, merely been used as the indicator), thus greatly limiting the usefulness of the data.

As is well known among those who study fisheries and marine mammals, DeLury (1947) suggested that estimates of the abundance of a population can be made assuming that, for a given population size, there is a constant relationship between the number of animals caught and the effort expended in catching them. Changes in the catch per unit effort, therefore, are a direct index of population abundance. The assumption that this relationship is constant, as DeLury noted, is 'seriously open to doubt, and must be tested carefully against observations before any conclusions are based on it'.

Thus those interested in determining the present and past abundance of marine mammals have been confronted with a dilemma. The animals are difficult to count, there are few long-term records, and the few that exist lend themselves only to relatively poor estimates of effort, allowing no means for testing whether the relationship between catch and effort remains constant over time. It is generally assumed that catch per unit effort will decrease monotonically as the population of prey decreases.

The records that we have accumulated on the bowhead whale have the distinct advantage of offering one of the best measures of hunting effort over a long period of time. In fact, the 66-year record we present here represents both one of the longest detailed mammalian population records in existence and one of the best long-term records of hunting and catch effort.

Where analyses are made of contemporary fisheries under direct observation, effort is usually reported as the

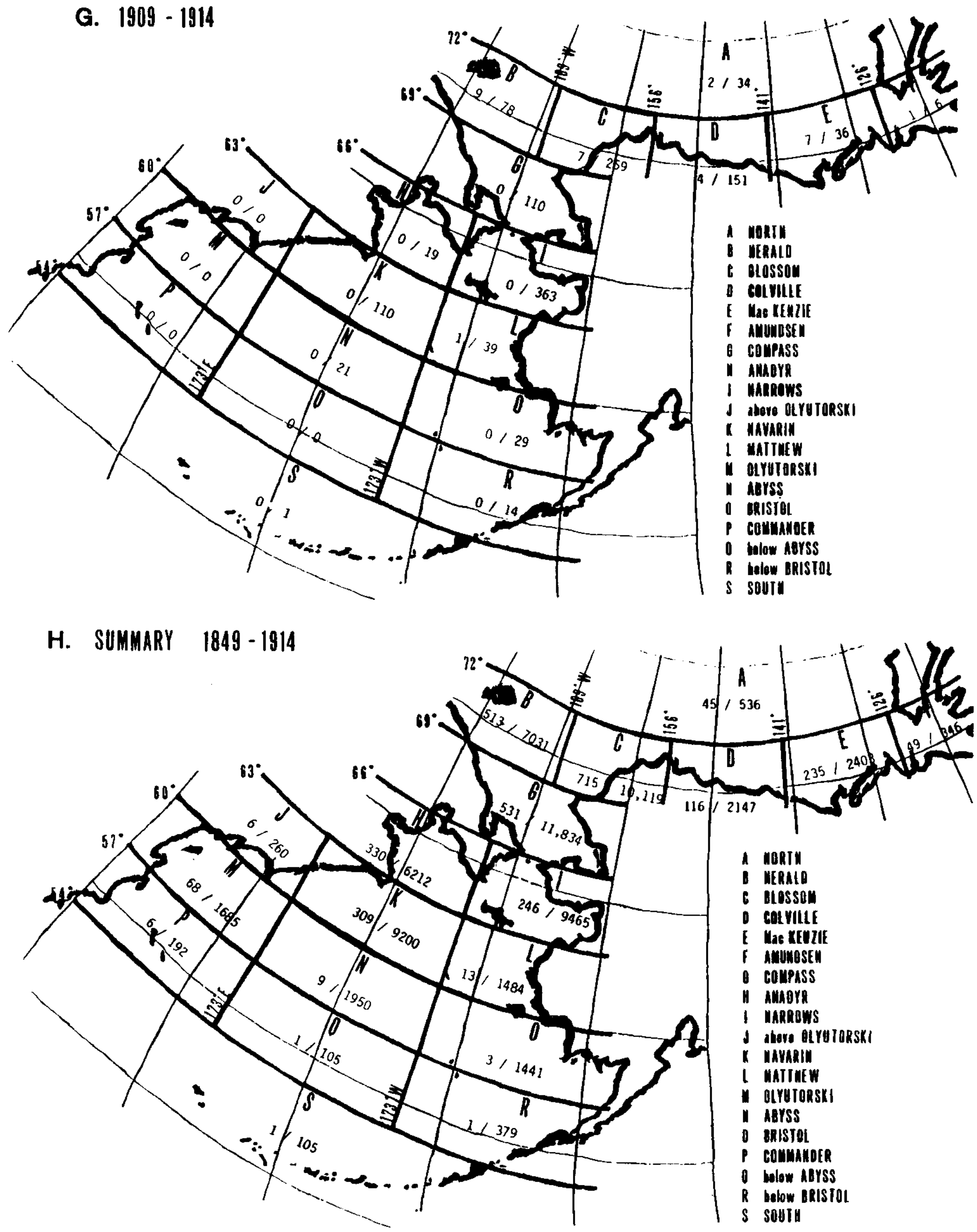


Fig. 11 (*cont.*)

catchers' effective days' work, sometimes weighted to account for non-working periods. In previous attempts to use historical records, the measures usually have been limited to the number of ships per year, with little account taken of the number of days whaling per ship or of the changes in techniques available. In contrast, the data reported here yield measures of effort based on days of effort.

Whaling effort as number of ship-days

From the daily observations in the whaling logbooks, we are able to determine the total number of days whaling of each voyage, and the simplest measure of effort we can provide is the total number of ship-days whaling per year. Because this is of interest to those who wish to compare our results with other studies that use this definition of effort, we use the total number of days whaling as one measure of effort to estimate the 1847 (pre-exploitation) bowhead whale population.

The catch per unit effort (CPUE), defined as the number of whales caught per ship-day, is shown in Fig. 12. It can be seen (Tables 1 and 2; Figs 2A–C and 13) that CPUE varies greatly, in contrast to the usual assumption that the effort remains constant but the catch declines as the population size declines. In Fig. 14 we have plotted CPUE and kill per unit effort (KPUE, defined as kill per ship-day) from 1849 to 1914 and inserted the available information (derived from historical newspaper accounts, principally) about whalers' perceptions of the availability of the whales and of the weather and ice conditions. We present these data recognizing that they are impossible to control statistically. Nevertheless, they do suggest that foul weather and heavy ice, as the whalers perceived them, hampered their hunting and, conversely, good weather and little ice contributed to their success.

We wonder, too, whether the bowheads quickly learned to avoid the ships in the very first years of the fishery; for the rapid decline of the CPUE from 1849 to 1854, accompanied by reports as early as 1851 that the whales were 'scarce and shy' may well indicate that the whales were adapting their behavior to this new threat.

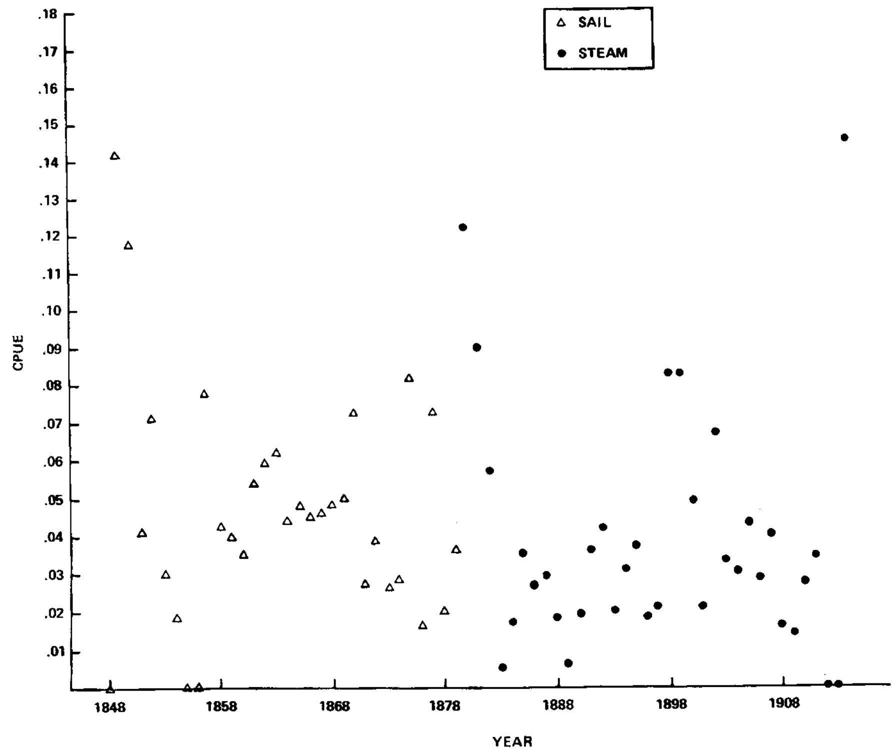


Fig. 12. Catch per unit effort (CPUE) versus time, where SAIL indicates sailing ship effort only and STEAM indicates both sailing and steam ship effort.

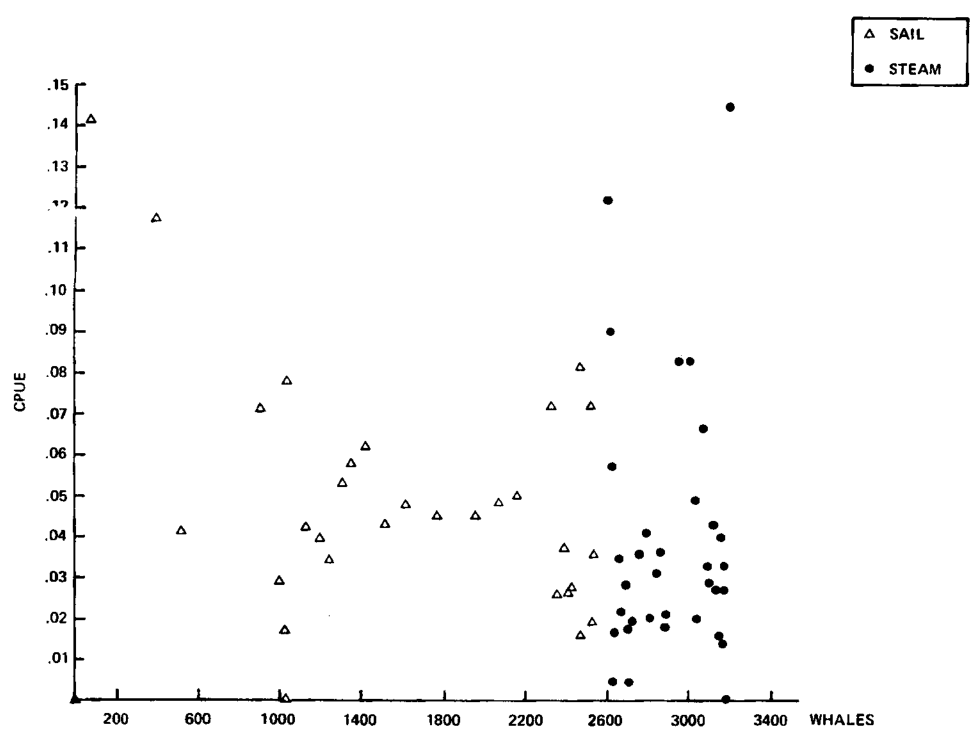


Fig. 13. CPUE versus the cumulative catch, where SAIL indicates sailing ships only and STEAM indicates both sailing and steam ships.

These figures suggest that the whalers did not operate on the naive policy that they would continue hunting at a high level regardless of the abundance of whales, nor were they immune to the vagaries of ice and weather. The plot of CPUE over time (Fig. 12) shows that there are periods of rise and fall. For example, CPUE is very high in 1849, and then declines steadily to a low in the mid-1850s, then increases again, only to decline. This rise and fall occurs at least four times during the whaling era. It suggests that the whalers annually made a rational decision about whether or not to pursue the whales in the western Arctic based on the success or failure of the ships there in the immediately preceeding years.

Thus, after a single ship first located and caught a number of bowheads in 1848 and a small fleet did as well in 1849 (resulting in a high CPUE), more and more ships

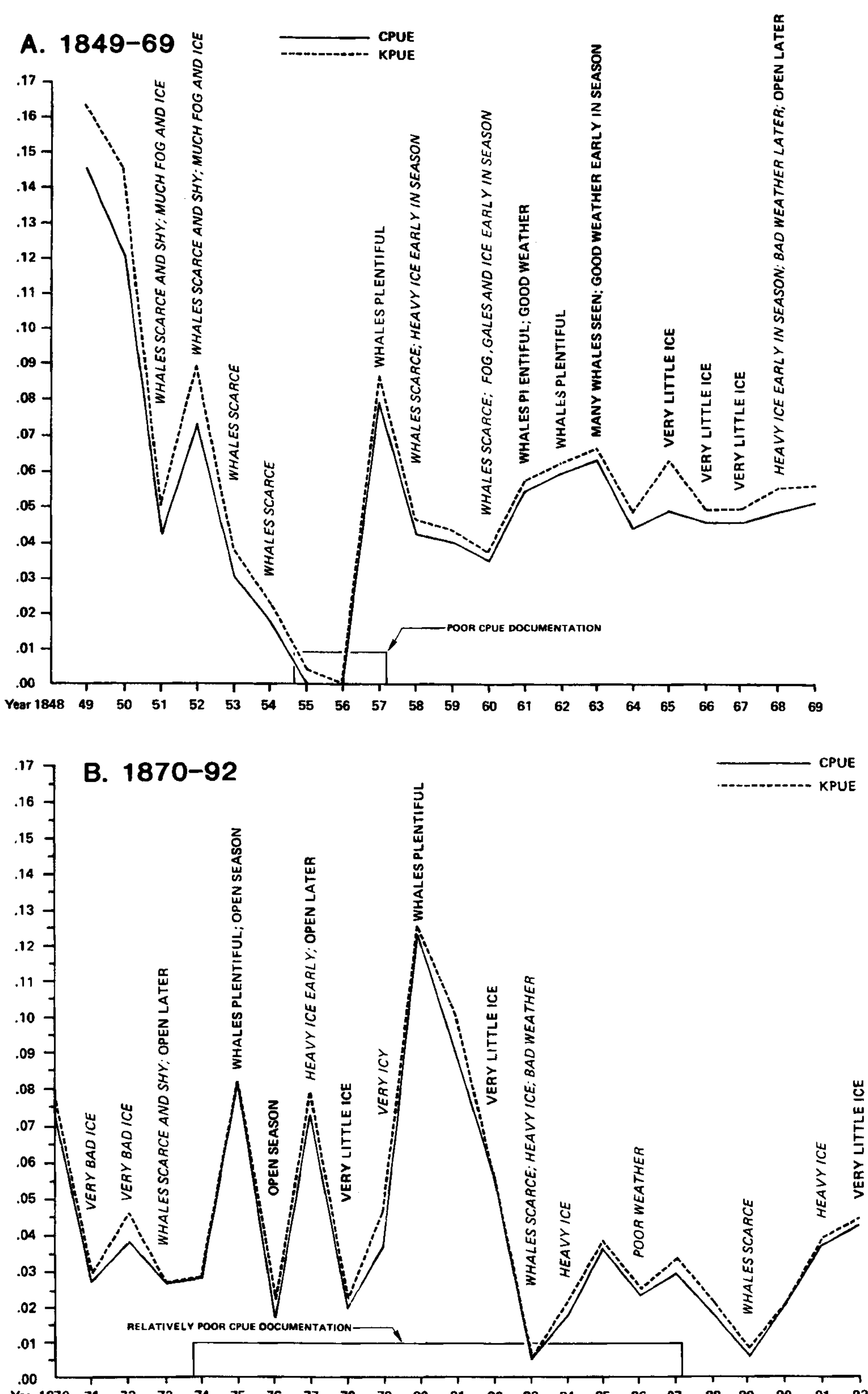


Fig. 14. Catch per unit effort (CPUE) and kill per unit effort (KPUE) versus time, annotated by whalers' reports on availability and environmental conditions.

joined the effort until, within 10 years, there was a great decline in the catch and in the CPUE. Following this was a short period (1855–1857) when only a few ships sought the bowheads in the western Arctic. But when, in 1857, they pushed farther into the Arctic, they again caught many whales, increasing the CPUE, leading to a subsequent increase in the number of ships and number of ship-days, another decline in CPUE, and another decline in the number of ships. The pattern repeats itself throughout the whaling era, suggesting that the whalemen followed a rational if informal strategy in deciding whether to invest their resources in the risk of an Arctic cruise. Any real group of fishermen, and for that matter many natural predators, could be expected to follow this procedure rather than to invest heavily in energy, effort and time regardless of the recent success of the hunt.

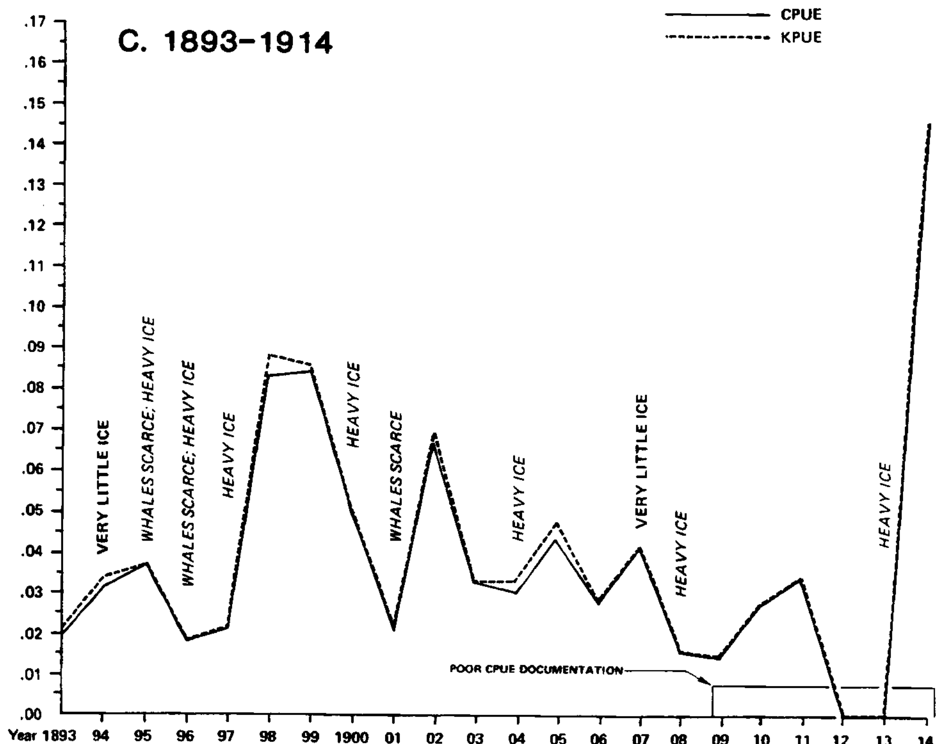


Fig. 14 (*cont.*)

Correcting the effort for weather conditions

Because, as we have noted, weather and ice conditions apparently affected the hunting effort, it is fortunate that the logbook records allow us to make corrections for those periods of time in which the weather prevented whaling. Once the whaleships reached their hunting ground there was relatively little time when the ships were not ready or able to chase a whale if it were sighted. The logbooks make clear that under almost all conditions a lookout was kept and the crew was ready to give chase if a whale appeared. Thus the primary limitations on the chase were the weather and ice.

It is not clear from direct written statements in the logbooks what weather and ice conditions made whaling impossible. We have therefore analyzed the records in several ways, and each of these are used later in estimates of the pre-exploitation population.

Two types of corrections were made for the weather conditions from the logbook data. First, an analysis was carried out to determine those combinations of weather conditions (ice, wind and visibility) under which no whales were ever caught during the 66-year period examined. These analyses show, for example, that only four whales were caught when the ice covered five-eighths of the visible ocean, and only a small percentage was caught when the ice covered one-half of the visible ocean. A few whales (22) were caught under visibilities of less than one mile; but these occurred under calm conditions with relatively little ice cover. Few whales (15) were caught under wind condition 7 (a strong gale), and only 19 under wind condition 6 (a moderate gale). For purposes of our analysis we grouped these conditions under the rubric of 'type 1 non-whaling days'. We then made one calculation of the size of the original bowhead population, defining 'type 1 effort' as the total number of whaling days minus the type 1 non-whaling days. The KPUEs used are given in Tables 4 and 5.

Apart from the previous calculation, we then assumed that certain weather and ice conditions would prevent successful whaling. (Not surprisingly, most whales were caught under conditions of moderate winds, moderate visibility and low percentage ice cover. Few were caught under visibilities exceeding five miles, but this indicates the relative rarity of such visibility in the Arctic summers.) We defined 'type 2 non-whaling days' as the days on which either or both of the following extreme conditions occurred: ice coverage of five-eighths or more of the ocean; wind in excess of a 'fresh gale' (wind condition 5). Another set of estimates of the original bowhead population was then calculated, defining 'type 2 effort' as the total number of whaling days minus the type 2 non-whaling days. The KPUEs used are given in Tables 6 and 7.

Estimates of effort using area searched

Because the logbook records provide daily information about both the location of the ship and a measure of visibility, we had originally thought that it might be possible to define effort in terms of the area of ocean searched by the whaling ships. Our examination of the logbook data made clear, however, that the position of a ship on two consecutive days was not a good index of the actual distance the ship traveled. Often ships would sail back and forth in an area where whales were thought to be, and the actual distance sailed was therefore much greater than that indicated by the change in latitude and longitude in a 24-hour period. Because of this problem we adopted a different method of analysis.

For this measure of effort, we conceived of both the ships and whales as floating in a uniform medium in which the area traveled by either could be ignored, and thus only the visible area and the time this area was viewed mattered as a measure of effort. The visible area was defined as a circle with a radius of the visibility listed for a day of observation. An average area seen multiplied by time was calculated for each ship for each year.

Table 4

Kill per unit effort (KPUE) from the data sample and weighted kill per unit effort (WKPUE) using type 1 effort[1]

Year	KPUE	WKPUE	WKPUE/KPUE
1849	0.16032	0.52288	3.26
1850	0.14206	0.37438	2.64
1851	0.04902	0.12009	2.45
1852	0.08763	0.27278	3.11
1853	0.03762	0.10509	2.79
1854	0.02207	0.06436	2.92
1855	0.00431	0.02222	5.16
1856	0.00000	0.00000	1.00
1857	0.08497	0.19697	2.32
1858	0.04578	0.16364	3.57
1859	0.04323	0.12782	2.96
1860	0.03635	0.12129	3.34
1861	0.05643	0.14286	2.53
1862	0.06136	0.13352	2.18
1863	0.06533	0.20856	3.19
1864	0.04795	0.13239	2.76
1865	0.06224	0.19617	3.15
1866	0.04838	0.14122	2.92
1867	0.04842	0.13855	2.86
1868	0.05450	0.13231	2.43
1869	0.05496	0.12500	2.27
1870	0.07599	0.17586	2.31
1871	0.02836	0.07828	2.76
1872	0.04472	0.09901	2.21
1873	0.02645	0.06287	2.38
1874	0.02783	0.06696	2.41
1875	0.08174	0.20833	2.55
1876	0.02174	0.04348	2.00
1877	0.07830	0.19930	2.55
1878	0.02174	0.08696	4.00
1879	0.04615	0.08654	1.87
1880	0.12448	0.38710	3.11
1881	0.10053	0.76000	7.56
1882	0.05660	0.17241	3.05
1883	0.00508	0.00974	1.92
1884	0.01977	0.03211	1.62
1885	0.03651	0.06321	1.73
1886	0.02448	0.04676	1.91
1887	0.03250	0.05556	1.71
1888	0.02017	0.04416	2.19
1889	0.00703	0.01639	2.33
1890	0.01946	0.02579	1.33
1891	0.03707	0.06818	1.84
1892	0.04270	0.08889	2.08
1893	0.02025	0.09467	4.67
1894	0.03340	0.08989	2.69
1895	0.03654	0.09565	2.62
1896	0.01840	0.04651	2.53
1897	0.02102	0.04715	2.24
1898	0.08783	0.19930	2.27
1899	0.08511	0.17391	2.04
1900	0.04938	0.09655	1.96
1901	0.02069	0.03586	1.73
1902	0.06818	0.32039	4.70
1903	0.03276	0.07917	2.42
1904	0.03234	0.04467	1.38
1905	0.04647	0.11197	2.41
1906	0.02778	0.07692	2.77
1907	0.04025	0.06786	1.69
1908	0.01576	0.03169	2.01
1909	0.01408	0.04545	3.23
1910	0.02721	0.09756	3.59
1911	0.03352	0.10345	3.09
1912	0.00000	0.00000	1.00
1913	0.00000	0.00000	1.00
1914	0.14493	0.17544	1.21

[1] 'Non-whaling Days', defined as those days with a combination of ice, wind, and visibility conditions under which no whales were caught during the entire 66-year period, were subtracted from total whaling days in each year, and the resulting 'Type 1 Days' used to calculate WKPUE = KILL/TYPE 1 DAYS. This measure of effort assumes that whaling on 'Non-whaling Days' was futile and hence that such days should not be included in the calculation of effort.

Initially, calculations were made to determine the daylight hours for each date and latitude, but the average daylight hours per ship, or per ship-year, was for all years almost exactly equal, and the years could not be distinguished from one another on this basis. Therefore the average visibility squared (to account for area viewed), multiplied by whaling days was used as a third measure of corrected effort (Table 8). These measures of effort are used in a subsequent section to estimate the pre-exploitation number of whales.

Catch and kill

Another problem encountered in estimating population abundance from catch reports is the lack of information about the number of animals killed but not caught, therefore decreasing the population size, but not appearing in the records. This is a particularly important problem with whale records where population sizes tend to be small and whales are frequently struck by harpoons and lost. This is all the more crucial in bowhead history because the struck whales were sometimes able to flee into the pack ice where the ships could not follow. A further advantage of the bowhead whale history presented here is that the logbooks contained not only the number caught, but also the number struck and lost, and the number found dead and processed as well as 'stinkers', whales found dead but too decomposed to process.

Fig. 15 presents the kill per unit effort from the data sample, where kill is taken to be the sum of the number caught plus those struck and lost dying. This figure shows a pattern similar to that of the CPUE over time (Fig. 12). As will be seen later, most of our estimates of the pre-exploitation population are made from the number killed. Later we use both a high and low estimate of kill to estimate the 1847 population size. The high estimate includes all whales struck and lost plus those caught; the low estimate uses only those recorded as struck and lost dying plus those caught (see also Fig. 16).

Estimates of the 1847 bowhead whale population

The DeLury method and several of its modifications have been used in the literature on marine mammals to estimate pre-exploitation population sizes (Tillman, 1977; Breiwick, 1978). We have estimated the 1847 population of the bowhead whale (the number present the year prior to the beginning of the pelagic bowhead whaling activity), using several of these methods. In the following discussion, we use the nomenclature of Tillman (1977). Methods are given in detail in Appendix 1.

Simple, unmodified DeLury method

Estimates of the 1847 populations using the simple, unmodified DeLury method, the weighted cumulative kill and the kill per unit effort, are given in Table 9. This method was chosen because it is a standard technique used in analyzing whale populations, familiar to those who have worked on this subject, and provides an estimate most readily comparable to estimates for the abundance of other whale populations. The DeLury method requires the use of two well-known, stringent assumptions that may bias the results: that the numbers of whales caught per unit effort is constant within a year, and that the recruitment or reproductive rate of the whale population is negligible compared to the catch and can,

Table 5

WKPUE determined using KPUE from the data sample and a weighting factor accounting for the percentage of type 1 whaling days[1]

Year	WKPUE	WKPUE/KPUE
1849	0.16176	1.01
1850	0.14807	1.04
1851	0.05052	1.03
1852	0.09118	1.04
1853	0.03923	1.04
1854	0.02296	1.04
1855	0.00443	1.03
1856	0.00000	1.00
1857	0.09088	1.07
1858	0.04748	1.04
1859	0.04471	1.03
1860	0.03702	1.02
1861	0.05895	1.04
1862	0.06376	1.04
1863	0.06941	1.06
1864	0.04848	1.01
1865	0.06354	1.02
1866	0.04880	1.01
1867	0.05072	1.05
1868	0.05333	0.98
1869	0.05390	0.98
1870	0.07226	0.95
1871	0.02654	0.94
1872	0.04460	1.00
1873	0.02665	1.01
1874	0.02900	1.04
1875	0.08501	1.04
1876	0.02081	0.96
1877	0.07768	0.99
1878	0.02141	0.98
1879	0.04287	0.93
1880	0.12765	1.03
1881	0.10431	1.04
1882	0.05047	0.89
1883	0.00471	0.93
1884	0.01672	0.85
1885	0.03506	0.96
1886	0.02319	0.95
1887	0.03220	0.99
1888	0.02035	1.01
1889	0.00732	1.04
1890	0.01918	0.99
1891	0.03763	1.02
1892	0.04096	0.96
1893	0.02071	1.02
1894	0.03453	1.03
1895	0.03820	1.05
1896	0.01907	1.04
1897	0.02016	0.96
1898	0.08372	0.95
1899	0.08303	0.98
1900	0.04868	0.99
1901	0.01934	0.93
1902	0.07009	1.03
1903	0.03138	0.96
1904	0.03291	1.02
1905	0.04646	1.00
1906	0.02893	1.04
1907	0.03889	0.97
1908	0.01479	0.94
1909	0.01450	1.03
1910	0.02916	1.07
1911	0.03157	0.94
1912	0.00000	1.00
1913	0.00000	1.00
1914	0.12544	0.87

[1] The weighting factor was based on the ratio of Type 1 days to readings in each year. 'Type 1 Days' were defined as those days with a combination of ice, wind and visibility under which a whale was caught in any year. 'Readings' was the number of days for which all three weather conditions were recorded. The actual weighting factor was calculated as: (TYPE 1 DAYS/READINGS)/[AVG OF (TYPE 1 DAYS/READINGS) for 66 YRS]. This method weights years in which there were more Type 1 days more heavily; it weights the KPUE by applying the ratio of (TYPE 1 DAYS/READINGS) in each year to all records, including those in which all three weather conditions were not recorded (39% of all records).

therefore, be ignored. This method gives an estimated population size in 1847 of 30,843 whales ($R = 0.681$; $F = 10.65$, significant at the 99% confidence level). Using three-year moving averages of the weighted cumulative kill and the kill per unit effort, this method yields an estimated 1847 population of 34,734 ($R = 0.794$; $F = 16.23$, significant at the 99% confidence level).

Chapman's modified DeLury method

Table 10 gives the results for Chapman's modified DeLury method, using several values of M, the natural mortality rate, in the range common for great whales. In this method the recruitment each year is assumed to be constant and approximated as the initial population size multiplied by M. The adjusted cumulative catch is calculated using either the weighted catch, the weighted kill, or the weighted total of kill and whales struck and lost alive. Excluding the cases with no natural mortality, the significant estimates ($F \geqslant 4$) vary from 10,000 to 22,000.

The 'q' method

Using estimates of q (the 'catchability coefficient' for the whales) obtained from Chapman's modified DeLury method, other estimates of the size of the bowhead population in 1847 were calculated according to the q method. These are shown in Table 11, for the same values of natural mortality rate and adjusted cumulative catch used in Chapman's method (Table 10). Excluding the cases with no natural mortality and those derived from non-significant Chapman method estimates ($F < 4$), the q method estimates range from 17,000 to 36,000.

Allen's modified DeLury method

Table 12 gives the results for Allen's modified DeLury method assuming either a constant recruitment rate or a time-lagged, density-dependent recruitment model. The second option introduces a time lag into the recruitment rate, under the assumption that the age of first breeding will cause such a delay. Although little is known about the actual age of first breeding of the bowhead, a reasonable estimate, based on our knowledge of whales in particular and large mammals in general, is most likely between 5 and 10 years, but might range from as low as 3 to as high as 16.

For the values of M and R examined, the constant recruitment rate model yields estimates of the 1847 bowhead population ranging between 11,000 and 47,000.

For the most reasonable time lags, between 5 and 10

Table 6

WKPUE determined using type 2 effort[1]

Year	WKPUE	WKPUE/KPUE
1849	0.17131	1.07
1850	0.14740	1.04
1851	0.05068	1.03
1852	0.09068	1.03
1853	0.03831	1.02
1854	0.02265	1.03
1855	0.00457	1.06
1856	0.00000	1.00
1857	0.08609	1.01
1858	0.04705	1.03
1859	0.04495	1.04
1860	0.03763	1.04
1861	0.05738	1.02
1862	0.06326	1.03
1863	0.06707	1.03
1864	0.04957	1.03
1865	0.06385	1.03
1866	0.05092	1.05
1867	0.04927	1.02
1868	0.05623	1.03
1869	0.05640	1.03
1870	0.07810	1.03
1871	0.02975	1.05
1872	0.04570	1.02
1873	0.02760	1.04
1874	0.02830	1.02
1875	0.08427	1.03
1876	0.02247	1.03
1877	0.08097	1.03
1878	0.02262	1.04
1879	0.04712	1.02
1880	0.12739	1.02
1881	0.10674	1.06
1882	0.06173	1.09
1883	0.00519	1.02
1884	0.01994	1.01
1885	0.03670	1.01
1886	0.02500	1.02
1887	0.03282	1.01
1888	0.02036	1.01
1889	0.00709	1.01
1890	0.01949	1.00
1891	0.03747	1.01
1892	0.04317	1.01
1893	0.02046	1.01
1894	0.03401	1.02
1895	0.03685	1.01
1896	0.01849	1.01
1897	0.02130	1.01
1898	0.10088	1.15
1899	0.08581	1.01
1900	0.05072	1.03
1901	0.02133	1.03
1902	0.06947	1.02
1903	0.03339	1.02
1904	0.03250	1.00
1905	0.04731	1.02
1906	0.02786	1.00
1907	0.04060	1.01
1908	0.01610	1.02
1909	0.01439	1.02
1910	0.02778	1.02
1911	0.03468	1.03
1912	0.00000	1.00
1913	0.00000	1.00
1914	0.14925	1.03

[1] 'Non-whaling Days', defined as days with extreme conditions of ice and/or wind, were subtracted from total whaling days in each year, and the resulting 'Type 2 Days' used to calculate WKPUE = KILL/TYPE 2 DAYS. This measure of effort assumes that whaling on 'Non-whaling Days' was futile and hence that such days should not be included in the calculation of effort. (Whales were apparently caught under all conditions of visibility.)

years, the density-dependent recruitment model yields estimates of the 1847 population ranging between 23,000 and 25,000. This method is relatively insensitive to time lags above 10 years, and a lag of more than 16 years seems biologically unreasonable. Thus, unless bowhead whales mature much more rapidly than would be expected for great whales and other larger mammals, this method suggests that the 1847 population numbered about 25,000.

Using an age of first breeding of eight, and therefore a time lag of eight years, we have investigated the effects of variations in other parameters, including the rates of annual natural mortality and recruitment, on the estimate of the 1847 population. Varying annual natural mortality from 0.08 to 0.03 and recruitment from 0.08 to 0.03, this method gives estimates of the 1847 population ranging from 15,000 to 35,000.

Estimates of the 1847 population with weather and area corrections

In our previous discussion of hunting effort, we gave three methods of weighting the effort by weather conditions. Two of these corrected for weather conditions under which whales could not be chased or caught, and the third attempted to correct the number of whaling days by the area of the ocean visible from a ship. Here these three methods are used as a measure of effort, and employed with the unmodified DeLury method to provide additional estimates of the pre-exploitation bowhead population. As can be seen in Table 13, the corrections for weather result in somewhat lower estimates that overlap with the unweighted estimates, providing values ranging from 20,000 to 30,000 whales.

One estimate using the area seen by whaling ships also gives a lower value, 18,573 ± 3,711. This estimate has the appearance of greater precision, and was one for which we had high hopes at the beginning of the project; however, our work in abstracting and analyzing the logbook records leads us now to doubt the reliability of this method. It was impossible either to estimate the amount of zig-zagging a ship might have done during the 24 hours between the recording of its positions (which usually occurred at noon) or to know about possible fluctuations in visibility, wind conditions or ice coverage during a 24-hour period when the logbook record usually included only the weather at the time of observation. A further limitation of this technique is that we could not distinguish visibilities greater than five miles with any precision and all visibilities of five miles or more are recorded merely as five miles.

As noted before, it is not possible to determine the ultimate fate of all whales that were judged to have been

Table 7

WKPUE determined using KPUE from the data sample and a weighting factor accounting for the percentage of type 2 whaling days[1]

Year	WKPUE	WKPUE/KPUE	Year	WKPUE	WKPUE/KPUE
1849	0.15285	0.95	1882	0.05305	0.94
1850	0.13988	0.98	1883	0.00509	1.00
1851	0.04846	0.99	1884	0.02028	1.03
1852	0.08709	0.99	1885	0.03767	1.03
1853	0.03820	1.02	1886	0.02457	1.00
1854	0.02217	1.00			
1855	0.00420	0.97	1887	0.03320	1.02
1856	0.00000	1.00	1888	0.02070	1.03
1857	0.08664	1.02	1889	0.00723	1.03
			1890	0.02019	1.04
1858	0.04605	1.01	1891	0.03784	1.02
1859	0.04263	0.99	1892	0.04375	1.02
1860	0.03620	1.00	1893	0.02087	1.03
1861	0.05732	1.02	1894	0.03391	1.02
1862	0.06060	0.99	1895	0.03764	1.03
1863	0.06563	1.00	1896	0.01904	1.03
1864	0.04764	0.99	1897	0.02146	1.02
1865	0.06267	1.01			
1866	0.04691	0.97	1898	0.07296	0.83
1867	0.04922	1.02	1899	0.08752	1.03
			1900	0.04898	0.99
1868	0.05417	0.99	1901	0.02027	0.98
1869	0.05498	1.00	1902	0.06954	1.02
1870	0.07598	1.00	1903	0.03320	1.01
1871	0.02772	0.98	1904	0.03317	1.03
1872	0.04498	1.01	1905	0.04714	1.01
1873	0.02575	0.97	1906	0.02885	1.04
1874	0.02824	1.01	1907	0.04122	1.02
1875	0.08125	0.99			
1876	0.02137	0.98	1908	0.01585	1.01
1877	0.07763	0.99	1909	0.01427	1.01
			1910	0.02760	1.01
1878	0.02161	0.99	1911	0.03346	1.00
1879	0.04634	1.00	1912	0.00000	1.00
1880	0.12574	1.01	1913	0.00000	1.00
1881	0.09815	0.98	1914	0.13106	0.90

[1] The weighting factor was based on the ratio of Type 2 days to readings in each year. 'Type 2 Days' were defined as days without extreme conditions of ice and wind. (Whales were apparently caught under all conditions of visibility). 'Readings' was the number of days for which all three conditions were recorded. The actual weighting factor was calculated as: (TYPE 2 DAYS/READINGS)/[AVG OF (TYPE 2 DAYS/READINGS) FOR 66 YRS]. This method weights years in which there were more Type 2 days more heavily; it weights the KPUE by applying the ratio of (TYPE 2 DAYS/READINGS) in each year to all records, including those in which all three conditions were not recorded (39% of all records).

struck and lost alive. We can consider the maximum effect these whales might have had on the population by assuming that all whales struck and lost alive later died. Adding these to the number known killed, we obtain a high estimate of the kill and we find that an unmodified simple DeLury method results in an estimate of the pre-exploitation bowhead population of 38,500 ± 12,692, a value slightly higher than our previous estimates.

Discussion of 1847 population estimates

With the DeLury method one is caught on the horns of a dilemma. The method assumes one is sampling from a closed population, and there are several ways that one can violate this assumption, including: the population has a significant density-dependent reproductive response, so that as the population is harvested the net recruitment rate increases; the population sampled is not the entire population; and the fraction of the population sampled varies over time, with immigration of the prey population and changes in the distribution of the whaling ships. Our approach was to attempt to use the method in a way that did least violence to the assumptions. This is not a simple task.

Length of data series used

Tillman, Breiwick, and Chapman (1983) argue that the appropriate time period to apply the DeLury method to the bowhead whale is for the first 7 to 10 years. They argue that 'it is only reasonable to apply this model to data obtained during the first t_r years of exploitation, where t_r is the average age at recruitment into the fishery'. The basis for this argument is first that the population is assumed to be sufficiently constant at the beginning of the harvesting to allow one to use the method at all. Second, it assumes that there is a strong density-dependent response of the net recruitment rate to a decrease in the population accompanying the harvesting. Third, it is assumed that this density-dependent effect will be strong enough so that the DeLury method will result in a significantly distorted estimate when applied to longer time periods. Fourth, it is also assumed that time lags in the population's response to displacement from the supposed equilibrium will have significant effects on population size.

While these effects are possible, it is also true that the shorter the time period, the less likely that enough data points will be involved to obtain a statistically significant regression line or to represent accurately the real trend for

Table 8

WKPUE determined using effort measured as the area viewed by ships in each year

Year	WKPUE	WKPUE/KPUE	Year	WKPUE	WKPUE/KPUE
1849	0.01746	0.11	1882	0.00440	0.08
1850	0.01654	0.12	1883	0.00103	0.20
1851	0.00780	0.16	1884	0.00339	0.17
1852	0.01068	0.12	1885	0.00644	0.18
1853	0.00574	0.15	1886	0.00366	0.15
1854	0.00282	0.13	1887	0.00609	0.19
1855	0.00055	0.13			
1856	0.00000	1.00	1888	0.00250	0.12
1857	0.02012	0.24	1889	0.00082	0.12
			1890	0.00594	0.31
1858	0.00470	0.10	1891	0.00472	0.13
1859	0.00488	0.11	1892	0.00421	0.10
1860	0.00305	0.08	1893	0.00144	0.07
1861	0.00618	0.11	1894	0.00298	0.09
1862	0.00920	0.15	1895	0.00346	0.09
1863	0.00822	0.13	1896	0.00216	0.12
1864	0.00602	0.13	1897	0.00256	0.12
1865	0.00639	0.10			
1866	0.00531	0.11	1898	0.01320	0.15
1867	0.00537	0.11	1899	0.01335	0.16
			1900	0.00873	0.18
1868	0.00564	0.10	1901	0.00390	0.19
1869	0.00654	0.12	1902	0.00622	0.09
1870	0.00910	0.12	1903	0.00472	0.14
1871	0.00295	0.10	1904	0.00895	0.28
1872	0.00606	0.14	1905	0.00669	0.14
1873	0.00382	0.14	1906	0.00327	0.12
1874	0.00411	0.15	1907	0.00819	0.20
1875	0.01264	0.15			
1876	0.00428	0.20	1908	0.00222	0.14
1877	0.00762	0.10	1909	0.00201	0.14
			1910	0.00581	0.21
1878	0.00173	0.08	1911	0.00554	0.17
1879	0.00849	0.18	1912	0.00000	1.00
1880	0.01188	0.10	1913	0.00000	1.00
1881	0.00838	0.08	1914	0.03279	0.23

the entire population. Tables 14–16 give the 1847 population estimates obtained with the DeLury method for every set of consecutive years (the first two, the first three, the first four, etc.). Indeed one can see from these tables that, with the first 7 to 10 years of data, the DeLury method results in very low values of R and R^2. For example, in Table 15, using years 1 to 8, the method accounts for only 7% of the variation ($R^2 = 0.07$); using years 1 to 10, only 17% of the variation is accounted for.

A rule of thumb for the use of regression analysis is that, even for statistically significant relationships (that is, when the F test is significant), the regression is only meaningful and worth reporting when the R^2 is close to 0.50, meaning that near to 50% or more of the variation is accounted for. For example, Breiwick (1978) used 'highest R^2 (percent variation explained by the regression) and largest sample size' as criteria for selecting the best fit. As can be seen from Tables 14–16, by the time R^2 approaches 0.45 or 0.5, the estimates of the original population are approximately 20,000 or greater. The exact value depends on which measure one uses for whales killed: the catch (Table 14); the reported kill, the catch plus those reported struck and lost dying (Table 15); or the upper bound of the kill, the reported catch plus all struck and lost, both lost dying and lost alive (Table 16).

Another consideration in our analysis was the changes in the distribution of the catch and kill over time which indicated that the whaling ships found new geographical areas that were previously unexploited (Fig. 11). These areas apparently were either refuges to which the whales fled to avoid pursuit in the areas they had previously occupied, or pockets of essentially isolated sub-populations. If the latter were the case, then it would not be legitimate to assume that the reductions observed in the first 7 to 10 years could be used as a basis for an estimate for the entire population. If the first were true, one would still expect that there were whales in the previously unexploited areas that could not be considered part of the population hunted in the first 7 to 10 years. Again, the use of this short period alone would violate the assumption that one had a closed population. One would expect that a DeLury method estimate for the first 7 to 10 years, when only part of the bowhead habitat was being exploited, would be less than that in the final estimate, and this is exactly what one finds. That is, the DeLury estimates reported by Tillman *et al.* (1983) are consistent with the idea that the whales hunted during the first ten years were only part of the bowhead whale population.

It is instructive to consider the time series of DeLury method regressions (Tables 14–16) and compare them with the changes in the geographic distribution of the ships and the kill (Fig. 11) and with the changes in total catch and kill by decade (Figs 9 and 10). Considerable economic and social change impinged on the bowhead fishery during the first decade. Part of the bowhead whaling area was discovered in 1848, was rapidly

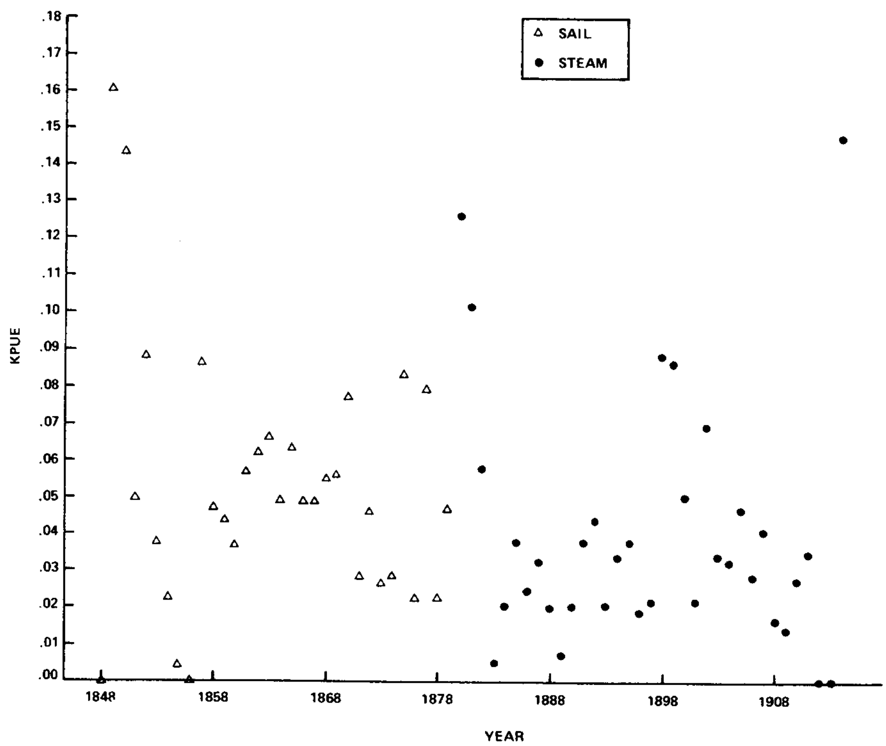


Fig. 15. KPUE from the data sample versus time, where SAIL indicates sailing ship effort only and STEAM indicates both sailing and steam ship effort.

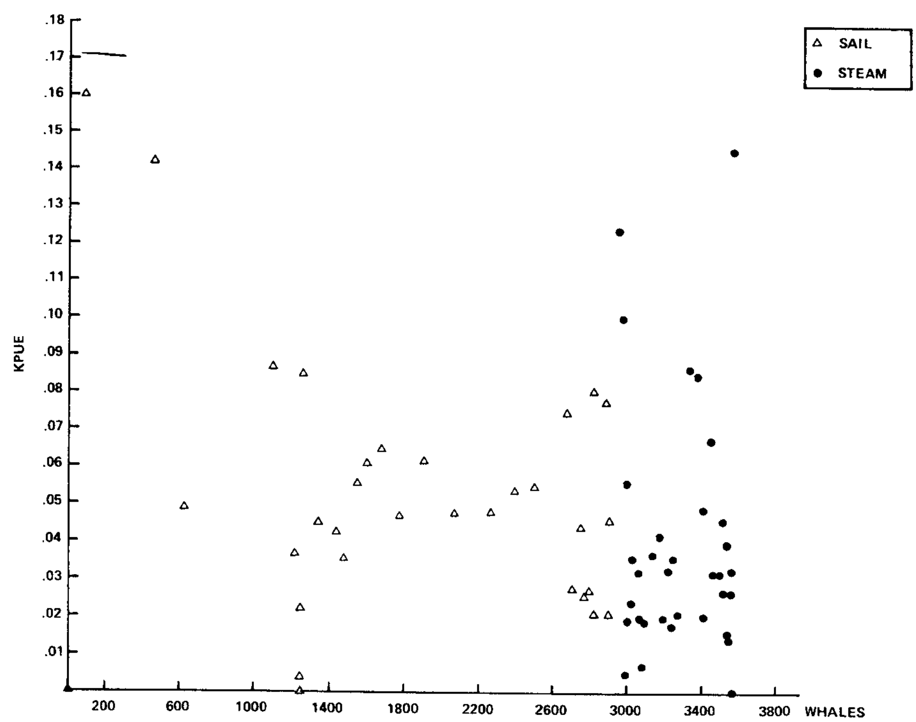


Fig. 16. KPUE versus cumulative kill, where SAIL indicates sailing ships only and STEAM indicates both sailing and steam ships.

exploited during the next few years, and was apparently depleted. Then there was a rapid temporary decrease in the whaling activity. It is not surprising therefore that the regression analysis shows a great deal of variation, since the catch per unit effort changed rapidly during this period. This is consistent with the observation that the R^2 reaches its minimum value for estimates during the period of 7 to 10 years from the beginning.

Density-dependent, time-lagged recruitment

We have also examined the possibility of whether a strong density-dependent relationship between recruitment and population size and the occurrence of time lags would have a large effect on our results. Because so little is known about the life history and population dynamics of bowhead whales, such considerations are highly specula-

Table 9

Unmodified DeLury method estimates of the 1847 bowhead whale population

Measure of catch or kill	Measure of effort	Population estimate 95% confidence interval	R	F
Cumulative catch	Total days	34,255 ± 15,764	0.69	5.37
Cumulative kill	Total days	32,653 ± 11,677	0.68	9.34
Cumulative kill + struck and lost alive	Total days	35,837 ± 9,546	0.67	17.85
Cum. weighted catch	Total days	31,837 ± 13,701	0.69	6.21
Cum. weighted kill	Total days	30,843 ± 10,396	0.68	10.65
Cum. wtd. kill + struck and lost alive	Total days	38,500 ± 12,692	0.69	11.27
3-year moving avg. of cum. wtd. kill	Total days	37,172 ± 12,828	0.80	9.30
3-year moving avg. of cum. wtd. kill	Total days	34,734 ± 9,293	0.79	16.23
3-year moving avg. of cum. wtd. kill + struck and lost alive	Total days	43,574 ± 11,533	0.80	16.79

Table 10

Estimates of the 1847 bowhead population using Chapman's modified DeLury method[1]

M	Weighted catch	Weighted kill	Weighted kill plus struck and lost alive
0.00	28,660 (5.7)	29,293 (9.9)	31,966 (18.5)
0.01	18,728 (7.8)	19,214 (13.1)	21,601 (24.4)
0.02	13,301 (9.4)	14,370 (14.5)	16,072 (24.2)
0.03	10,643 (8.7)	11,619 (11.1)	14,130 (14.4)
0.04	9,504 (6.1)	10,869 (6.4)	13,511 (6.4)
0.05	8,943 (3.9)	10,496 (3.4)	13,184 (2.7)
0.06	8,242 (2.5)	9,014 (1.8)	6,618 (1.1)
0.07	6,889 (1.7)	4,219 (1.0)	0 (0.0)
0.08	4,574 (1.2)	0 (0.0)	0 (0.0)

[1] Each estimate is followed by the value of F enclosed in the parentheses. $F \geqslant 4$ is significant at the 95% level; $F \geqslant 7$ at the 99% level.

Table 11

q method estimates of the 1847 bowhead population

M	Weighted catch	Weighted kill	Weighted kill plus struck and lost alive
0.00	67,722	60,886	59,503
0.01	36,304	32,761	32,053
0.02	22,155	20,890	21,493
0.03	17,452	18,364	21,372
0.04	17,872	21,442	28,743
0.05	20,962	28,098	43,063
0.06	25,296	37,242	66,207
0.07	30,030	48,315	—
0.08	34,683	—	—

Table 12

Estimates of the 1847 bowhead population using Allen's modified DeLury method

A. Assuming constant recruitment (No lag or density dependence)

M	R	Population
0.08	0.08	21,153
0.08	0.055	38,447
0.08	0.03	47,049
0.055	0.08	14,570
0.055	0.055	20,602
0.055	0.03	34,752
0.03	0.08	11,356
0.03	0.055	14,303
0.03	0.03	20,077

B. Using Allen's model of recruitment rate ($M = 0.04$ $R_0 = 0.03$ $N_I = 30{,}000$)

Lag	Population
0	25,169
1	21,086
2	22,360
3	23,428
4	23,613
5	23,389
6	23,947
7	23,951
8	24,240
9	24,702
10	24,529
15	25,486
20	26,535

tive. Ideally, one would want to construct a model of the population that included age and sex structure, because for any long-lived species such structure may have important effects on the long term and short term expectations for the populations (Wu and Botkin, 1978). However, almost all the information about the bowhead required to construct such a model with any accuracy is lacking. Therefore we resorted to very simple methods and developed the following model:

Given an initial population of N_0, a rate of increase of r and a lag time in years, lag, this model calculates the annual change in population in year t due to causes other than pelagic hunting as:

$$\Delta N_t = N_{t-1} r(1-(N_{t-\text{lag}}/N_0)).$$

The population in year t is then calculated by adding the annual change, ΔN_t, and subtracting the number of whales estimated to have been killed in that year:

$$N_t = \Delta N_t + N_{t-1} - \text{HUNTING}_t$$

where HUNTING_t is the appropriate value from the time series of weighted catch (WCATCH), weighted kill (WKILL) or weighted sum of kill and whales struck and lost alive

Table 13

Unmodified DeLury method estimates of the 1847 bowhead whale population using corrected measures of effort

Measure of catch or kill	Measure of effort	Population estimate 95% confidence interval	R	F
Cum. weighted kill	No. of Type 1 whaling days	27,374 ± 10,138	0.58	9.24
Cum. weighted kill	Percentage of Type 1 whaling days[1]	29,216 ± 8,854	0.67	13.44
Cum. weighted kill	No. of Type 2 whaling days	30,519 ± 10,272	0.67	10.72
Cum. weighted kill	Percentage of Type 2 whaling days[2]	30,899 ± 10,085	0.69	11.35
Cum. weighted kill	Days × area visible	41,197 ± 25,434	0.68	2.93
Cum. weighted kill	Total days weighted by area visible.	18,573 ± 3,711	0.34	39.68

[1] See Table 5, footnote 1. [2] See Table 7, footnote 1.

Table 14

DeLury method estimates of initial bowhead population size for all consecutive sets of years, using weighted catch

Years included	Population estimate	R^2	F	Years included	Population estimate	R^2	F
2	2,988	0.41	0.0	34	34,718	0.55	1.5
3	3,141	0.12	6.3	35	29,625	0.52	2.4
4	4,729	0.23	6.7	36	27,539	0.51	3.0
5	6,032	0.16	11.7	37	27,431	0.51	3.3
6	6,375	0.12	21.3	38	26,434	0.50	4.0
7	6,205	0.08	36.1	39	26,050	0.49	4.4
8	6,126	0.06	51.7	40	25,102	0.48	5.2
9	7,031	0.14	15.5	41	23,761	0.46	6.4
10	7,342	0.17	16.1	42	23,300	0.46	7.2
11	7,667	0.19	16.5	43	23,596	0.46	7.4
12	7,943	0.21	17.5	44	24,134	0.46	7.4
13	8,492	0.25	14.9	45	23,787	0.46	8.2
14	9,151	0.29	12.3	46	23,935	0.46	8.6
15	9,862	0.33	10.3	47	24,297	0.46	8.7
16	10,246	0.35	10.5	48	23,948	0.46	9.6
17	10,787	0.37	10.1	49	23,743	0.45	10.4
18	11,336	0.39	9.8	50	25,857	0.47	8.0
19	12,002	0.40	9.4	51	28,411	0.49	6.1
20	12,870	0.42	8.6	52	29,405	0.50	5.8
21	13,917	0.44	7.8	53	28,811	0.49	6.5
22	16,133	0.47	5.3	54	30,746	0.50	5.6
23	16,097	0.46	6.3	55	30,755	0.50	5.9
24	16,632	0.46	6.6	56	30,614	0.50	6.2
25	16,601	0.45	7.6	57	31,222	0.51	6.2
26	16,663	0.45	8.6	58	30,973	0.51	6.6
27	19,218	0.48	5.6	59	31,394	0.51	6.6
28	18,486	0.46	6.9	60	30,571	0.50	7.4
29	20,649	0.49	5.2	61	29,790	0.50	8.2
30	19,967	0.48	6.3	62	29,639	0.50	8.7
31	20,197	0.48	6.7	63	29,752	0.50	8.9
32	26,065	0.51	2.8	64	28,624	0.48	10.1
33	32,177	0.54	1.7	65	27,674	0.47	11.2
				66	31,837	0.48	6.2

(WSKILL). This process continues until the entire data set has been used (66 years) or the population is driven to extinction by the hunting removals.

The assertion that only the first 7 to 10 years of the whaling record should be used essentially implies that one assumes that the population was close to a stable condition prior to the whaling (and therefore approximated a closed population), and that there is a strong density-dependent effect. As this is similar to the assumptions for a logistic equation, we have used a logistic model with a time lag to study the implications of such assumptions. For the model we have used, the time lag is variable, and we have considered lags of zero (no lag) to 10 years. We have used values for r, the net recruitment rate, which are very optimistic for a large long-lived mammal. As has been shown elsewhere, any long-lived species with calving intervals on the order of four years or greater is unlikely even under the best conditions to have a net recruitment rate of more than 5% (Wu and Botkin, 1980).

The intuitive motivation for this statement is as follows: if the sex ratio is even, and females reproduce every four years, only $\frac{1}{8}$ would reproduce in any year (16%). But when there is a long prepuberty period, and a considerable fraction of the population is immature, the actual fraction of the females in the population available

Table 15

DeLury method estimates of initial bowhead population size for all consecutive sets of years, using weighted kill

Years included	Population estimate	R^2	F	Years included	Population estimate	R^2	F
2	5,016	0.44	0.0	34	31,123	0.53	3.2
3	3,798	0.13	6.1	35	28,198	0.51	4.3
4	5,882	0.24	5.7	36	27,026	0.49	5.2
5	7,509	0.17	10.7	37	26,990	0.49	5.6
6	7,878	0.13	20.5	38	26,394	0.48	6.4
7	7,691	0.10	34.7	39	26,283	0.48	7.0
8	7,542	0.07	49.9	40	25,685	0.47	8.0
9	8,562	0.14	17.6	41	24,721	0.45	9.4
10	8,884	0.17	18.9	42	24,348	0.45	10.5
11	9,218	0.19	19.9	43	24,582	0.45	10.8
12	9,473	0.20	21.7	44	25,009	0.45	10.9
13	10,002	0.24	19.4	45	24,739	0.45	12.0
14	10,618	0.27	16.8	46	24,905	0.45	12.5
15	11,272	0.31	14.6	47	25,169	0.45	12.8
16	11,646	0.33	14.9	48	24,903	0.44	14.0
17	12,348	0.36	13.3	49	24,743	0.44	15.1
18	12,876	0.37	13.2	50	26,434	0.46	12.0
19	13,486	0.39	12.9	51	28,278	0.47	9.8
20	14,363	0.40	11.8	52	28,945	0.48	9.6
21	15,346	0.42	10.7	53	28,552	0.47	10.5
22	17,164	0.45	8.0	54	29,880	0.49	9.4
23	17,219	0.44	9.2	55	29,892	0.49	9.9
24	17,893	0.45	9.4	56	29,897	0.49	10.3
25	17,852	0.43	10.8	57	30,412	0.49	10.3
26	17,890	0.43	12.1	58	30,251	0.49	10.9
27	19,759	0.46	9.0	59	30,529	0.49	11.1
28	19,433	0.44	10.4	60	29,993	0.49	12.1
29	21,183	0.47	8.3	61	29,473	0.48	13.1
30	20,763	0.46	9.6	62	29,373	0.48	13.8
31	21,277	0.47	9.7	63	29,452	0.48	14.2
32	25,422	0.50	5.0	64	28,677	0.47	15.6
33	29,795	0.53	3.2	65	28,006	0.45	17.0
				66	30,843	0.46	10.7

for conception is much smaller. Since calving intervals in reality are often longer, and since females die while pregnant, the upper bound on an expected recruitment rate is certainly below 10%, and rarely as much as 5%.

Using this model, a variety of cases have been considered (Table 17). In each case the initial population level was chosen as the carrying capacity for the model. As can be seen from Table 17, even when $r = 0.07$, if the initial population of the bowhead were 10,000 and the population were harvested as reported, then under all conditions the population would become extinct, with or without density dependency, with or without time lags of 7 or 10 years.

When the initial population is 20,000, the population usually persists under the reported hunting pressure. The predicted absolute abundance differs with different time lags and recruitment rates, but the qualitative result does not change with the addition of a strong density-dependent relationship or a strong time lag.

These results suggest that, for a population like the bowhead whale, the effects of density dependency and time lags will not affect the important qualitative outcomes. Thus on the basis of the simulation results as well as the results of the other considerations discussed earlier, we conclude that less violence is done to the assumption of a closed population by using the entire data set and thereby encompassing all the whales in the known range of the bowhead, than by restricting the estimate to a part of that population in order to avoid the effects of changes in recruitment.

One might prefer, considering our discussion to this point, to use the DeLury estimates for the shortest time periods that give reasonable values of F and R^2. Even so, the result would be that the estimate of the original population is 20,000 or greater.

In summary, we have estimated the pre-exploitation size of the western Arctic bowhead population with the unmodified and modified DeLury methods, using a variety of estimates of catch and kill and of effort. The range of these estimates overlap for the most part and suggest that reasonable bounds for the original number are no less than 20,000 and no more than 40,000, with an average number of approximately 30,000.

The decline of the bowhead whale

Our data indicate that the bowhead whale suffered a decline both in absolute numbers and in the average size of an individual whale during the pelagic whaling period. In the following sections we discuss the significance of these declines and their possible interrelationship.

Changes in size of whales caught

The direct observations of the numbers of whales caught and the distribution of the catch demonstrate that pelagic whaling operations rapidly depleted the number of bowhead whales. However, pelagic whaling operations may have had other effects on the whale population. It has been speculated that pelagic whaling would tend to alter the age and size distribution of a population, because the ships would tend to take larger whales and those whales that are more easily approached and taken,

Table 16

DeLury method estimate of initial bowhead population size for all consecutive sets of years, using the weighted sum of kill plus whales struck and lost alive

Years included	Population estimate	R^2	F	Years included	Population estimate	R^2	F
2	9,097	0.46	0.0	34	32,450	0.51	7.1
3	5,333	0.14	1.2	35	30,662	0.48	8.8
4	8,601	0.27	5.0	36	30,236	0.48	9.9
5	10,794	0.19	10.7	37	30,397	0.48	10.5
6	11,289	0.15	21.0	38	30,010	0.47	11.7
7	10,814	0.11	35.9	39	29,944	0.47	12.6
8	10,533	0.08	51.6	40	29,582	0.46	14.0
9	11,847	0.15	20.4	41	28,861	0.44	15.9
10	12,257	0.17	22.0	42	28,591	0.43	17.4
11	12,708	0.19	23.1	43	28,832	0.43	18.0
12	12,989	0.21	25.7	44	29,182	0.44	18.3
13	13,526	0.23	24.9	45	28,933	0.43	19.9
14	14,283	0.27	21.5	46	29,068	0.43	20.8
15	15,073	0.30	18.7	47	29,419	0.43	21.1
16	15,506	0.32	19.2	48	29,284	0.43	22.6
17	16,361	0.35	17.0	49	29,162	0.42	24.1
18	16,957	0.36	17.0	50	30,769	0.44	19.3
19	17,656	0.37	16.8	51	32,093	0.45	17.0
20	18,525	0.39	16.0	52	32,511	0.46	17.1
21	19,474	0.40	15.2	53	32,196	0.45	18.4
22	21,142	0.43	12.2	54	33,239	0.46	17.0
23	21,499	0.42	13.4	55	33,228	0.46	17.8
24	22,227	0.43	13.6	56	33,348	0.46	18.4
25	22,141	0.42	15.6	57	33,842	0.47	18.3
26	22,209	0.41	17.3	58	33,748	0.47	19.2
27	23,672	0.43	14.5	59	33,869	0.47	19.8
28	23,479	0.42	16.4	60	33,691	0.46	20.9
29	25,130	0.45	13.3	61	33,570	0.46	21.9
30	24,772	0.44	15.1	62	33,441	0.46	23.0
31	26,010	0.45	13.5	63	33,543	0.46	23.6
32	29,252	0.48	8.6	64	32,949	0.45	25.5
33	31,744	0.51	7.0	65	32,421	0.44	27.3
				66	34,316	0.45	20.1

Table 17

Simulated bowhead population declines using density-dependent, time-lagged recruitment model. Tabulated are the population sizes occurring at the end of the 67-year period of pelagic whaling (or year of extinction), given various initial stock sizes (N_0), kill measures, time lags and net recruitment rates (r)

N_0	Kill measure	Estimated population size at end of whaling era for three given time lags		
		0	7	10
		$r = 0.03$		
10,000	WSKILL[1]	0 (yr 11)[3]	0 (yr 11)	0 (yr 11)
	WKILL[2]	0 (yr 20)	0 (yr 19)	0 (yr 19)
20,000	WSKILL	3,435	0 (yr 63)	0 (yr 51)
	WKILL	10,588	9,237	8,393
		$r = 0.05$		
10,000	WSKILL	0 (yr 11)	0 (yr 11)	0 (yr 11)
	WKILL	0 (yr 22)	0 (yr 19)	0 (yr 19)
20,000	WSKILL	11,895	8,393	5,029
	WKILL	15,517	15,224	14,785
		$r = 0.07$		
10,000	WSKILL	0 (yr 12)	0 (yr 11)	0 (yr 11)
	WKILL	0 (yr 24)	0 (yr 20)	0 (yr 19)
20,000	WSKILL	16,612	16,549	15,183
	WKILL	17,880	18,575	19,172

[1] WSKILL = weighted sum of kill plus whales struck and lost alive.
[2] WKILL = weighted kill.
[3] Year in which extinction occurred.

such as mothers with calves. If this were true, pelagic whaling might suppress the reproductive potential of a whale population more than would be indicated by a change in numbers alone. This effect might take place if the individuals with greatest reproductive potential were removed at a greater rate than the rest of the population.

Although there is no direct evidence of Arctic whalemen consciously selecting one whale over another (apart from the closest one), it may have been that certain classes of bowheads were, in general, more available to the pelagic whalers. The logbook data provide us with some insight into this question, because frequently (but not always) the logbooks contained records of the barrels of oil obtained from the whales they processed. From these one can calculate the average number of barrels of oil per whale for each year. A significant decrease in the oil yield per whale observed over the whaling era would suggest a decrease in the average size of the whales, as well as in the relative abundance of older members of the population.

Table 18 gives the barrels of oil and the number of whales by year (for those instances when both were given). The table also includes the average barrels per year and, for later reference, the price per barrel and the total average value of a whale.

The number of barrels per whale declines, particularly until 1874, after which the data are rather sparse. A linear regression of the average barrels of oil per whale versus the year indicates a statistically significant decline of 0.6 barrels/whale/year (Table 19). Since we have no reason

Table 18

Bowhead oil production and price by year[1]

Year	Barrels	Whales	Barrels/ whale	Dollars/ barrel	Dollars/ whale
1849	245	2	122.5	12.28	1,505
1850	4,052	31	130.7	15.44	2,018
1851	4,330	36	120.3	14.17	1,705
1852	6,855	56	122.4	21.42	2,622
1853	3,088	23	134.3	18.27	2,453
1854	373	3	124.3	18.74	2,330
1855	0	0	0.0	22.36	0
1856	0	0	0.0	25.04	0
1857	0	0	0.0	22.99	0
1858	1,412	13	108.6	17.01	1,848
1859	2,274	19	119.7	15.28	1,828
1860	1,151	10	115.1	15.59	1,795
1861	860	8	107.5	13.86	1,490
1862	100	1	100.0	18.58	1,858
1863	431	4	107.8	29.92	3,224
1864	824	7	117.7	40.32	4,746
1865	432	7	61.7	45.67	2,819
1866	1,918	19	100.9	38.11	3,848
1867	3,829	40	95.7	22.99	2,201
1868	365	4	91.3	25.83	2,357
1869	870	10	87.0	31.81	2,768
1870	772	8	96.5	21.10	2,037
1871	0	0	0.0	21.73	0
1872	0	0	0.0	20.63	0
1873	0	0	0.0	19.53	0
1874	372	4	93.0	19.06	1,772
1875	127	1	127.0	20.47	2,600
1876	0	0	0.0	19.21	0
1877	851	8	106.4	16.38	1,742
1878	0	0	0.0	13.86	0
1879	0	0	0.0	12.28	0
1880	291	2	145.5	16.06	2,337
1881	0	0	0.0	15.12	0
1882	460	4	115.0	16.85	1,938
1883	70	1	70.0	17.01	1,191
1884	111	1	111.0	17.64	1,958
1885	0	0	0.0	14.17	0
1886	0	0	0.0	10.40	0
1887	234	2	117.0	10.08	1,179
1888	0	0	0.0	11.03	0
1889	0	0	0.0	11.97	0
1890	0	0	0.0	13.23	0
1891	80	1	80.0	14.80	1,184
1892	129	2	64.5	13.39	863
1893	135	1	135.0	13.39	1,807
1894	0	0	0.0	10.24	0
1895	130	2	65.0	8.82	573
1896	147	2	73.5	11.03	810
1897	0	0	0.0	11.65	0
1898	0	0	0.0	10.71	0
1899	0	0	0.0	11.03	0
1900	105	1	105.0	11.65	1,224
1901	0	0	0.0	11.97	0
1902	0	0	0.0	11.65	0
1903	0	0	0.0	11.34	0
1904	0	0	0.0	9.76	0
1905	0	0	0.0	10.40	0
1906	0	0	0.0	11.65	0
1907	0	0	0.0	10.08	0
1908	0	0	0.0	9.76	0
1909	0	0	0.0	11.97	0
1910	0	0	0.0	11.97	0
1911	0	0	0.0	11.34	0
1912	0	0	0.0	11.03	0
1913	0	0	0.0	6.93	0
1914	0	0	0.0	2.83	0

[1] Sources for economic data: Tower (1907); Hegarty (1959).

Table 19

Regression of barrels per whale on year

Intercept	119.52
Regression coefficient	−0.61269
Standard error of regression coefficient	0.23525
Computed T-value	−2.6044
Correlation coefficient	−0.4237
Standard error of estimate	20.121

Analysis of variance for the regression

Source of variation	D.F.	Sum of squares	Mean squares	F-value
Attr. to regression	1	2,746.138	2,746.138	6.783
Dev. from regression	31	12,550.832	404.866	
Total	32	15,296.970		

to believe that the change in size caught is due to a change in the kind of whale sought by whalers, the change appears to be related to the population, not to the effort. Thus the data suggest that pelagic whaling did cause a change in the age structure of the population, ie., a shift towards smaller and presumably younger individuals.

From analogy with other large mammals one can speculate that the shift from larger to smaller whales would tend to have a negative effect on reproductive potential. For example, such a shift might cause a decrease in the reproductive potential of the population, which in turn would hamper the ability of the population to recover after the period of pelagic whaling. However, too little is known about the social behavior, age at first breeding and other aspects of the bowhead whale to do more than speculate about the effect of this reduction in average size of whales.

The decline of the bowhead population

Estimating the changes in the relative abundance of the bowhead from 1848 to 1914 is the most difficult of all tasks we have attempted. If the life-history characteristics of the bowhead whale were known accurately, including accurate measures of longevity, age at first breeding, calving intervals, the rates and sources of mortality, and changes in birth and death rates with changes in population density, then estimating the changes in the size of the bowhead population would be a relatively straightforward problem. One would need merely to take the population size at the beginning of each year, calculate the number of births and number of deaths due to causes other than to pelagic whaling operations, subtract from that the number of whales killed as a result of pelagic whaling operations, then obtain an estimate of the population size at the beginning of the next year. Unfortunately, the bowhead is among the least studied of all large mammals, and we know little if anything about any of its primary life-history characteristics. This lack of information forces us to use indirect methods to gain insight into change in the relative abundance of the bowhead during the period of pelagic whaling.

If one assumes that the number of whales killed was directly proportional to the abundance, then Fig. 8 and Table 1 suggest that the population decreased rapidly, dropping to two-thirds of its original size by 1858 and one-third by 1868. Biological phenomena are rarely simple, however, and it is possible that the decrease in the whales caught was not only the result of a decrease in the population but also of an increase in the ability of the whales to avoid being caught.

Because recent studies (Braham *et al.*, 1979; Evans and Underwood, 1978) indicate that the present size of the western Arctic bowhead population is approximately 2,000 to 3,000, our estimates suggest that the current population is approximately 5–15% of its size in 1847.

Our estimates of the 1847 bowhead population average approximately 30,000 with limits of the range of reasonable estimates being 20,000 to 40,000. Given the amounts of harvesting by pelagic whaling vessels, one might query under what conditions of birth and mortality from other sources is it reasonable to expect that the bowhead whale population declined to a size of approximately 3,000 by 1915.

As previously noted so little is known about the life history characteristics of the bowhead that it was not reasonable to use complex age structure models to test the consequences of our data. Lacking information of this kind, we have chosen to examine the consequences of whaling on a hypothetical population characterized by a given initial population size, constant birth and natural mortality rates, and the annual catch and kill as determined from our study.

Using a range of reasonable values for recruitment and natural mortality rates for great whales, it is informative to determine whether a population subject to any values within this range, and subject to the annual kill that we have reported, could have declined from a size of 30,000 in 1847 to a population close to its estimated abundance of 3,000 in 1915.

Fig. 17A shows that a population of 30,000 animals with a recruitment of 3% and annual mortality of 3%, with no time lags or density dependent responses, would have declined under our reported annual kill from 30,000 to less than 12,000 by 1915, and that the same population in which all animals struck and lost alive also died would have declined to approximately 6,000 by 1915.

For comparison, Fig. 17B shows the results of the simulation when a starting population of 40,000 is used; Figs 17C and 17D show simulations using annual mortality of 4% and recruitment of 3%; and Figs 17E and 17F show simulations using mortality of 3% and recruitment of 4%. The latter two cases, with a 1% excess of recruitment over mortality, result in a decline followed by an increase after the pelagic whaling era when the kill or the kill plus whales struck and lost alive are subtracted – but no evidence of such recovery has been noted in the natural population. In the cases where mortality exceeds recruitment by 1%, a starting population of 30,000 (Fig. 17C) declines to about 4,000 animals, if the kill is added to natural mortality, and is near extinction if the struck and lost alive are also considered to have died; while a starting population of 40,000 (Fig. 17D) declines to levels very close to those reached under balanced recruitment and mortality (Fig. 17A) by a population of 30,000.

It is interesting to note that a population with recruitment equal to mortality from sources other than pelagic whaling would not have suffered a decline to 3,000 by 1915 if it began with a population size of 30,000 in 1847 and was subjected to the harvest amounts per year that we have given. For such a simple, hypothetical population some excess of mortality from other sources over recruitment is required in addition to pelagic whaling. However it should also be noted that the extremely simple model used here is the most optimistic one; any more complex model that involved time lags or the effects of sex and age structure would give estimates equal to or less than those given here for the decline in a hypothetical population.

During the span of time covered by our data sample (1849–1914) bowheads were also being taken from the population by Eskimos and by commercial shore-based

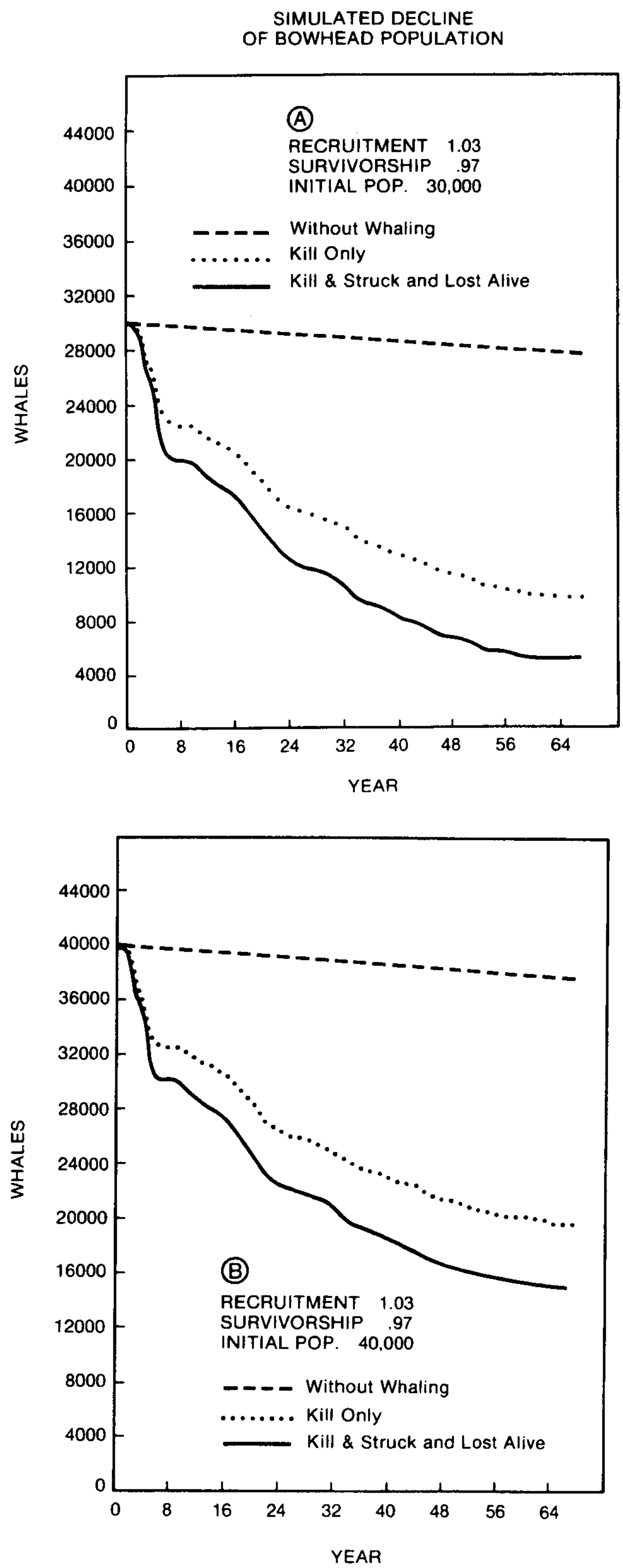


Fig. 17. Simulated decline of the bowhead population, given different initial population sizes, constant rates of recruitment and natural mortality and time series of whaling removals.

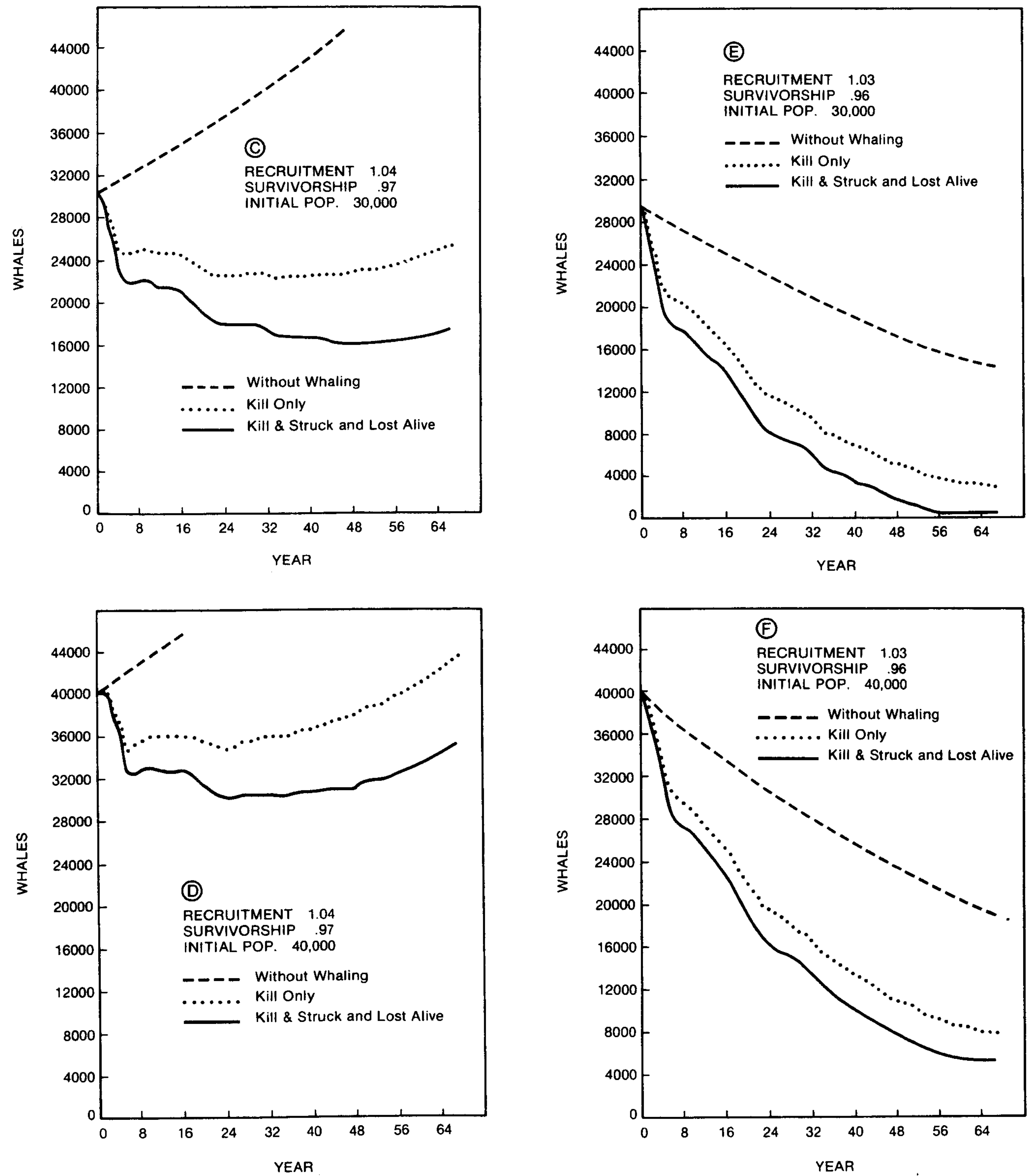


Fig. 17 (*cont.*)

whaling crews (see, for instance, Marquette and Bockstoce, 1980). It is regrettable, however, that, at present, these data are incomplete for the period of our data sample, and hence it would be misleading to incorporate them in this report. It is enough to state that, although the shore-based bowhead kill was a small proportion of the pelagic bowhead kill, it was significant, and future projects should plan to analyze closely the shore-based kill and to amalgamate it with the pelagic data presented here.

Because of the kills from shore-based operations, we must consider cases in which the mortality rate exceeded the recruitment rate. As Fig. 17E shows, a population in which the mortality was 4% and recruitment 3% per year would have declined under our reported kill from 30,000 in 1848 to approximately 4,000 in 1915; and a population in which all whales struck and lost alive by the pelagic fishery also died would have declined to less than 200 whales. (Such a population, not subject to pelagic whaling, would have declined to only 16,000.)

If the pre-exploitation population of bowheads was closer to the upper bounds of our estimates, approximately 40,000 individuals, then such a population with a 3% recruitment rate and 4% mortality rate would have declined to approximately 8,000 if all struck and lost whales died. Such a population not subject to pelagic whaling would have declined to 24,000 by 1915 (Fig. 17F).

Future research

Although the study has produced significant and far-reaching results, we feel that two areas in particular must now be analyzed to give our report its fullest utility. The present state of understanding of the historical shore-based kill is, at best, preliminary. With competent analysis and more thorough research of ephemera it should be possible to obtain a reliable estimate of the changing kill and hunting effort in the period from 1848 to 1914. Such an investigation would complement the data presented in this report and allow a thorough understanding of the total historical bowhead kill.

Second, there is a need for further modeling of the bowhead whale population decline. As we have noted, little is known about the life history of this species, or any of the important population parameters. For that reason, only the simplest of population models was applied in this report. However, we have developed an age-structured, stochastic model for whales that allows great flexibility. It would be instructive to employ this model with a range of reasonable parameter values to learn under which sets of parameters a decline from 30,000 to 3,000 whales could be expected during the 67-year period of pelagic whaling.

SUMMARY

We have carried out a study of the history of the bowhead whale during the period of pelagic whaling, from 1848 to 1914, using as our primary source of information the extant logbooks from whaling ships. From the logbooks we have obtained daily observations of the locations of each ship; its local weather; its reports of whales seen; its hunting procedure, kill and catch. From these we have calculated several measures of hunting effort, including the number of ship-days whaling, the number of ship-days whaling corrected for weather conditions under which whaling was not possible, and the number of ship-days whaling corrected for the area of ocean visible each day. These estimates of catch, kill and effort have been used to estimate the 1847 pre-exploitation population of bowheads. Our results suggest that the population numbered approximately 30,000, and was no less than 20,000 and no more than 40,000.

The data also demonstrate that a statistically significant decrease occurred in the size of the average whale taken during the period of pelagic whaling. We speculate that this change in size of the average whale caught implies a change in the size and age structure of the population, and could have indirect effects on the bowheads' reproductive and mortality rates.

Our data also show that the whales were progressively eliminated from large parts of their original range, and that the rate of reduction was on the order of 3° latitude per decade. We speculate that, if the whales permanently abandoned large areas of their former feeding grounds, the ability of the population to increase may have been greatly impaired, or that any increase toward the pre-exploitation size of the population might take much longer than would be expected simply from typical reproductive and survivorship values for great whales.

Our analysis indicates that 16,600 whales were taken and 18,650 killed during the 67-year period of pelagic whaling. The kill would have greatly reduced a simple, hypothetical whale population which had been in steady-state (with births equal to non-hunting sources of mortality). However, some additional sources of mortality or decrease in reproduction would be required for such a population to be reduced from 30,000 to the present estimates of the population size, which are on the order of 3,000. Possible additional sources of mortality include shore-based whaling stations, not analyzed by our study, and aboriginal hunting. In addition, the indirect effects of whaling, ie., the decrease in the range and changes in the age structure, may have also reduced the net growth potential of the population.

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Appendix 1
POPULATION ESTIMATES USING THE DELURY METHOD

In the Leslie and unmodified DeLury methods, a population estimate is obtained from the catch and effort data alone (Leslie and Davis, 1939; DeLury, 1947). The catch per unit effort (CPUE) in successive years is plotted against the accumulated catch; a least-squares linear regression line is fitted to the points and extrapolated to CPUE = 0; and the intercept on the accumulated catch scale gives an estimate of the initial population size.

The model may be written as:

$$U_t = kN_0 - kC_t \qquad (1)$$

where U_t = CPUE in season t
C_t = accumulated catch to season t
k = proportion of population captured by one unit of effort when $t = 0$
N_0 = initial population size

The least-squares estimate of the initial population size is then obtained by solving (1), which is equivalent to a linear regression of the form ($y = a - bx$), using standard regression methods (Draper and Smith, 1966). The population estimate is then given by:

$$N_0 = [a/b]$$

Alternatively, the logarithm of the CPUE may be plotted against the accumulated units of effort. This form of the method, due to DeLury (1947) is then written:

$$\log[U_t] = \log[kN_0] - k(\log_{10} e)\, U_t \qquad (2)$$

and a regression line is fitted as before. The population is given by:

$$N_0 = \frac{|\text{antilog}\,(a)|}{b/\log_{10} e}$$

The variance of N_0 is estimated as

$$\text{Var}\,(N_0) = (1/b^2)\ \text{Var}\,(a) + (a^2/b^4)\,\text{Var}\,(b) + 2\,(a/b^3)\,\text{Cov}\,(a, b)$$

using the 'delta method' of Seber (1973). Since the estimate of N_0 may be statistically biased, a correction factor, also due to Seber, is calculated as:

$$\text{estimated bias} = -\bar{Y} S^2_{y/x} / (b^3 \sum_{i=1}^{n} (X_i - \bar{X})^2$$

where $\bar{Y}$ = mean value of CPUE
$S^2_{y/x}$ = variance about linear regression
$\bar{X}$ = mean value of cumulative catch
n = number of seasons

The estimated bias is subtracted from the estimate of N_0 if it exceeds 10% of the magnitude of the standard deviation of N_0. An approximate 95% confidence interval may then be estimated as

$$N_0 \pm t[\text{Var}\,(N_0)]^{\frac{1}{2}}$$

where t is the 95% upper tail value of the t-distribution with $(n-2)$ degrees of freedom.

In this report we have not used the logarithmic form (2) of the model; according to Caughley (1977) it has the same constraints and can be derived from the same equation as the first form (1). We have referred to the Leslie/DeLury model as 'the unmodified DeLury method'.

Assumptions underlying the DeLury model:

1. Sampling is from a closed population. Under this assumption, natural mortality and recruitment may be ignored, and the entire population is available to the fishery.

2. 'Catchability' remains constant during the sampling period. Any individual whale is as likely to be caught as any other, and its 'catchability' does not change over the years.

3. There is no competition between ships. Under this assumption, ships do not interfere with one another or otherwise compete.

4. *The annual catch represents a significant proportion* of the population. The method depends upon the decrease in the CPUE bearing a direct relationship to the decline of the population.

MODIFIED DELURY METHOD ESTIMATES

The DeLury method has been modified by several authors to incorporate estimates of recruitment and natural mortality.

Chapman's modified DeLury model

Chapman's (1974) modification assumes constant, and therefore density-independent, recruitment equal to MN_0, the mortality rate multiplied by the initial population size.

The population in year t is given by

$$N_t = (N_{t-1} - C_t)\, e^{-M} + R_t \qquad (1)$$

and the catch in year t is given by

$$C_t = qf_t \bar{N}_t \qquad (2)$$

where $t = 1, 2, \ldots, n$
N_t = population at start of season $t+1$
C_t = catch during season t
R_t = recruitment during season t
f_t = standardized effort during season t
q = catchability coefficient
M = natural mortality rate (instantaneous annual)
$\bar{N}_t$ = average population during season t

The recruitment, R_t, is approximated by MN_0, and e^{-M} is approximated by $1-M$ (via a Taylor series expansion). Substituting into equation (1) we have the following:

Season	*Population size*
0	N_0
1	$N_1 = (N_0 - C_1)(1-M) + MN_0 = N_0 - C_1(1-M)$
2	$N_2 = (N_1 - C_2)(1-M) + MN_0$
	$= N_0 - C_1(1-M)^2 - C_2(1-M)$
⋮	⋮
t	$N_t = N_0 - \sum_{i=1}^{t} C_i(1-M)^{t-i+1}$ (3)

In the following discussion of these methods, the notation and nomenclature of Tillman and Breiwick (Tillman, 1977; Tillman and Breiwick, 1977) will be followed. The average population size during a season is approximated by subtracting half of the catch from the population size at the beginning of the season

Season	*Average population size*
1	$\bar{N}_1 = n_0 - \frac{1}{2}C_1$
2	$\bar{N}_2 = N_1 - \frac{1}{2}C_2$
⋮	⋮
t	$\bar{N}_t = N_{t-1} - \frac{1}{2}C_t$ (4)

since, as Allen (1966) asserts, '...it is probably better to assume that the catch per unit effort is proportional to the stock at mid season'.

Now substituting (4) into (2) we have

$$C_t = qf_k(N_{t-1} - \tfrac{1}{2}C_t) \qquad (5)$$

while from (3) we obtain

$$N_{t-1} = N_0 - \sum_{i=1}^{t-1} C_i(1-M)^{t-i}$$

and substituting (6) into (5)

$$\text{CPUE}_t = (C/f)_t = q(N_0 - \sum_{j=1}^{t-1} C_j(1-M)^{t-j} - \tfrac{1}{2}C_t)$$

The value of N_0 now may be estimated as in the unmodified DeLury method, with

$$Y_t = \text{CPUE}_t \quad \text{and} \quad X_t = \sum_{j=1}^{t-1} C_j(1-M)^{t-j} + \tfrac{1}{2}C_t$$

The *q* method

Once a value of N_0 has been obtained from Chapman's modified DeLury method, the value of the catchability coefficient, q, can be estimated. Given the regression coefficients

$$a = qN_0 \quad \text{and} \quad b = q \quad \text{then} \quad a/b = N_0$$

so

$$a/N_0 = q$$

Then q method (Allen, 1966) can be used to obtain a direct estimate of mean population size during season t with the following equation:

$$\bar{N}_t = U_t/q$$

where q = catchability coefficient
U_t = CPUE in season t

An estimate of the population size at the start of the season is obtained by adding half of the harvest for that season to the estimate of the mean population size:

$$N_{t-1} = N_t + \tfrac{1}{2}C_t$$
$$n_0 = \bar{N}_1 + \tfrac{1}{2}C_1$$

Allen's modified DeLury model

Allen's (1966) modification of the DeLury model employs estimates of M and R in the following equation:

$$\bar{N}_1 = \frac{\sum_{i=1}^{t-1} \bar{C}_i}{1 - Y_i - M\sum_{i=1}^{t-1} Y_i + \sum_{i=2}^{t} R_i Y_i}$$

where $\bar{C}_i$ = average catch = $\frac{1}{2}(C_i + C_{i+1})$
Y_i = normalized CPUE = U_i/U_1

Since, Allen notes, the estimate is 'particularly sensitive to the relation between the catch per effort (C/E) in the first and last years of the period', a series of estimates is obtained for increasing values of t up to the last year, each beginning with the same year, and a better (final) estimate is then obtained as the mean of the series. To estimate the population size at the start of the season, one-half of the first years' catch is added. In the absence of recruitment rate data, recruitment was (a) assumed to be constant and (b) estimated using Allen's model of recruitment rate:

$$r_t = r_0 - (r_0 - M)\,(N_{t-\text{lag}}/N_I)^{n+1}$$

where r_0 = initial recruitment rate
N_I = estimate of initial population size
n = 1.3898
M = rate of natural mortality
lag = lag time in years.

SC/32/PS6

Reanalysis of Historical Whaling Data for the Western Arctic Bowhead Whale Population

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INTRODUCTION

A concern in determining the status of the Western Arctic population of bowhead whales has been estimating its level at the start of exploitation. Analysis of historical whaling records seemed to offer a basis for obtaining this estimate (Anon., 1983). Two early studies were undertaken based upon secondary records, that is upon summaries or partial analyses of the primary records of whalers' logbooks and journals. Mitchell's (1977) cumulative catch estimate indicated a range of 11,000–18,000 as the initial level prior to exploitation. Breiwick, Mitchell and Chapman (1980) developed an iterative model which calculated a range of 14,000–26,000 as the initial level using Mitchell's data.

A criticism of these early efforts is that they were based upon secondary records which contained many errors. Consequently, the US National Marine Mammal Laboratory, supported partly by the US Marine Mammal Commission and several private foundations, contracted with the Old Dartmouth Historical Society to analyze the extant primary records and to provide an improved estimate of initial abundance. The results of that two-year effort are given in Bockstoce and Botkin (1983).

The estimates of total annual kills and kills per unit of weather corrected effort obtained by Bockstoce and Botkin seem the best that can be done on the basis of available records (19% of the possible total). However, there is no way to determine for certain what biases exist in this surviving sample of the records. Bockstoce and Botkin also go on to estimate the initial stock of Western Arctic bowheads, giving as their range of reasonable estimates 20,000 to 40,000, and asserting that 30,000 is a most likely value. We believe that their methods involve assumptions that can hardly be fulfilled. Furthermore, we obtain alternative estimates by procedures which avoid these problems; these estimates are generally much lower than those of Bockstoce and Botkin.

Their first method, referred to as the DeLury method, though their formulation is the Leslie procedure, applies only to a closed population, ie.. with no source of mortality other than the harvest and no recruitment. If natural mortality has just balanced births throughout the 66-year period considered, of course the procedure would still be valid. However, with the variations in births and deaths that must have occurred, this is essentially impossible. Moreover, as far as we can discern, there have been no studies of the robustness of the DeLury procedure in such a situation.

They also used the method developed by Chapman (1974), a modification of the Leslie–DeLury procedure, which was developed for a population that was in equilibrium and which then experienced a decline under rapid exploitation. It is reasonable to apply this method only for an initial period of exploitation equal to the number of years taken to attain the age of recruitment, during which it may be assumed that recruitment is constant and equal to the number recruited prior to exploitation. However, it is again unlikely that this assumption would apply over a 66-year period.

Finally, Bockstoce and Botkin used Allen's (1966) modified DeLury procedure that introduces recruitment and accounts for it in the model. Two variations were considered – constant recruitment and recruitment varying according to the modified logistic equation. This method has been little studied and its robustness or sensitivity to assumptions are unknown. In any case, it will certainly give varying estimates depending on assumptions for ratios of recruits to parents, R, and for natural mortality rate, M. Moreover, there are other procedures available that use recruitment and indices of abundance to estimate initial stock size: Allen's (1966) least squares method and the iterative model of Breiwick *et al.* (1980). It might have been more appropriate to utilize either of these two better known procedures to estimate initial abundance.

We now consider some of these alternative estimation methodologies applied to the historical kill per unit effort data provided by Bockstoce and Botkin.

Data used

The historical removal data used in this reanalysis are given in table 2 of Bockstoce and Botkin. Their weighted kill data (WKILL) consist each season of the total number caught plus those whales struck and lost and believed to have died.

The index of abundance used is the kill per unit of weather corrected effort (WKPUE). These are given in tables 4 and 6 of Bockstoce and Botkin. In their table 4, days with a combination of ice, wind, and visibility conditions under which no whales were caught during the entire 66-year period were subtracted from total whaling days in each year, giving 'type 1' whaling effort. In their table 6, days with extreme conditions of ice and/or wind were subtracted from total whaling days in each year, giving 'type 2' whaling effort.

Chapman's modified DeLury estimates

Chapman's (1974) modification of the DeLury procedure essentially results in a general linear regression model which relates indices of abundance (WKPUEs) to annual removals (WKILLs) and constant annual recruitment occurring at pre-exploitation levels. The intercept and slope of the fitted regression provide direct estimates of N_0, the initial stock size, and q, the catchability coefficient. Assumptions inherent to this model are discussed by Tillman and Breiwick (1977).

As previously noted, it is usual practice to apply this model to data obtained during the first t_r years of exploitation, where t_r is the average age at recruitment into the fishery. Lacking data on this parameter for bowheads, we have followed Breiwick *et al.* (1980) and examined the estimates resulting from values of 5, 7, 10, and 15 years, where 5–7 are probably the most reasonable guesses. Also examined were different WKPUEs, based upon different effort definitions, and different values of M, the coefficient of natural mortality.

Table 1 shows the results obtained when directly estimating N_0. The WKPUEs based upon type 2 effort give slightly higher estimates than those based upon type 1 effort, but overall the values are very similar. Estimates are not sensitive to the values of M used but do change depending on the t_r chosen.

Assuming a t_r range of 5–7 years is most reasonable, the range of initial estimates obtained is 7,100–8,100 whales. Given that just over 11,000 whales were taken during the first two decades of the fishery (Table 2), these estimates seem low. Even increasing the t_r to 10 or 15 years does not help much, raising the estimates to only 10,000 at most.

Allen's modified DeLury estimates

Allen's (1966) modification of the DeLury method accounts for both natural mortality and recruitment when relating initial stock size to annual kills and normalized catch per unit effort data. A series of estimates are generated over the history of exploitation by extending the data series one additional year up to the maximum available. The final estimate of initial stock size is then obtained as the mean of the series.

The method requires estimates of R, the ratio of recruits to parents, over the time series. Lacking data on this variable, a variety of constant values were examined, as were several values of M and t_r. Only the WKPUE based on type 1 effort was considered.

Preliminary tests indicated that, for several combinations of parameters, very small or very large negative estimates occurred adjacent to very large positive estimates within the series of estimates. This circumstance occurred most often in the middle of the series and often resulted in nonsensical estimates when taking the mean of the series: negative, too large (greater than the total cumulative catch), too small (much less than the cumulative catch in the first decade). The estimator provided reasonable results only if constrained to that portion of the series at the start or at the end. Given that R was held constant, it seemed most reasonable only to consider initial series defined by t_r values of 5, 7, and 10 years.

The estimates obtained (Table 3) are most sensitive to the t_r chosen. Again assuming a t_r range of 5–7 years is most reasonable, the range of initial stock sizes obtained is 6,100–8,900 whales. In some cases these estimates are even lower than the previous modified DeLury estimates, and all of them again seem quite low given the early catch history (Table 2). Even if the value of t_r is increased, the estimates of initial abundance are still low.

Table 1

Chapman's (1974) modified DeLury estimates of initial abundance using different effort definitions in determining kill per unit effort (KPUE), ages at recruitment, and values of M

Basis of KPUE	Period	Average age at recruitment	Estimates for different values of M: 0.01	0.03	0.05
Type 1 effort	1848–52	5	7,547	7,324	7,112
	1848–54	7	8,029*	7,671*	7,336*
	1848–57	10	8,432*	7,822*	7,293*
	1848–62	15	9,826*	8,502*	8,241*
Type 2 effort	1848–52	5	7,758	7,538	7,329
	1848–54	7	8,099*	7,741*	7,386*
	1848–57	10	8,677*	8,027*	7,467*
	1848–62	15	10,075*	8,682*	7,633*

* Linear regression significant at the 5% level.

Table 2

Comparison of kill histories obtained from two sources

Decade	Kills by source: Breiwick *et al.* (1980)	Bockstoce and Botkin (1982)
1848–57	13,392	7,237
1858–67	6,256	3,973
1868–77	2,791	2,583
1878–87	2,146	2,255
1888–97	4,000	1,381
1898–07	649	1,077
1908–15	226	129

Table 3

Allen's (1966) modified DeLury estimates of initial abundance using WKPUE based on type 1 effort and different periods (lag times) and values of M and R (ratio of recruits to parents)

Period	Lag time	M	Estimates for different values of R: 0.01	0.03	0.05	0.08
1848–52	5	0.04	7,268	6,891	6,553	6,108
		0.06	7,880	7,435	7,041	6,527
		0.08	8,611	8,078	7,611	7,010
1848–54	7	0.04	7,604	7,236	6,905	6,463
		0.06	8,208	7,778	7,394	6,887
		0.08	8,921	8,412	7,961	7,374
1848–57	10	0.04	8,716	8,219	7,780	7,209
		0.06	9,515	8,918	8,399	7,732
		0.08	10,489	9,757	9,131	8,340

Breiwick's iterative estimates

The iterative procedure of Breiwick *et al.* (1980) is essentially a simulation model which accounts for natural mortality and the total kill history and introduces varying recruitment using the modified logistic model and different lag times (t_r values). Given an estimate of current abundance, a guess at initial abundance, and the kill history, the model forward calculates to the current year and then compares the calculated stock size with its given or presumed value. The value of initial stock size is subsequently modified in succeeding iterations until the current stock size calculated by the model is the same as the given or presumed value.

Table 4

Estimates of initial abundance using the iterative model of Breiwick *et al.* (1980) for various values of lag time, M, $(r-M)_{max}$ and 1977 stock level

1977 stock level	Lag time	M	Estimates for different values of $(r-M)_{max}$ 0.01	0.03	0.05
1,500	5	0.04	15,720	13,000	11,440
		0.06	14,580	12,110	10,680
		0.08	13,575	11,305	9,990
	7	0.04	14,900	12,430	11,010
		0.06	13,545	11,350	10,080
		0.08	12,390	10,420	9,280
2,100	5	0.04	16,030	13,080	11,460
		0.06	14,910	12,200	10,705
		0.08	13,920	11,410	10,020
	7	0.04	15,240	12,530	11,040
		0.06	13,900	11,470	10,120
		0.08	12,770	10,560	9,325
2,700	5	0.04	16,360	13,170	11,485
		0.06	15,260	12,300	10,730
		0.08	14,285	11,530	10,060
	7	0.04	15,590	12,640	11,070
		0.06	14,270	11,600	10,160
		0.08	13,160	10,715	9,380

Table 4 gives the results for presumed current stock sizes of 1,500, 2,100, and 2,700 whales respectively. These estimates of initial abundance are not very sensitive to changes in values of current stock size or of lag time. They are, however, quite sensitive to which values of M or of maximum net recruitment, $(r-M)_{max}$, are chosen.

For lag times of 5–7 years, the range of initial estimates obtained is 9,300–16,400 whales. This range is higher than that for all of the preceding DeLury estimates but is in agreement with the first 20 years of Bockstoce and Botkin's kill history (Table 2) during which 11,210 whales were taken. This range is much less than that obtained by Breiwick *et al.* (1980), 14,000–26,000 whales. However, this difference may be ascribed to the larger historical kills used by them as compared with those reported by Bockstoce and Botkin (Table 2).[1]

Allen's least squares estimates

Allen (1966) developed a method for estimating initial abundance which minimizes the sums of squares of the differences between actual and expected catches. The method requires estimates of W, the proportions of new recruits which enter the recruited stock each year, over the time series. Lacking data on this variable, a variety of constant values were examined. Given values of W and M, Allen's model solves for the N_0 and q which minimize the sums of squares.

As indicated in Table 5, the results obtained by this method are extremely sensitive to the parameters chosen. In fact, runs have been constrained to consider only values of $W \geqslant M$ since preliminary tests indicated that nonsensical estimates, much greater than total cumulative kill, resulted otherwise. Following Breiwick *et al.* (1980), if one excludes the most extreme parameter values as being unlikely ($W-M \geqslant 0.06$), a range of initial abundance of 10,300–21,800 is obtained. This range seems to agree with both Breiwick's iterative values and the historical kill (Table 2).

[1] For an updated application of the iterative model to historical data from the pelagic and shore-based bowhead fisheries, one should see Breiwick and Mitchell (1983).

Table 5

Allen's (1966) least squares estimates of initial abundance using WKPUE based on type 1 effort and different values of M and W (proportion of new recruits in recruited stock each year)

M	Estimates for different values of W 0.04	0.06	0.08	0.10	0.12
0.04	21,827	14,053	10,741	8,898	7,713
0.06	—	21,191	13,733	10,531	8,742
0.08	—	—	20,351	13,340	10,284

DISCUSSION

Given the historical kill of over 11,000 whales during the first two decades of Western Arctic whaling, all of the estimates of initial abundance based upon derivatives of the DeLury method seem too low, all being under 11,000 for the combinations of life history parameters examined. This circumstance primarily results from the fact that, due to required assumptions on recruitment for these methods, we have been constrained to use only the first 5–15 years of data in the historical series. Thus these DeLury estimators do not seem to be very powerful tools when applied to these bowhead data strictly in accordance with their inherent assumptions.

The low DeLury estimates obtained may result from the possibility, stated by Bockstoce and Botkin, that the Western Arctic bowhead population was comprised of several discrete stocks, each with its own feeding area, which were successively fished out. If this were the case, as they further point out, then it would not be legitimate to assume that the reductions observed in the first 5–15 years could be used as a basis for estimating the size of the entire population: they might only provide an estimate of part of it.

We agree that this possible 'stock effect' may be confounding the data analysis and the ensuing estimation procedures. Because of this problem, we also agree that one should probably utilize as much of the available data series as possible when estimating total population size. However, we do not agree that the DeLury procedures are the best ones to use in this instance.

Breiwick's iterative model and Allen's least squares method are estimation procedures which take full advantage of the available data series without requiring one to make unreasonable assumptions about recruitment. Moreover, in the trials undertaken here, the estimates provided by these two procedures tended to bracket the 20-year historical kill of 11,210 whales:

Breiwick 9,300–16,400
Allen 10,300–21,800

These two procedures would thus seem to provide a reasonable basis for estimating initial population size, and a likely range of estimates of initial abundance might be 10,000–20,000 bowhead whales, as contrasted with the 20,000–40,000 range of Bockstoce and Botkin.

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SC/33/PS7

Estimated Initial Population Size of the Bering Sea Stock of Bowhead Whales (*Balaena mysticetus*) from Logbook and Other Catch Data

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ABSTRACT

Initial population estimates of the Bering Sea stock of bowhead whale (*Balaena mysticetus*) are made using the method of Breiwick *et al.* (1980), pelagic catch data based on a sample of logbooks (Bockstoce and Botkin, 1893) and shore-based catch data from the literature (Marquette and Bockstoce, 1980). The range of resulting 1848 population estimates is from 8,000 to 18,000 bowhead whales. The results, given the magnitude of the early catches, suggest that the maximum net recruitment rate may be ⩽ 0.03 and that the initial population size was probably nearer the upper range of estimates obtained.

INTRODUCTION

The present population size of the Bering Sea stock of bowhead whales (*Balaena mysticetus*) in the western Arctic (here defined as the stock of bowhead whales inhabiting the Bering, Chukchi, and Beaufort Seas) has been estimated to be about 2,300 (Braham *et al.*, 1979). Estimates of the 'initial' population size in 1848, prior to commercial exploitation, have been made by Mitchell (1977, Ms.), Breiwick, Mitchell and Chapman (1980), and Bockstoce and Botkin (1983). This paper presents new estimates of the historical population size of the western Arctic bowhead whale with the method of Breiwick *et al.* (1980) but using pelagic catch data based on a sample of logbooks (Bockstoce and Botkin, 1983) and shore-based catch data from a more complete search of the literature (Marquette and Bockstoce, 1980).

METHODS

Catch history

There are no complete records of bowhead catch available for the pelagic or shore-based fishery except for the last few years of the latter. There are two types of estimates of pelagic catch available. The data of Mitchell (1977, Ms.) were estimates based on production statistics as well as catch per vessel. Production statistics between bowhead and right whales were mixed through at least 1860 as the right whale fishery declined. The data of Bockstoce and Botkin (1983) are estimates based upon logbook and journal records of bowheads taken per voyage (19% of voyages) extrapolated to the total number of voyages.[1]

Table 1 gives the catch, and the struck and lost data used in our study. The pelagic fishery data (1848–1914) were taken from Bockstoce and Botkin (1983; their table 2)[2] who sampled available logbooks from the fishery and extrapolated the catch and the struck and lost data to the total number of known voyages. They use a zero catch for 1848, since there were no data on effort for the voyage. We have taken the known catch of 15 (their table 1) and applied the average struck and lost rate from 1849–1854 to give a total kill in 1848 of 18 whales. The cumulative pelagic catch for the period 1848–1914 used by Breiwick *et al.* (1980; table 1) was 21,823 compared with 16,613 used in this paper.

Catch data for the Alaskan and Siberian shore-based fishery were taken from Marquette and Bockstoce (1980) who extracted catch statistics from a review of the literature. The shore-based total catch in Table 1 is the sum of the landed and the killed but lost categories of Marquette and Bockstoce (1980). These data are to be compared with the original compilation of Mitchell (1977 Ms.) as published in table 1 of Breiwick *et al.* (1980) where the cumulative total of known kill, 1848–1977, was 1,234. The more complete compilation of Marquette and Bockstoce (1980, table 2) gives, for the same period, a cumulative total of 1,643 for 'landed' and 'killed but lost' catch.

Struck and lost data for the shore-based fishery are not well known for the pre-1970 fishery [cf. table 2, Marquette and Bockstoce 1980]. The pelagic fishery struck and lost data in our Table 1 are the difference between the weighted kill and weighted catch given in table 2 of Bockstoce and Botkin (1983). The loss rates calculated by Mitchell [1977 Ms.; published in table 1 of Breiwick *et al.*, 1980] were based on limited data. The later struck and lost data (1971–present) are more reliably known and the reported data were used for this period (Marquette and Bockstoce, 1980). Our results pertain to a 100 percent moribund rate for struck and lost animals. Marquette *et al.* (in press), however, present data for the 1981 bowhead harvest that suggest a moribund rate of 82 percent. We have also applied this rate to the Eskimo shore-based struck and lost data (1848–1977) to assess the affect of a less than 100 percent moribund rate.

[1] These data were first presented in an unpublished contract report submitted to the US National Marine Fisheries Service; Bockstoce, J. R. and Botkin, D. B. 1980. The historical status and reduction of the western Arctic bowhead whale (*Balaena mysticetus*) population by the pelagic whaling industry, 1848–1914. Final report to the National Marine Fisheries Service (submitted to National Marine Mammal Laboratory) by Old Dartmouth Historical Society (New Bedford Whaling Museum), contract 03-78-M02-0212, p. [i]-v + 1–120.

[2] Cited as Table II in the original contract report.

Table 1

American pelagic and Eskimo shore-based extrapolated catch and struck-lost data for western Arctic bowhead whales. See text for data sources and further explanation

	Pelagic fishery			Shore-based fishery			
Season	Catch	Struck and lost	Total	Catch	Struck and lost[2]	Total	Total kill
1848	15	3	18	—[1]	—	0	18
1849	507	64	571	—	—	0	571
1850	1,719	348	2,067	—	—	0	2,067
1851	757	139	896	—	—	0	896
1852	2,188	494	2,682	17	9	26	2,708
1853	628	168	796	7	4	11	807
1854	105	25	130	24	12	36	166
1855	0	2	2	—	—	0	2
1856	0	0	0	—	—	0	0
1857	72	6	78	—	—	0	78
1858	424	35	459	—	—	0	459
1859	335	31	366	—	—	0	366
1860	211	10	221	—	—	0	221
1861	293	13	306	—	—	0	306
1862	150	7	157	—	—	0	157
1863	288	15	303	—	—	0	303
1864	396	38	434	—	—	0	434
1865	455	133	588	—	—	0	588
1866	503	37	540	—	—	0	540
1867	566	33	599	—	—	0	599
1868	456	60	516	—	—	0	516
1869	340	30	370	5	3	8	378
1870	594	26	620	5	3	8	628
1871	125	8	133	—	—	0	133
1872	163	31	194	4	2	6	200
1873	147	0	147	—	—	0	147
1874	95	0	95	—	—	0	95
1875	200	0	200	—	—	0	200
1876	57	19	76	—	—	0	76
1877	244	18	262	—	—	0	262
1878	72	8	80	—	—	0	80
1879	203	58	261	3	2	5	266
1880	452	8	460	12	6	18	478
1881	374	44	418	10	6	16	434
1882	240	0	240	1	1	2	242
1883	39	0	39	2	1	3	42
1884	114	19	133	10	6	16	149
1885	277	10	287	41	23	64	351
1886	123	10	133	8	4	12	145
1887	180	24	204	23	13	36	240
1888	117	16	133	17	10	27	160
1889	42	11	53	49	27	76	129
1890	127	0	127	6	3	9	136
1891	228	6	234	32	18	50	284
1892	308	9	317	17	10	27	344
1893	141	0	141	26	15	41	182
1894	141	10	151	48	27	75	226
1895	94	0	94	10	6	16	110
1896	58	0	58	40	22	62	120
1897	73	0	73	38	21	59	132
1898	216	12	228	40	22	62	290
1899	204	4	208	10	6	16	224
1900	112	0	112	20	11	31	143
1901	29	0	29	14	8	22	51
1902	132	0	132	18	10	28	160
1903	95	0	95	8	4	12	107
1904	68	6	74	5	3	8	82
1905	86	7	93	8	4	12	105
1906	36	0	36	17	10	27	63
1907	70	0	70	9	5	14	84
1908	33	0	33	48	27	75	108
1909	10	0	10	25	14	39	49
1910	16	0	16	10	6	16	32
1911	30	0	30	7	4	11	41
1912	0	0	0	18	10	28	28
1913	0	0	0	5	3	8	8
1914	40	0	40	9	5	14	54
1915	0	0	0	6	3	9	9
1916	0	0	0	16	9	25	25
1917	0	0	0	15	8	23	23
1918	0	0	0	17	10	27	27
1919	0	0	0	7	4	11	11
1920	0	0	0	16	9	25	25
1921	0	0	0	5	3	8	8
1922	0	0	0	25	14	39	39
1923	0	0	0	5	3	8	8
1924	0	0	0	24	13	37	37
1925	0	0	0	32	18	50	50
1926	0	0	0	20	11	31	31
1927	0	0	0	8	4	12	12
1928	0	0	0	15	8	23	23
1929	0	0	0	17	10	27	27
1930	0	0	0	8	4	12	12
1931	0	0	0	18	10	28	28
1932	0	0	0	7	4	11	11
1933	0	0	0	5	3	8	8
1934	0	0	0	4	2	6	6
1935	0	0	0	7	4	11	11
1936	0	0	0	10	6	16	16
1937	0	0	0	16	9	25	25
1938	0	0	0	13	7	20	20
1939	0	0	0	8	4	12	12
1940	0	0	0	12	7	19	19
1941	0	0	0	23	13	36	36
1942	0	0	0	11	6	17	17
1943	0	0	0	7	4	11	11
1944	0	0	0	2	1	3	3
1945	0	0	0	12	7	19	19
1946	0	0	0	12	7	19	19
1947	0	0	0	11	6	17	17
1948	0	0	0	5	3	8	8
1949	0	0	0	6	3	9	9
1950	0	0	0	9	5	14	14
1951	0	0	0	14	8	22	22
1952	0	0	0	8	4	12	12
1953	0	0	0	23	13	36	36
1954	0	0	0	5	3	8	8
1955	0	0	0	23	13	36	36
1956	0	0	0	7	4	11	11
1957	0	0	0	3	2	5	5
1958	0	0	0	2	1	3	3
1959	0	0	0	1	1	2	2
1960	0	0	0	19	11	30	30
1961	0	0	0	11	6	17	17
1962	0	0	0	13	7	20	20
1963	0	0	0	10	6	16	16
1964	0	0	0	16	9	25	25
1965	0	0	0	9	5	14	14
1966	0	0	0	15	8	23	23
1967	0	0	0	7	4	11	11
1968	0	0	0	17	10	27	27
1969	0	0	0	21	12	33	33
1970	0	0	0	29	16	45	45
1971	0	0	0	24	3	27	27
1972	0	0	0	40	3	43	43
1973	0	0	0	38	15	53	53
1974	0	0	0	23	28	51	51
1975	0	0	0	17	23	40	40
1976	0	0	0	56	38	94	94
1977	0	0	0	32	79	111	111
Total	16,613	2,055	18,668	1,643	980	2,623	21,291

[1] Presumed to be greater than zero but in the absence of information zero is used.

[2] The following loss rates were used for the shore-based fishery: 1848–1880 = 0.50; 1881–1970 = 0.56; 1971–present = reported data. The pre-1881 loss rate of 0.50 applied to the shore-based fishery is our arbitrary estimate derived from limited data showing loss rates for different periods of time of 0.48 and 0.56 for pre-1977 shore-based whaling in Alaska (Mitchell, 1977 MS). The 0.56 rate (from Mitchell, 1977 MS) as used by Breiwick *et al.* (1980) is also used here. The 0.48 rate (from Mitchell, 1977 MS) as used by Breiwick *et al.* (1980) is not used here in lieu of actual reported data for 1971–1977.

Table 2

Initial population size estimates (in thousands) for various combinations of parameters. Density-dependent exponent is 1.00 ($P_{msy} = 0.5$)

P_{78}	τ	M	$r_0 - M$ 0.01	0.03	0.05
1,800	3	0.03	17.79	14.41	12.49
		0.06	16.19	13.18	11.46
		0.09	14.81	12.10	10.54
	5	0.03	17.06	13.93	12.16
		0.06	15.01	12.34	10.81
		0.09	13.35	11.04	9.70
	7	0.03	16.41	13.50	11.85
		0.06	14.01	11.63	10.26
		0.09	12.20	10.19	9.01
2,400	3	0.03	18.09	14.48	12.50
		0.06	16.52	13.27	11.48
		0.09	15.15	12.20	10.57
	5	0.03	17.39	14.02	12.18
		0.06	15.36	12.46	10.85
		0.09	13.73	11.18	9.75
	7	0.03	16.75	13.61	11.89
		0.06	14.39	11.77	10.31
		0.09	12.60	10.37	9.08
3,000	3	0.03	18.41	14.56	12.52
		0.06	16.86	13.36	11.51
		0.09	15.51	12.32	10.61
	5	0.03	17.73	14.12	12.21
		0.06	15.73	12.58	10.89
		0.09	14.12	11.34	9.80
	7	0.03	17.10	13.72	11.92
		0.06	14.78	11.93	10.36
		0.09	13.02	10.57	9.17

Table 3

Minimum population size (in thousands) for various combinations of parameters resulting from the initial population estimates in Table 2. Number in parenthesis is the season corresponding to the minimum population size. Density-dependent exponent is 1.00 ($P_{msy} = 0.5$)

P_{78}	τ	M	$r_0 - M$ 0.01	0.03	0.05
1,800	3	0.03	1.80 (1978)	1.01 (1915)	0.56 (1915)
		0.06	1.80 (1978)	1.03 (1910)	0.58 (1910)
		0.09	1.80 (1978)	1.04 (1910)	0.59 (1910)
	5	0.03	1.80 (1978)	1.04 (1910)	0.59 (1910)
		0.06	1.80 (1978)	1.07 (1910)	0.62 (1910)
		0.09	1.80 (1978)	1.10 (1909)	0.65 (1909)
	7	0.03	1.80 (1978)	1.06 (1910)	0.61 (1909)
		0.06	1.80 (1978)	1.11 (1909)	0.65 (1909)
		0.09	1.80 (1978)	1.16 (1909)	0.71 (1909)
2,400	3	0.03	2.40 (1978)	1.16 (1910)	0.63 (1910)
		0.06	2.40 (1978)	1.20 (1910)	0.65 (1910)
		0.09	2.40 (1978)	1.23 (1910)	0.68 (1910)
	5	0.03	2.40 (1978)	1.21 (1910)	0.66 (1910)
		0.06	2.40 (1978)	1.27 (1909)	0.71 (1909)
		0.09	2.40 (1978)	1.33 (1909)	0.77 (1909)
	7	0.03	2.40 (1978)	1.25 (1909)	0.70 (1909)
		0.06	2.40 (1978)	1.34 (1909)	0.77 (1909)
		0.09	2.40 (1978)	1.43 (1909)	0.86 (1909)
3,000	3	0.03	2.87 (1915)	1.32 (1910)	0.69 (1910)
		0.06	2.88 (1915)	1.38 (1910)	0.73 (1910)
		0.09	2.88 (1915)	1.44 (1909)	0.77 (1909)
	5	0.03	2.90 (1915)	1.39 (1910)	0.75 (1910)
		0.06	2.92 (1915)	1.48 (1909)	0.82 (1909)
		0.09	2.93 (1910)	1.58 (1909)	0.90 (1909)
	7	0.03	2.92 (1912)	1.44 (1909)	0.79 (1909)
		0.06	2.94 (1910)	1.58 (1909)	0.91 (1909)
		0.09	2.96 (1909)	1.71 (1909)	1.03 (1909)

Vital parameters

There are few data with which to estimate any vital parameters for bowhead whales. We have used essentially the same range of parameters as in Breiwick *et al.* (1980):

1978 stock level	1800, 2400, 3000
Natural mortality rate (M)	0.03, 0.06, 0.09
Maximum net recruitment rate ($r_0 - M$)	0.01, 0.03, 0.05
Lag time (τ)	3, 5, 7
Density-dependent exponent	1.00, 5.04

Model

The model used to estimate the 1848 stock size is the same as that used by Breiwick *et al.* (1980):

$$r_t = M + [1-(P_{t-\tau}/P_0)^z](r_0 - M)$$
$$R_t = r_t P_{t-\tau}$$
$$P_{t+1} = (P_t - K_t)(1-M) + R_t \qquad (1)$$

where r_t = recruitment rate in season t

M = natural mortality rate
$r_0 - M$ = maximum net recruitment rate
$P_{t-\tau}$ = population size at the beginning of season $t-\tau$ (τ = lag time assumed for population response)
P_0 = initial population size (start of 1848 season)
K_t = number of animals killed in season t
z = density-dependent exponent

Equation (1), due to Allen (1966), is solved iteratively for P_0 by specifying a 1978 population size, natural mortality rate, maximum net recruitment rate and lag time. Furthermore, two different values of z were used, 1.00 and 5.04, corresponding to the population sizes at which MSY occurs at 50% and 70% of the initial population size.

Sensitivity analysis

One way to assess the sensitivity of the output parameter to the value of an input parameter is to define a sensitivity parameter as the relative change in output (here, the initial population estimate) divided by the relative change in the input. This was done for some of the vital parameter values corresponding to a density-dependent exponent of 1.00.

RESULTS

Tables 2 and 3 give the solutions of equation 1 for the various parameter combinations. Although not directly comparable to those given in Table 3 of Breiwick *et al.* (1980) because some of the parameter values differ, the results in Table 2 can be seen to be somewhat lower than those in the previous study. This can be attributed to the difference in the pelagic catch data used. In the present study the estimated total pelagic kill from 1848–1915 is 18,668 while in the former it is 27,068. The estimated catches are substantially different especially for the first decade of the pelagic fishery.

Tables 4 and 5 give the lowest population size reached and the corresponding season using the model and the initial population size estimates and parameters from Tables 2 and 3. For all but moderate current population sizes and low maximum net recruitment rates ($r_0 - M$),

Table 4

Initial population size estimates (in thousands) for various combinations of parameters. Density-dependent exponent is 5.04 ($P_{msy} = 0.7$)

			$r_0 - M$		
P_{78}	τ	M	0.01	0.03	0.05
1,800	3	0.03	16.49	12.47	10.51
		0.06	15.05	11.46	9.69
		0.09	13.80	10.56	8.95
	5	0.03	15.89	12.22	10.43
		0.06	14.03	10.89	9.34
		0.09	12.52	9.79	8.41
	7	0.03	15.34	11.97	10.34
		0.06	13.17	10.39	9.01
		0.09	11.50	9.14	7.95
2,400	3	0.03	16.69	12.50	10.51
		0.06	15.28	11.50	9.69
		0.09	14.04	10.60	8.95
	5	0.03	16.11	12.25	10.44
		0.06	14.28	10.94	9.35
		0.09	12.79	9.85	8.43
	7	0.03	15.58	12.02	10.35
		0.06	13.44	10.45	9.03
		0.09	11.80	9.23	7.97
3,000	3	0.03	16.90	12.53	10.52
		0.06	15.50	11.53	9.70
		0.09	14.28	10.64	8.96
	5	0.03	16.34	12.29	10.45
		0.06	14.53	10.99	9.36
		0.09	13.07	9.91	8.44
	7	0.03	15.82	12.06	10.36
		0.06	13.72	10.52	9.05
		0.09	12.10	9.31	8.00

the lowest population size was reached around 1909–1915, indicating a gradual recovery to the 1978 level. For a current population size of 1800 and 2400 coupled with a low maximum net recruitment rate the population trajectories showed a continual decline to the current level (c.f. Tables 3 and 5).

The results of the sensitivity analysis are given in Table 6. The sign of the sensitivity parameter indicates the direction of change in the initial population size. The sensitivity parameter is a nonlinear function of the other parameters in the model. It will vary with the level of the fixed as well as the varied parameters. This can be seen by observing the first line in each block of Table 4 where the sensitivity of the initial population size to $r_0 - M$ is compared. In general, the estimate of initial population size is most sensitive to $r_0 - M$, M, τ and current population size (1978) in descending order of importance. The differences in initial population size between Tables 2 and 3 are not very large but do indicate that as the population size giving MSY increases the initial population estimate decreases.

The population estimates which resulted from applying an 82 percent moribund rate to the struck and lost whales were only slightly different from those given in Tables 2 and 4. The initial population estimates were from a few tens to at most 150 animals less.

DISCUSSION

This study is an attempt to assess the limitations of the data available. It utilizes the catch estimated from logbook data and voyages in the same manner as our previous analysis, which used catch data estimated from extrapolations of production statistics as well as catch per vessel. It appears that Mitchell's (1977 Ms.) extrapolations overestimated the catch in the first decade of the fishery (e.g. Breiwick *et al.*, 1980, table 1).

Our previous reservations (Breiwick *et al.*, 1980) about the aboriginal catch data have been met in part by the

Table 5

Minimum population size (in thousands) for various combinations of parameters resulting from the initial population estimates in Table 4. Number in parenthesis is the season corresponding to the minimum population size. Density-dependent exponent is 5.04 ($P_{msy} = 0.7$)

			$r_0 - M$		
P_{78}	τ	M	0.01	0.03	0.05
1,800	3	0.03	1.80 (1978)	0.92 (1915)	0.51 (1915)
		0.06	1.80 (1978)	0.93 (1910)	0.52 (1915)
		0.09	1.80 (1978)	0.94 (1910)	0.53 (1910)
	5	0.03	1.80 (1978)	0.95 (1910)	0.54 (1910)
		0.06	1.80 (1978)	0.96 (1910)	0.55 (1910)
		0.09	1.80 (1978)	0.98 (1909)	0.57 (1909)
	7	0.03	1.80 (1978)	0.97 (1910)	0.56 (1909)
		0.06	1.80 (1978)	1.00 (1909)	0.58 (1909)
		0.09	1.80 (1978)	1.03 (1909)	0.61 (1909)
2,400	3	0.03	2.32 (1927)	1.03 (1910)	0.56 (1915)
		0.06	2.30 (1915)	1.05 (1910)	0.57 (1910)
		0.09	2.29 (1915)	1.07 (1910)	0.58 (1910)
	5	0.03	2.33 (1927)	1.07 (1910)	0.59 (1910)
		0.06	2.32 (1927)	1.11 (1909)	0.62 (1909)
		0.09	2.31 (1910)	1.14 (1909)	0.64 (1909)
	7	0.03	2.34 (1927)	1.10 (1909)	0.62 (1909)
		0.06	2.33 (1910)	1.16 (1909)	0.66 (1909)
		0.09	2.32 (1909)	1.22 (1909)	0.71 (1909)
3,000	3	0.03	2.66 (1915)	1.14 (1910)	0.60 (1910)
		0.06	2.66 (1915)	1.17 (1910)	0.62 (1910)
		0.09	2.66 (1915)	1.20 (1909)	0.64 (1909)
	5	0.03	2.69 (1912)	1.19 (1910)	0.64 (1910)
		0.06	2.69 (1910)	1.25 (1909)	0.68 (1909)
		0.09	2.69 (1910)	1.31 (1909)	0.72 (1909)
	7	0.03	2.70 (1910)	1.24 (1909)	0.68 (1909)
		0.06	2.71 (1909)	1.33 (1909)	0.74 (1909)
		0.09	2.72 (1909)	1.41 (1909)	0.81 (1909)

Table 6

Relative sensitivity of initial population estimates to changes in parameters of the model. Density-dependent exponent is 1.00 ($P_{msy} = 0.5$)

Parameters				
P_{78}	M	τ	$r_0 - M$	Sensitivity parameter
1,800	0.03	3	0.01–0.03[1]	−0.0950
1,800	0.03	3–5[1]	0.01	−0.0616
1,800	0.03–0.06[1]	3	0.01	−0.0410
1,800–2,400[1]	0.03	3	0.01	0.0506
1,800	0.03	3	0.01–0.05	−0.0745
1,800	0.03	3–7	0.01	−0.0582
1,800	0.03–0.09	3	0.01	−0.0838
1,800–3,000	0.03	3	0.01	0.0523
1,800	0.03	3	0.03–0.05	−0.1999
1,800	0.03	5–7	0.01	−0.0953
1,800	0.06–0.09	3	0.01	−0.1705
2,400–3,000	0.03	3	0.01	0.0708

[1] Indicates that the parameter was varied from the lower to the higher value while the other parameters were fixed.

literature survey carried out by Marquette and Bockstoce (1980). It is unlikely that further literature research will yield appreciably more catch data, but there may be other unpublished sources of original data not yet examined. Certainly there are many years for which only minimum or no catch data are available but catches were clearly made. If further analyses are to be carried out on these data the next step would be to develop a technique to estimate the shore-based catch for the many years for which there are no catch statistics available. A substantially larger shore-based catch would produce higher initial stock sizes than we have estimated in this study.

As we stated previously (Breiwick *et al.*, 1980), we believe our model is useful but not fully adequate.

It should be recognized that some of the combinations of parameters in Tables 2 and 3 are unreasonable (eg. a high maximum net recruitment rate coupled with a relatively high lag time). Given that the most conservative estimate of the bowhead kill in the first decade was over 7,000 animals, the initial population estimates corresponding to maximum net recruitment rates greater than 0.03 seem unreasonable since these stock size estimates are very low.

The model, parameters, and parameter values used in this study, except for $r_0 - M > 0.03$, result in estimates of initial population size from 9,000 to 18,000. However, the magnitude of the kill during the first four decades of the pelagic fishery (about 15,000) indicates that the initial population size was probably nearer the top than the bottom of this range.

ACKNOWLEDGMENTS

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SC/33/PS14

Catch History, Abundance, and Present Status of Northwest Atlantic Humpback Whales*

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ABSTRACT

The present status of the western North Atlantic population of humpback whales (*Megaptera novaeangliae*) is of concern due to fishing mortality in West Greenland and Bequia and accidental mortality in fishing gear around Newfoundland and elsewhere along the east coast of North America. The purpose of this study was to reconstruct catch history and estimate initial population size.

Although there appears to be a degree of isolation between subunits of the western North Atlantic stock, adequate data are not available at present to define more than one stock. Therefore, we considered as a single population all the animals from Davis Strait to the West Indies. Humpbacks seen in summer near Iceland may or may not belong to this population.

Fisheries involving humpbacks have occurred in Davis Strait since at least the eighteenth century, at Iceland for a period of approximately ten years before and after the turn of the twentieth century, at Newfoundland–Labrador from 1898 to 1915 and from 1923 to 1951, in the Gulf of St Lawrence from at least the early nineteenth century until 1893, off New England from the early 1700s to the late 1800s, at Bermuda from the early 1600s to the Second World War, and in the West Indies from the mid-nineteenth century to the present.

The Yankee pelagic fishery in the West Indies was especially active between 1830 and 1890. A sample of logbooks and journals was studied in order to develop an estimate of the catch by Yankee whalers there. A calculated estimate of 25 barrels per whale was used to interpret oil production statistics for this fishery, and a factor of 1.85 was applied to landings to account for dead or moribund losses.

Four decades of high estimated total fishing mortality were identified: 1866–1875 (1,740), 1876–1885 (1,549), 1893–1902 (923), 1903–1912 (1,686). In addition, we estimate that 873 humpbacks were killed during the period 1922–1931. A conservative minimum estimate for population size in 1865 is 4,400 whales, or 4,700 if catches made at Iceland are included.

We estimate there are at least 1,800 humpbacks in the western North Atlantic today. A conservative assessment of the population's present status is that it has recovered to approximately half its 'initial' (i.e. 1865) size.

INTRODUCTION

At its annual meeting in 1976 the IWC Scientific Committee noted that humpback whale (*Megaptera novaeangliae*) mortality in fishing gear around Newfoundland (Fig. 1), strandings on the Atlantic coast of the United States, and the continued removals by West Indies and West Greenland whalers could mean that the western North Atlantic population of humpbacks was being harvested near the level of sustainable yield (Anon., 1977, p. 45). Since then, the landed catch in the West Greenland fishery has increased, and the small take at Bequia has continued (*International Whaling Statistics*), four additional strandings and one gillnet-caused death have occurred on the US coast (Mead, 1981 MS), and encounters with fishermen and fishing gear in Newfoundland have been documented with increased frequency (Lien *et al.*, 1979; Lien and Merdsoy, 1979a; Lien, 1980, 1981 MS; Lien and P. Beamish data summarized in Canadian IWC Progress Reports – Mitchell, 1980, 1981, 1982; Fig. 2). The Scientific Committee recommended in 1978 (Anon., 1979), and annually since then, that the exemption allowing a take of humpbacks by West Greenlanders be removed from the IWC Schedule.

Concurrent with the apparent increase in humpback mortality, some Newfoundland officials and the Canadian Maritime press have called for a resumption of whaling in Newfoundland in order to reduce the population of [humpback] whales, which are seen as a serious threat to the island's fishery-based economy (e.g. Anon., 1978a, b, c, d, e; 1979a, b; 1980a). Popular articles by scientists have encouraged the public perception of the western North Atlantic humpback population as being fully recovered. For example, 'Current estimates are as high as 3,000, which may be higher than the virginal stock size' (Lien and Gray, 1980). Also, the unproven hypothesis that humpback distribution has shifted inshore because of a fishery-caused decline in Grand Bank capelin (*Mallotus villosus*) stocks has become an article of faith to some (Whitehead, 1981). 'Lack of capelin on the Grand Banks induces whales to feed inshore' (Lien and Merdsoy, 1979b). Bryant *et al.* (1981) stated: 'Humpback whales have apparently abandoned the Grand Banks...possibly as a result of depletion of capelin stocks in that area.' We know of no evidence, published or unpublished, that humpbacks no longer occur on the Grand Banks.

The humpback's concentrated, nearshore summer distribution and its tendency to winter on shallow tropical banks make it accessible to scientists and tourists, just as it was to whalers formerly. The result is that much effort has gone into watching, photographing, and counting humpbacks, analogous to the effort devoted to studies of gray whales (*Eschrichtius robustus*) in the eastern North Pacific. Changes in such observer effort, especially around Newfoundland, make it difficult to judge the accuracy of statements about a substantial whale population increase. There is also a possibility that publicity about the whale entanglement problem, particularly as the prospect of indemnity for gear damage is raised (e.g. Anon., 1980b, c; Whitehead, 1981), will influence the reporting habits of fishermen, making temporal changes in incidence harder to detect. Finally, the presence of many different investigators censusing

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Fig. 1. A young humpback whale, *ca* 30 ft long, sex undetermined, being released from a cod trap near Sommerville, Newfoundland, 10 June 1981 (P. Beamish, *in litt.*, 21 November 1981 and 20 January 1982). The whale initially had the twine wrapped around it four times. Fishermen and researchers from Trinity, Nfld., rolled the animal out of the trap. This was one of eight successful releases of humpbacks in which Ceta-Research Inc. was involved during the summer of 1981. (Photograph by T. Goodwin, courtesy of P. Beamish)

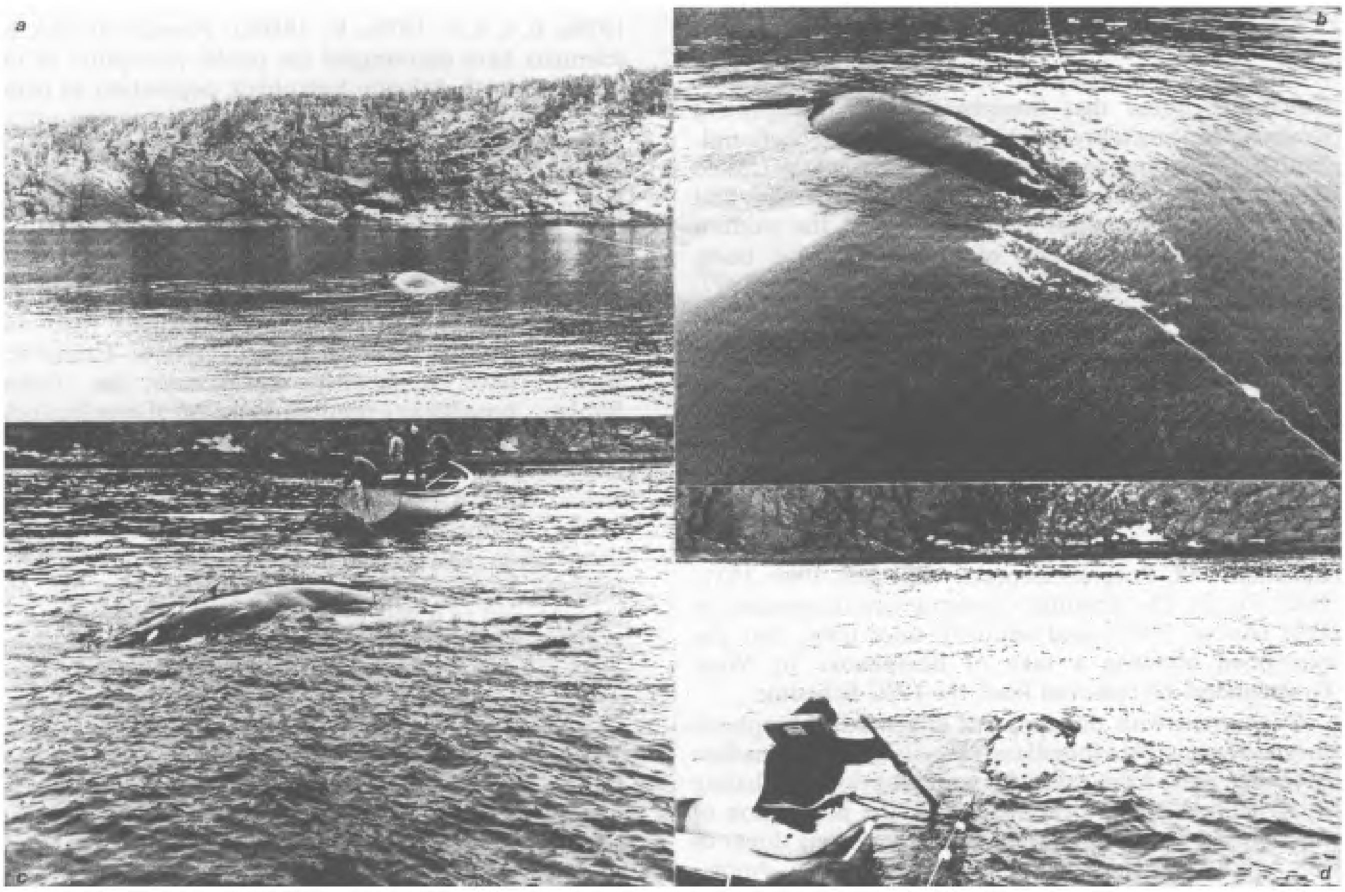

Fig. 2. Humpback whale entangled in salmon net on 30 June 1972 off Cavendish, Trinity Bay, Newfoundland. The whale, estimated to be about 30 ft long, was released alive on 30 June, with a piece of net still in its mouth. It was tagged with .410 Discovery mark no. 1572 and observed to swim away soon thereafter. (a) whale in salmon net, (b) detail showing netting in whale's mouth, (c) release crew approaching whale, (d) net being severed with a flensing knife. (EDM photos DR 49-72 by G. Horonowitsch)

humpbacks in the West Indies has led to a number of independent estimates of population size, and the disparities among them are difficult to reconcile, at least in part because of inadequate descriptions of estimation methods. Few of the estimates have been formally published, but even those that have not been are frequently mentioned in committee reports and popular articles.

The purpose of this study was to document the history of exploitation of humpback whales in the western North Atlantic and to estimate more rigorously early population size. The scope of our research was as follows: (1) discussion of stock identity, (2) summary of history of exploitation, (3) estimation of early population size using analysis of cumulative catch, (4) evaluation of estimates of present population size, (5) assessment of present status of the population, and (6) identification of problems and approaches for further research.

Abbreviations used are: BIWS = Bureau of International Whaling Statistics; IWC = International Whaling Commission; *IWS = International Whaling Statistics*; ODHS = Old Dartmouth Historical Society; PPL = Providence Public Library; *WSL = Whalemen's Shipping List*.

MATERIALS AND METHODS

We surveyed readily available, relevant published works, including scientific papers, books, reports, and popular articles. We also examined some periodical literature, particularly: the annual reviews of the whale fishery from 1843 to 1904 and entire volumes from 1850 to 1890 (volumes 8–48) of the *Whalemen's Shipping List and Merchants' Transcript* (*WSL*) published weekly in New Bedford through 1914; *The International Whaling Statistics* (*IWS*), Sandefjord, Norway; and a variety of newspaper clippings (in EDM library) covering eastern Canadian subjects, *ca.* 1967–present.

Unpublished data on the Newfoundland whale fishery provided by the Committee on Whaling Statistics on BIWS forms were used. A computer list of historical whale records for the east coast of North America compiled by J. G. Mead of the US National Museum, Washington, D.C., was examined (Mead, n.d. MS). A partial set of typescript worksheets (for vessels listed alphabetically, A–J) used by C. H. Townsend (1935) to prepare his whale charts were checked for details on humpback whaling (Townsend and Watson, n.d. MS).

In order to identify and characterize the nineteenth century Yankee pelagic humpback fishery, we examined a sample of whaling logbooks and journals in two major North American collections. Reeves spent one week using the Nicholson Collection in the Providence (Rhode Island) Public Library (PPL) and another week at the Old Dartmouth Historical Society (ODHS), New Bedford, Massachusetts. These two collections currently contain a combined total of approximately 1,636 Yankee logbooks and journals, a substantial proportion of those available worldwide. Logbooks and journals in both collections are indexed by vessel name, port of departure, master's surname, and destination (and see Starbuck, 1878, 1964; Hegarty, 1959). In addition, the ODHS has 'Abstracts of Whaling Logs and Journals' by J. S. Cumpston, an unpublished set of short abstracts of 922 documents giving selected details of itineraries and activities for logbooks and journals in the ODHS collection.

We also examined the 12 logbooks in the Morse Whaling Collection, Brown University, Providence, and the 39 logbooks available on microfilm from the Sterling Library, Yale University, New Haven, Connecticut. None of the material in these two collections proved useful for this study.

Procedures for selecting, scoring, and analyzing the logbook/journal sample are explained under the heading 'Selection of Logbook/Journal Samples' in the West Indies section below.

A major source of data to which we did not have direct access is the *Bluebooks* for St Vincent, West Indies, which give figures on whale oil exports (Adams, 1970, 1971; Price, 1979, 1981 MS). Because of problems in the interpretation of such data from other published sources (see West Indies 'Nineteenth Century Shore Whaling' section below) and their potential significance, we feel it would have been useful to examine the *Bluebooks* ourselves.[1]

Following procedures for estimating early population size by analysis of cumulative catch data (e.g. Mitchell and Reeves, 1981), we attempted to identify a period or periods of intensive humpback exploitation after which the population could be assumed or was reported by whalers to have been reduced to a low level. Chittleborough's (1965) estimate of net recruitment rate for a heavily exploited humpback population in the southern ocean was 0.046, the animals having been aged on the basis of two ear plug laminations accumulated per year (Chittleborough, 1959).[2] Such a low annual increment makes it possible to sum removals by hunting over a period of 10 years to estimate, crudely, minimum population size in Year One.

STOCK IDENTITY

Many earlier authors commented on humpback migration routes and stock identity in the North Atlantic. Humpbacks there, like those in other parts of the world, 'undertake migrations along well-defined courses at definite seasons' (Kellogg, 1929). There is a tropical 'breeding-migration' in winter and an antitropical 'feeding-migration' in spring and summer (Hinton, 1925). An exception may be the 'Finnmark stock' (Tomilin, 1967) observed passing the coast of Finnmark in February and March, the adult females often containing near-term fetuses (Risting, 1912; Ingebrigtsen, 1929; Jonsgård, 1966).

Kellogg's (1929) description, including his humpback distribution map, suggests two North Atlantic stocks, tied to the continental margins on either side of the ocean. He was uncertain about the population in Denmark Strait, which could be attributed to either the eastern or western stock. It was Tomilin's (1957, 1967) view that humpbacks in Denmark Strait come from the western side and that some of these animals travel as far northeast as Jan Mayen and the Barents Sea in summer. He considered a statement by Mörch (1911) – that parts of an American bomb-lance were found in a humpback killed at Finnmark – to 'confirm' that some humpbacks 'wintering in the Barents and Norwegian Sea also belong to the West Atlantic population' (Tomilin, 1967, p. 270). However, we know from our logbook sample that Yankee whalers often hunted humpbacks in the eastern North Atlantic, especially at the Cape Verdes, between 1850 and 1900 (also see Atwood's statement in Clark, 1887a, p. 22; M., E.J., 1864; Millet, 1924, p. 23; *WSL*). Therefore, Tomilin's interpretation of Mörch's statement is open to question.

While recognizing the high probability that Northern and Southern Hemisphere populations are largely separate, Hinton (1925) argued that humpbacks from the South Atlantic, inasmuch as they regularly cross the equator during their 'breeding-migration', occasionally join North Atlantic humpbacks that have lingered late on their own winter grounds, thus forming a mixed herd that proceeds toward the Arctic for the boreal summer. He cited morphometric data, the presence of similar-sized fetuses in Northern and Southern Hemisphere animals during March, and the recovery of a harpoon at Iceland supposedly of South American origin (Haldane, 1908) as evidence. Haldane's (1908, p. 69) 'curious' harpoon of 'South American origin' more likely originated from experimental whaling activities around Iceland and elsewhere in the North Atlantic from the 1860's onward (e.g. Schmitt *et al.*, 1980). We regard Hinton's case for 'interchange between the northern and southern races in the equatorial regions' to be inconclusive, but it cannot be entirely discounted.

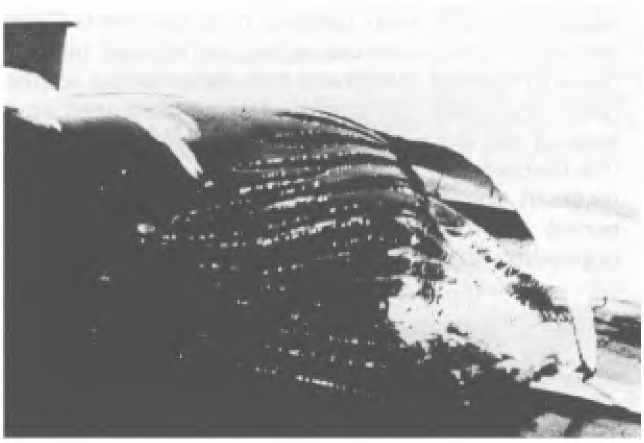

Fig. 3. Female humpback whale, 45 ft. (13.6 m) long, taken in Canadian scientific catch, landed at Dildo, Newfoundland, on 5 June 1971. As Mörch (1911) first noted and others have pointed out, pigmentation features such as the white throat and black belly may prove valuable in analyzing the relationships of families or substock units within humpback whale populations. (EDM photo DR 33-71:10 by B. Peers; whale No. D 30-71)

Winn *et al.* (1981) compared song patterns of humpbacks in different areas (North Atlantic, North Pacific, South Pacific) and concluded that, 'despite annual change in song organization, significant differences in humpback song occur between isolated ocean basins, while only subtle differences exist within an oceanic population (Hawaii and Pacific Mexico).' Only one recording of an Atlantic humpback outside the West Indies was used in their analysis. This Cape Verde animal's song was 'essentially equivalent' to songs recorded 'simultaneously' in the West Indies. These results support Payne's earlier (1979) analysis of Atlantic and Pacific songs. A larger sample of Atlantic humpback songs is required before the usefulness of such data for stock differentiation can be evaluated.

We reviewed humpback whale distribution charts based on records of whalers (Clark, 1887b; Townsend, 1935) and merchant seamen (Slijper *et al.*, 1964; Morzer-Bruyns, 1971) in the North Atlantic. These do little more than substantiate statements by others concerning the existence of eastern and western stocks, although several of Townsend's and Slijper *et al*'s records are of interest. Townsend plotted one or more captures in April at *ca.* 25° N, 57° W and another at *ca.* 31° N, 43° W; Slijper *et al.* plotted sightings across much of the North Atlantic between 30° N and 50° N in July and August and various sightings in the open sea in other months. Also, Morzer-Bruyns indicated a continuous summer distribution across the Atlantic between roughly 40° N and 60° N. Sightings outside the Caribbean or Cape Verdes wintering grounds from our logbook sample (Table 8), along with statements by Martin (1981 MS), indicate that humpbacks are not totally confined to continental coasts or island chains and that some movement occurs across the mid-North Atlantic. Eastern and western North Atlantic populations appear not to be completely geographically isolated, on this evidence.

An extensive effort was made between 1966 and 1971 to mark a large number of North Atlantic whales with Discovery tags (Mitchell, 1968, 1970, 1974). During this period more than 160 humpbacks were tagged successfully in the central and western North Atlantic, from Surinam north through the Caribbean to Disco Island in Davis Strait (Mitchell, 1973a). An experimental sampling program carried out by Canadian shore whaling stations in 1969–1971 delivered 41 of a sample of 70 whales requested (Fig. 3), but only 16 of these met the request for large animals 45 ft or over (to increase the likelihood of recovering tags). No tags were recovered in the sample. To date, the only significant recapture in the western North Atlantic demonstrated the return of a humpback to West Greenland waters in successive years (Mitchell, 1974, 1977). A limited amount of additional tagging has been done since 1971 (Mitchell, 1977), but only one recovery – within less than four weeks and near the same Newfoundland location as where the ice-entrapped whale was tagged – has been made (Mitchell, 1979a).

Fluke and dorsal fin photographs have been used as a means of identifying individual humpbacks (Kraus and Katona, 1977; Balcomb and Nichols, 1978; Katona and Kraus, 1979; Katona *et al.*, 1979; Katona and Whitehead, 1981; Figs 4 and 5). Of 1,010 different whales catalogued in this sample before May 1980, 120 were resighted in different geographic areas or in the same area after an interval of more than one month (Katona *et al.*, 1980). This led Katona *et al.* to postulate the existence of 'separate populations' or 'separate substock units' in the Newfoundland–Labrador region and the Gulf of Maine–Nova Scotia region during summer, and also the possibility of there being a 'small distinct subpopulation' in the Gulf of St Lawrence. Lack of a significant sample from other summer grounds, notably Davis Strait and Denmark Strait, meant that speculation concerning other population units could not be evaluated. Connections between Silver Bank in the Caribbean and both Newfoundland and the Gulf of Maine, and between Puerto Rico and Newfoundland–Labrador, have been demonstrated. Also, there is evidence of whales passing Bermuda en route to the Gulf of Maine, Newfoundland, and Labrador.

Since 1976 H. Winn and G. Scott have outlined and modified, in a series of manuscripts and public lectures, a hypothesis for more than one stock in the western North Atlantic. Although this hypothesis has not been presented, criticized and defended in a refereed scientific

Fig. 4. The variable pigmentation on the ventral surface of humpback whale flukes has been used to study movements of individual whales at sea. This whale was photographed near Bermuda in April, 1970 from the M/V *Erline*. (EDM photo 803:224)

journal (see Winn and Scott, 1977), it has been referred to in literature and therefore requires consideration. In 1978 the IWC Sub-Committee on Protected Stocks recommended against publication of a Winn and Scott paper on this subject, having 'found their argument unconvincing and in the absence of other data accepts the previous hypothesis of one western Atlantic stock' (Anonymous, 1979, p. 85). Katona *et al.* (1980) summarized the hypothesis and evaluated it in light of the results of their fluke-matching study. We quote their summary below, as it is the only published version of the hypothesis:

> The upper stock supposedly breeds on Navidad, Silver, and Mouchoir Banks north of Haiti and the Dominican Republic, then migrates north through the Bahamian region and along the east coast of North America to feed from Cape Cod to Labrador. The middle stock is visualized as breeding between Mona Passage and the island of Dominica, then migrating north past Bermuda in March and April, and on to Greenland. The lower stock is thought to breed from Venezuela to Martinique, then to migrate north through the open ocean to feeding grounds in Iceland and Greenland.

Katona *et al.* had no means of critically testing the possibility of a middle and a lower stock, but they were able to 'modify' Winn and Scott's concept of an upper stock by noting that at least some of the Silver Bank animals visit Bermuda during their migration to New England and some animals pass through Bermuda *en route* to Newfoundland and Labrador. They also argued for a 'clear division' between US–Nova Scotia animals and Newfoundland–Labrador animals.

Mitchell (1973b) stated:

> humpback whales associate in groupings of from 20–30 to perhaps 100–200. At present it is suspected, but not proven scientifically, that these groupings are actually family units or small isolated stocks and, therefore, that each is vulnerable to literal biological extinction if any future exploitation is not spread over many such groups in the northwest Atlantic population.

The early whalers were well aware of the humpback's conservatism. Nordhoff (1857, p. 175) called the humpback 'the most stupid of whales' for clinging 'obstinately to the place it has once chosen'. Ingebrigtsen (1929) noticed that humpbacks were less resilient to exploitation than other whales, having 'far more definite habits of life and haunts than other whales, so that when whaling begins at any one place or is carried on continuously the stock is so reduced that breeding ceases'. Trends in the catch of humpbacks at various North Atlantic stations leave no doubt that local populations can be fished to very low levels in a short time. Ingebrigtsen (1929) calculated that close to 3,300 whales were killed in 'North European waters' between 1885 and 1927, most of them off Finnmark (1,500) and Iceland (1,500), and stated this catch 'appears to have entirely exterminated' the stock in the north-east Atlantic. High catches for a few years at Newfoundland–Labrador and Iceland near the turn of the twentieth century (detailed below) were followed by dramatic reductions in humpback landings, apparently due to decreased availability (Tønnessen, 1967). In the absence of evidence that humpbacks suddenly became less desirable from an economic point of view, population depletion is indicated. Kapel (1979) attributed the decline in the Danish catch off West Greenland during the 1930s to the 'rather substantial number taken by pelagic fleets in the Davis Strait (1922–24) and from the same stock in other areas in the 1920s'. An extreme example from the winter grounds is Grenada, where a Norwegian station using modern whaling equipment fished out the local humpback population in two years (see below).

There are other lines of evidence suggesting that there can be more than one stock on either side of an ocean basin (Fig. 6). Mörch's (1911) observations at South Georgia, in the South Atlantic (also see Risting, 1912; Hinton, 1925), for example, indicate a degree of genetic isolation between herds appearing at different times on the same whaling grounds. 'At certain times all the Humpbacks that are brought in have the belly nearly white; this variety may then disappear and those caught for some time may have the belly marbled; schools with their bellies entirely dark may then put in an appearance, succeeded by the first variety, and so on' (Mörch, 1911, p. 663).

We believe there is more than one fishable stock of humpbacks in the western North Atlantic, and if direct exploitation is ever resumed on a large scale, a management program recognizing stock differences will be essential. On present evidence, however, we are not

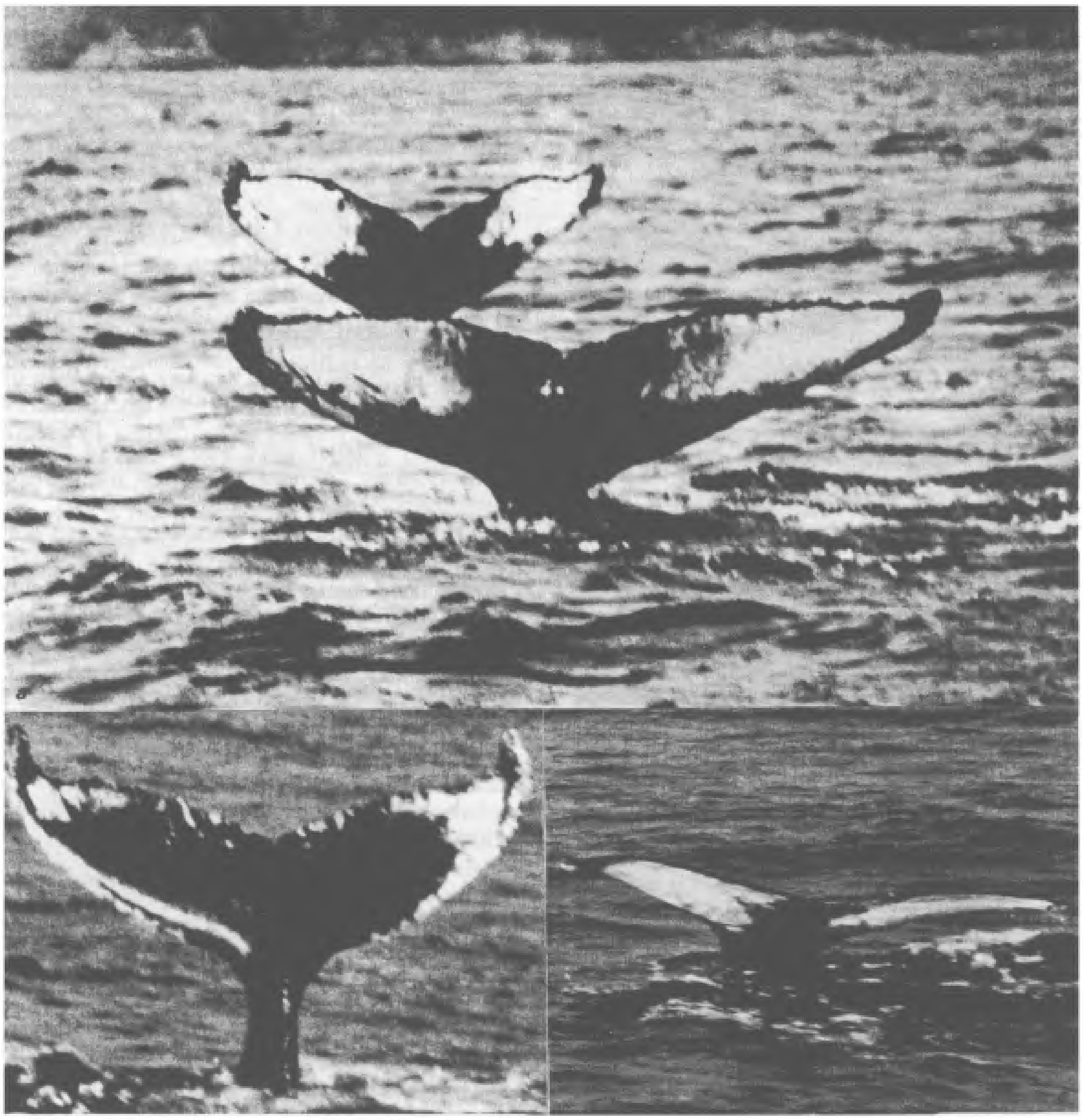

Fig. 5. Flukes of two humpback whales observed at 1413 hrs, 8 September 1980, in Trinity Bay, Newfoundland, 48° 20′ N, 53° 15′ W (a) and two humpback whales observed at ca 1800 hrs, 3 July 1980, from aboard the M.V. *Meta* on the edge of Southeast Shoal, Grand Bank, ca 44° N, 49° 15′ W (b, c). (Photos by R. J. MacFarlane [a] and T. Cartier [b, c])

prepared to attempt a delineation of stock boundaries, and in this paper we treat the western North Atlantic population as if it were one stock. We are reluctant to speculate about the affinities of the humpbacks seen and formerly hunted around Iceland. Two cumulative catch estimates for the western North Atlantic population have been made, one including and the other excluding Iceland catches.

CATCH HISTORY BY REGION

In Table 1 we have listed known and estimated removals by hunting from the western North Atlantic stock of humpback whales since 1850. We consider our estimates conservative, and additional research undoubtedly will reveal more known kills than we have been able to document. Below, we review the history of humpback whaling between West Greenland/Iceland and Venezuela to substantiate our estimates (Table 1).

I. **Davis Strait**

(i) *Nineteenth-Century European and American whaling*

The British whaleman John Walker of the *Jane* of Bo'ness 'one year in default of better game, killed fifteen Humpbacks in Disco Bay' (Brown, 1868, p. 548). The *Jane* of Bo'ness was whaling in Davis Strait in 1853 and was lost in Melville Bay in 1858 (Lubbock, 1937, p. 358, 369). Therefore, the kill of 15 Davis Strait humpbacks must have occurred before 1858, and it probably was after 1840, by which time the availability of bowhead whales (*Balaena mysticetus*) had declined.

Bowheads were the primary target of the European and American whalers operating in Davis Strait between 1719 and 1915 (Lubbock, 1937). However, the practice of taking humpbacks after failing to find bowheads may have occurred more frequently than is generally believed. As Van Beneden (1887, p. 19) stated: 'A défaut de Baleines véritables dans la baie de Baffin, souvent les baleiniers se rejettent sur les *Humpback* pour compléter leur chargement.' In particular, we suspect the Danish

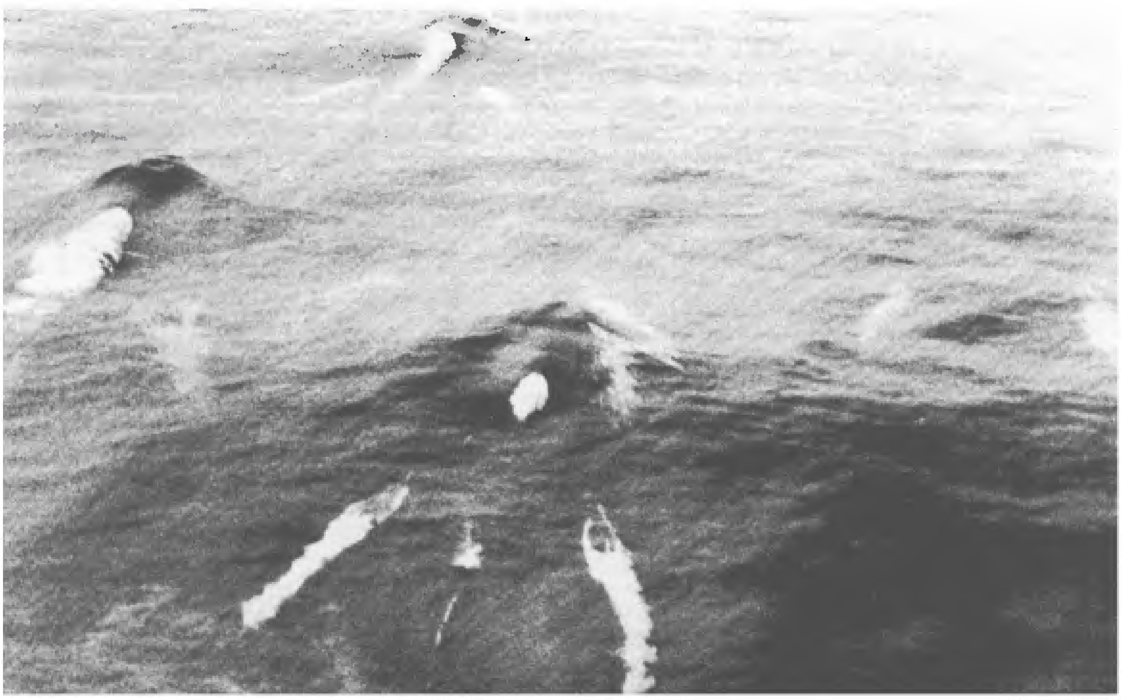

Fig. 6. A pod of four humpback whales on Navidad Bank on 18 February 1969, all with dorsally white flippers. Three of the whales are blowing underwater. The dorsal surface of the flippers is usually white on Northwest Atlantic humpbacks; in some other regions there is a higher incidence of dark flippers than of white. (EDM photo 281:28, M/V *Polarstar*)

stations at West Greenland (Eschricht and Reinhardt, 1866) took humpbacks opportunistically. Eschricht, van Beneden, and other nineteenth-century European scientists used humpbacks supplied by Captain Holböll, the district Governor in Godthåb, from the Davis Strait fishery for their anatomical and systematic studies (Eschricht and Reinhardt, 1866, p. 1*n*; True, 1904, p. 49, 61). Rink (1877) stated that European boats often were lent to the West Greenlanders for humpbacking, and large iron lances were supplied to native humpbackers by the European whalers (Fabricius, 1962). Yankee whalers who visited the Arctic after 1820 were aware of the market for humpback oil and may have lowered for humpbacks occasionally when they encountered them. For example, in late June 1857 the bark *Tempest* of New London reported groups of humpbacks at 74° N off East Greenland but found them 'unapproachable' (*Tempest*, 1857–1861).

While recognizing that European and American whalers in the Arctic occasionally took humpbacks, we are unable to make an estimate of this kill.

(ii) *Modern Norwegian pelagic whaling*

The *Lloydsen*, a combined catcher and floating factory, visited Davis Strait in 1911 and 1912, taking a total of 32 blue whales (*Balaenoptera musculus*) and 12 humpbacks off West Greenland (Tønnessen, 1971, pp. 24–5). A Norwegian walrus hunting expedition captured 10 humpbacks off West Greenland in 1919 (Isachsen and Isachsen, 1932, p. 60). Norwegian floating factories operated in the northern North Atlantic and adjacent Arctic waters during the period 1922 to 1937 (Hjort and Ruud, 1929; Jonsgård, 1955). They made substantial catches of humpbacks in Davis Strait during 1922–1924, totaling 327 whales. Jonsgård (1955) suggested the decline in the humpback catch in 1924 resulted in a greater catch of blue whales and probably fin whales (*Balaenoptera physalus*) (see Jonsgård, 1977, Table 18). It is unclear whether this trend was due to local depletion of humpbacks or to a change in the whalers' preferences.

After 1924, Norwegian pelagic whaling was redirected to other grounds, including the areas of Svalbard, Bear Island, Iceland, and East Greenland, while visits to Davis Strait continued to be made at least occasionally (Jonsgård, 1955). Unfortunately, published catches for the period 1929 to 1937 are attributed only to the 'Arctic' or the 'North Atlantic' and not to any specific ground (Jonsgård, 1977, table 19). Jonsgård (1955), however, indicated that 14 expeditions were sent out between 1929 and 1934 and that they visited the areas around Bear Island, Spitsbergen, and Iceland, including Denmark Strait, as well as Davis Strait from Labrador and Cape Farewell to north of Disko Island. As several areas could be visited during a single cruise, it is necessary to examine logbooks of the voyages or other unpublished sources to determine positions for the catches.

Jonsgård (1955) read catch logs of nine of the 14 expeditions for data on blue whales, but he did not indicate where humpbacks were taken. Å. Jonsgård (in litt., 14 October 1981) kindly supplied us with details on the humpback catches by these nine expeditions (Table 2). Of the 79 humpbacks taken, 34 were killed in Davis Strait, all but one of them by the *Norskehavet* in 1931 (*Norsk Hvalfangst-Tidende*, 1932, No. 3, p. 68).

Seven catcher boats were operating in Davis Strait in 1937, and a total of seven humpbacks was taken by the two Norwegian factories in the North Atlantic that year (Jonsgård, 1955; 1977, table 19).

(iii) *Modern Danish shore-based and pelagic whaling*

Kapel (1979) summarized the history of modern whaling conducted by the Danish catcher boats off West Greenland between 1924 and 1958. Catch data which Kapel described as reliable appear in his Table 1B. Prior

(continued on p. 162)

Table 1

Estimated number of humpbacks killed by whaling in the western North Atlantic, by year, 1850–1971. Appropriate loss rate factors have been used to account for whales killed but not secured. See text for substantiation and explanation of estimation procedures.

Year	West Greenland/ Denmark	Norwegian Davis Strait	Iceland	Newfoundland/ Labrador; Nova Scotia	Gulf of of St Lawrence	New England	Bermuda	Grenadines	Yankee Pelagic[1] West Indies	Barbados	Total
1850	—	—	—	—	5	8	—	—	—	—	13
1851	—	—	—	—	5	—	4	—	—	—	9
1852	—	—	—	—	5	22	2	—	11	—	40
1853	—	—	—	—	9	8	14	—	19	—	50
1854	—	—	—	—	9	—	2	—	—	—	11
1855	—	—	—	—	9	—	0	—	—	—	9
1856	—	—	—	—	9	—	0	—	—	—	9
1857	—	—	—	—	9	2	0	—	—	—	11
1858	—	—	—	—	19	—	0	—	—	—	19
1859	—	—	—	—	16	14	10	—	—	—	30
1860	—	—	—	—	16	—	—	—	—	—	16
1861	—	—	—	—	13	38	—	—	—	—	51
1862	—	—	—	—	10	—	—	—	—	—	10
1863	—	—	—	—	6	—	—	—	1	—	7
1864	—	—	—	—	10	—	—	—	2	—	12
1865	—	—	12	—	6	—	—	—	—	—	6–18 (Iceland)
1866	4	—	14	—	5	1	2	—	224	—	236–250 (Iceland)
1867	4	—	—	—	10	—	—	—	307	—	321
1868	4	—	—	—	10	—	—	—	133	—	147
1869	4	—	—	—	10	—	—	—	127	5	146
1870	4	—	—	—	9	—	—	—	179	3	195
1871	4	—	—	—	6	—	2	—	82	40	134
1872	4	—	—	—	3	—	—	—	129	25	161
1873	4	—	—	—	4	—	—	—	100	23	131
1874	4	—	—	—	6	—	—	—	108	32	150
1875	4	—	—	—	16	2	—	—	67	30	119
1876	4	—	—	—	12	—	—	7	111	27	161
1877	4	—	—	—	9	—	—	7	92	30	142
1878	4	—	—	—	5	4	—	7	76	20	116
1879	4	—	—	—	8	14	—	7	86	20	139
1880	4	—	—	—	6	8	—	44	90	20	172
1881	4	—	—	—	5	29	—	44	71	20	173
1882	4	—	—	—	4	—	—	44	82	20	154
1883	4	—	—	—	2	—	—	44	94	20	164
1884	4	—	—	—	2	—	—	44	67	20	137
1885	4	—	—	—	4	—	—	44	119	20	191
1886	8	—	—	—	4	—	—	44	66	20	142
1887	8	—	—	—	4	—	—	44	15	20	91
1888	8	—	—	—	14	—	—	44	4	20	80
1889	5	—	—	—	—	—	—	44	—	20	69
1890	0	—	1	—	—	—	—	44	—	20	64–65 (Iceland)
1891	—	—	1	—	—	—	—	44	2	20	66–67 (Iceland)
1892	5	—	1	—	—	—	—	44	—	20	69–70 (Iceland)
1893	12	—	2	—	—	—	—	44	—	20	76–78 (Iceland)
1894	14	—	8	—	—	—	—	44	—	20	78–86 (Iceland)
1895	12	—	8	—	—	1	—	44	—	20	77–85 (Iceland)
1896	5	—	6	—	—	—	—	44	—	20	69–75 (Iceland)
1897	11	—	6	—	—	—	—	44	—	20	75–81 (Iceland)
1898	5	—	130	15	—	—	—	44	—	20	84–214 (Iceland)
1899	11	—	98	10	—	—	—	44	—	20	85–183 (Iceland)
1900	14	—	60	16	—	—	—	44	—	20	94–154 (Iceland)
1901	14	—	215	18	—	—	—	44	—	20	96–311 (Iceland)
1902	14	—	346	111	—	—	—	44	—	20	189–535 (Iceland)
1903	14	—	7	304	—	—	—	44	—	6	368–375 (Iceland)
1904	14	—	7	298	—	—	—	44	—	6	362–369 (Iceland)

Table 1 (*continued*)

Year	West Greenland/ Denmark	Norwegian Davis Strait	Iceland	Newfoundland/ Labrador; Nova Scotia	Gulf of of St Lawrence	New England	Bermuda	Grenadines	Yankee Pelagic[1] West Indies	Barbados	Total
1905	7	—	—	171	—	—	—	44	—	6	228
1906	7	—	—	61	—	—	—	44	—	6	118
1907	7	—	—	43	—	—	—	44	—	6	100
1908	7	—	—	25	—	—	—	44	—	6	82
1909	7	—	—	84	—	—	—	44	—	6	141
1910	5	—	—	59	—	—	—	44	—	6	114
1911	5	6	1	28	—	—	—	44	—	6	89–90 (Iceland)
1912	5	6	—	23	—	—	—	44	—	6	84
1913	5	—	5	8	—	—	—	44	—	6	63–68 (Iceland)
1914	5	—	—	14	—	—	—	9	—	—	28
1915	3	—	—	5	—	—	—	9	—	—	17
1916	3	—	—	—	—	—	—	9	—	—	12
1917	3	—	—	—	—	—	—	9	—	—	12
1918	3	—	—	4	—	—	—	9	—	—	16
1919	3	11	—	2	—	—	—	9	—	—	25
1920	—	—	—	—	—	—	—	9	—	—	9
1921	—	—	—	—	—	—	—	3	—	1	4
1922	1	129	—	—	—	—	—	9	—	—	139
1923	—	159	—	3	—	—	—	8	—	4	174
1924	11	39	—	17	—	—	—	12	—	2	81
1925	8	—	—	37	—	—	—	1	—	109	155
1926	13	—	—	19	—	—	—	3	—	75	110
1927	10	—	—	93	—	—	—	1	—	—	104
1928	10	—	—	22	—	—	—	5	—	—	37
1929	10	—	—	12	—	—	—	3	—	—	23
1930	6	—	—	7	—	—	—	1	—	—	14
1931	4	35	—	—	—	—	—	3	—	—	42
1932	4	1	—	—	—	—	1	3	—	—	9
1933	1	—	—	—	—	—	—	1	—	—	2
1934	2	—	—	—	—	—	—	1	—	—	3
1935	6	—	0	10	—	—	—	3	—	—	19
1936	5	—	0	11	—	—	—	1	—	—	17
1937	4	7	1	10	—	—	—	1	—	—	23
1938	1	—	0	—	—	—	—	1	—	—	2
1939	2	—	1	4	—	—	—	3	—	—	10
1940	—	—	—	7	—	—	2	0	—	—	9
1941	—	—	—	3	—	—	—	1	—	—	4
1942	—	—	—	1	—	—	2	0	—	—	3
1943	—	—	—	6	—	—	—	0	—	—	6
1944	—	—	—	11	—	—	—	0	—	—	11
1945	—	—	—	10	—	—	—	0	—	—	10
1946	4	—	—	5	—	—	—	0	—	—	9
1947	5	—	—	6	—	—	—	1	—	—	12
1948	1	—	0	16	—	—	—	3	—	—	20
1949	2	—	2	12	—	—	—	0	—	—	16
1950	4	—	0	17	—	—	—	0	—	—	21
1951	5	—	1	31	—	—	—	0	—	—	37
1952	—	—	0	1	—	—	—	0	—	—	1
1953	1	—	2	—	—	—	—	0	—	—	3
1954	—	—	—	—	—	—	—	0	—	—	0
1955	—	—	—	—	—	—	—	0	—	—	0
1956	—	—	—	—	—	—	—	0	—	—	0
1957	—	—	—	—	—	—	—	0	—	—	0
1958	2	—	—	4	—	—	—	6	—	—	12
1959	—	—	—	—	—	—	—	6	—	—	6
1960	1	—	—	—	—	—	—	2	—	—	3
1961	1	—	—	—	—	—	—	0	—	—	1
1962	2	—	—	—	—	—	—	0	—	—	2
1963	—	—	—	—	—	—	—	3	—	—	3
1964	—	—	—	—	—	—	—	2	—	—	2
1965	1	—	—	1	—	—	—	2	—	—	4
1966	4	—	—	—	—	—	—	0	—	—	4
1967	5	—	—	—	—	—	—	3	—	—	8
1968	5	—	—	—	—	—	—	3	—	—	8
1969	3	—	—	6[2]	—	—	—	3	—	—	12
1970	—	—	—	15[2]	—	—	—	8	—	—	23
1971	4	—	—	20[2]	—	—	—	3	—	—	27

[1] For years prior to 1866, only data from 'read sample' and 'sighted sample' have been used to estimate kill, assuming 25 bbls/whale and a loss rate factor of 1.85.

[2] No loss rate factor applied.

Table 2

Catch of humpback whales by nine Norwegian pelagic expeditions in the North Atlantic and adjacent Arctic oceans, 1930–34. (Data courtesy of Dr. Å. Jonsgård, *in litt.*, 14 Oct. 1981; and see Jonsgård, 1955, Table 4.)

			Humpback whales caught		
Expedition	Hunting period	Catchers	Davis Strait	Denmark Strait and Iceland	Bear Island and Spitsbergen
Haugar	1930 16/4–7/9	3	0	0	16
Pioner	1930 8/6–22/9	3	0	0	9
Norskehavet	1931 2/6–30/9	4	33	1	0
Pioner	1931 8/6–1/10	3	0	0	5
Norskehavet	1932 22/5–4/10	5	1	4	0
Esperanza	1933 11/6–21/9	3	0	0	0
Hauger	1933 5/6–31/8	4	0	0	6
Pioner	1933 15/4–14/10	3	0	1	0
Haugar	1934 3/6–26/10	4	0	2	1
Totals			34	8	37

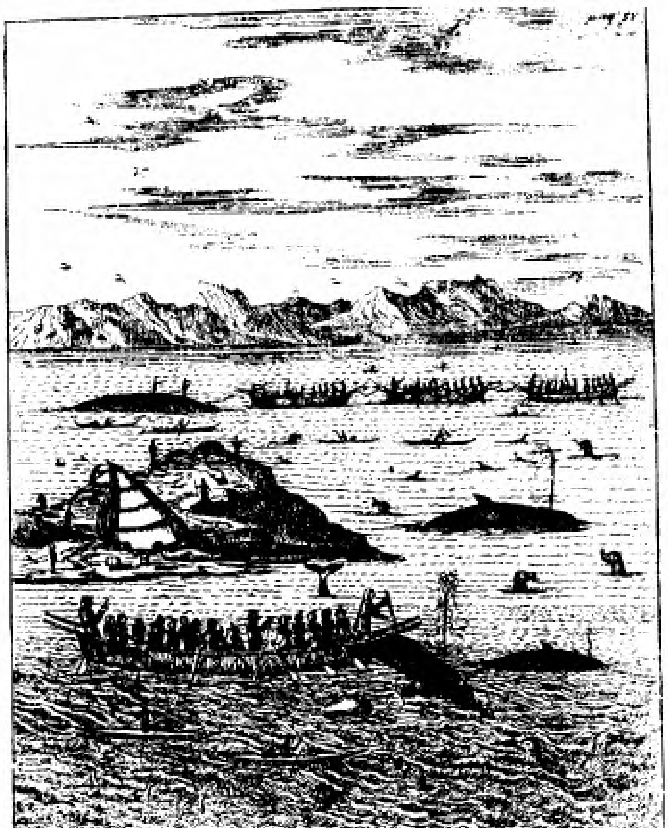

Fig. 7. Illustration of Eskimo whaling in West Greenland from Egede, 1741. This may represent the earliest good illustration of humpback (our presumption based on the presence of a dorsal fin on at least two of the whales) whaling along the West Greenland coast. Note particularly the detailed illustration of the use of harpoon-line-float technology and multiple umiaks to tow carcasses. (In a later version of the same illustration, pl. 7 in the English edition of Egede, 1745, the phocids acquire large external ears, the poke becomes unrecognizable, and other details are oversimplified.) [Reprinted from Gad, 1971, vol. 1, p. 266, with permission.]

to World War II the humpback was the second most important species after the fin whale; after the war, more sperm whales (*Physeter macrocephalus*) than humpback whales were caught. Ninety-two humpbacks were taken from 1924 to 1939, whereas only 20 were taken from 1939 to 1958.

(iv) *Traditional and transitional whaling by West Greenlanders*

The most sustained fishery for humpbacks in Davis Strait is that of native West Greenlanders (Fig. 7). There is a substantial Danish-language literature on the hunting of large whales in West Greenland, much of which we were unable to obtain or use (e.g. Rink, 1852–1857; Gad, 1967, 1969 [but see Gad, 1971, 1973]; and other references cited by Kapel, 1979). The earliest reference (Fabricius, 1780) described techniques of a well-developed fishery, so Greenlanders certainly were hunting humpbacks before this time. The many uses to which this whale was put (Fabricius, 1818, 1962) indicate that it was hunted with considerable enthusiasm (Fig. 8). Blubber was sold at trading stations (Rink, 1877, p. 271).

Kapel's (1979) Table 1A begins in 1886, but by 1877 the local humpback fishery had 'greatly decreased' (Rink, 1877, p. 122). The average annual landed catch at Frederikshåb (the only 'station' reporting regularly) was 5.5 whales between 1886 and 1899. The highest catch in one year at Frederikshåb apparently was 13 taken in 1844 (Rink, 1877, p. 127–8), although one author stated that as of 1841 the 'regional record' was 22 in one year (Winge, 1902, 1981). Frederikshåb certainly was the center of the West Greenland humpback fishery in the late nineteenth century (Brown, 1868, p. 548), but Sukkertoppen may have been a more important area for whaling at mid-century (Winge, 1902). Also, at least a few humpbacks were killed off Godthåb and Egedesminde.

Kapel's Table 1A indicates that the most intensive period of fishing was approximately 1893–1914, when the reported landed catch totaled 130 humpbacks. This includes catches made at Godthåb after the turn of the century, due to renewed interest in whaling.

Neither Winge (1902), his source, nor Kapel (1979) himself comments on the reliability and completeness of the records kept by the colonial administration prior to 1900. It seems likely that at least some whales were taken outside Frederikshåb district and that the total West Greenland catch between 1886 and 1899 was, therefore, somewhat higher than the 66 listed in Kapel's Table 1A.

Struck whales frequently escaped or sank (Fabricius, 1962, p. 130–1; Rink, 1877, p. 122, 127). Humpbacks were usually lanced before being harpooned (see Moeller, 1964, 1967). Although there is no quantitative data available for estimating the struck-but-lost rate, we can

Fig. 8. Flensing a 'Kepokak-whale' (humpback) on the West Greenland coast. This is an interesting early illustration of the utilization of humpbacks by the West Greenlanders (and see our Fig. 7). Rink indicates in his caption to the figure that the whale was 'probably a drift whale,' and the implements being used appear to have little relation to European whale flensing tools. (Fig. No. 3, opposite p. 271 of Rink, 1877; courtesy of National Library of Canada, Ottawa)

assume that many more humpbacks have been killed off West Greenland than the record of landings shows (Fig. 9).

For West Greenland kills after 1885 we have used Kapel's (1979) figures, with a loss rate factor of 1.5 used to account for hunting loss. For the period 1866–1885, which is considered for our cumulative catch estimate (see below), we estimate four humpbacks killed per year, considering: (1) Rink's (1877, p. 128) estimate of two per year caught until 1877; (2) the average landings of 5.5 per year from 1886 to 1899 (Kapel, 1979); and (3) the undocumented hunting loss reflected in Rink's (1877, p. 127) statement that the hunt was 'often frustrated by the sinking of the killed animal before it can be towed to the shore'.

II. Iceland

Available published information on catches at Iceland has been summarized elsewhere (*IWS*; Jonsgård, 1977). It is important to note that a substantial 'unspecified' catch occurred between 1890 and 1912, ranging from 84 to 1,249 whales in a given year. Risting (1931, p. 7) stated in regard to this portion of the catch: 'The animals recorded here are chiefly blue- and fin-whales. Humpbacks were only caught in considerable numbers in the period from 1898 to 1902.' We have, accordingly, pro-rated the unspecified catch for this five-year period, using the percentage of humpbacks in the specified catch, year by year (Table 1).[3]

Another consideration is that some whaling for humpbacks occurred at Iceland between 1863 and 1872, when Thomas Welcome Roys and others were experimenting with rocket-harpoons for catching rorquals (Fig. 10). The main target of this experimental fishery was the blue whale, but at least six humpbacks were taken by Roys's vessels in 1865 and seven in 1866. In the early years, half or more of the whales killed were lost due to sinking (Paijkull, 1868; Schmitt *et al.*, 1980). We, accordingly, list the 1865 removals as twelve, and 1866 as fourteen, in Table 1.

It is possible that humpbacks taken at Iceland belonged to a stock other than the one under discussion here. We consider this possibility in our discussion of cumulative catch estimates below.

III. Newfoundland–Labrador

(i) *Before 1898*

Early hunting people who inhabited the coast of Labrador used humpback whales, as evidenced by remains found in an archaeological site near Nain (Spiess, 1978). However, we have no certain evidence that the people caught the whales rather than finding them stranded on the shore.

The Spanish Basques were whaling in Newfoundland and Labrador waters during the sixteenth century, particularly in the Strait of Belle Isle, which was known then as the Grand Bay (Barkham, 1977a, b; 1978; 1980). Portuguese, French, English and Breton fishermen were also active there, although it is not clear that they were engaged in whaling as well as fishing. The English definitely participated to some extent in subsequent Grand Bay whaling, and some American whalers worked in Grand Bay and along the Labrador coast prior to 1760 (Prowse, 1895; 1972, pp. 60–3, 596–7). There is even some suggestion of Bermudan involvement in the Newfoundland whale fishery in the 1780s (Prowse, 1972, p. 417).

Yankee whaling in Newfoundland and Labrador became a more regular enterprise during the 1760s (Stackpole, 1953, p. 48–9). Twelve vessels, each employing

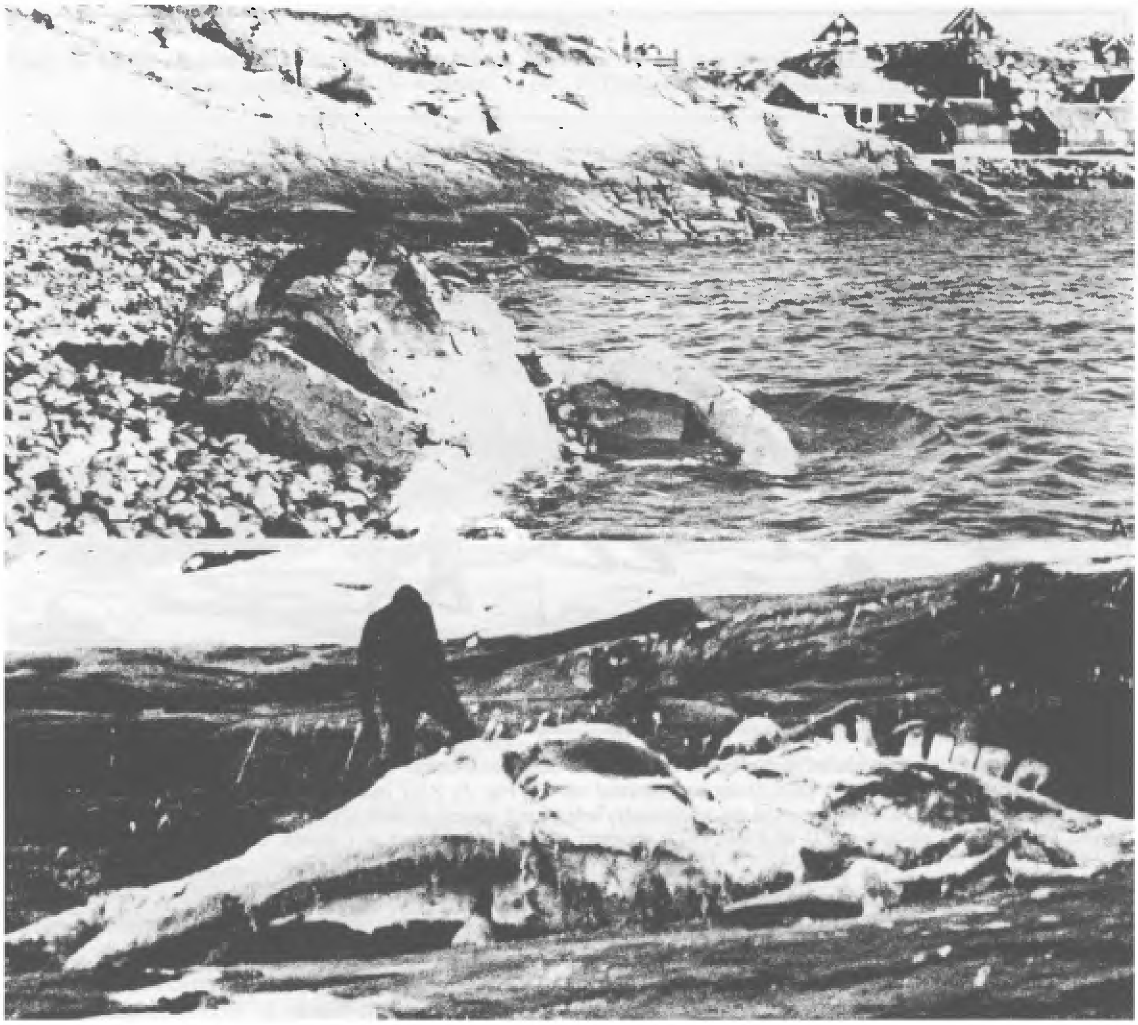

Fig. 9. Remains of humpback whales on the beaches at Godthaab, West Greenland, in late 1960s and early 1970s. A significant portion of the West Greenland take of humpbacks during this period was by fishermen/whalers out of Godthaab, and many carcasses were towed into Godthaab Fjord where they were dismembered, and the meat and blubber used locally. A number of small humpbacks were noted in the remains examined and some were collected (e.g. EDM 679, 681, etc.). **A**. – Flensed head from recent kill, at Godthaab, 24 August 1966, EDM photo 15:31; **B**. – Rotten carcass in Godthaab Fjord, 31 October 1973, EDM photo 1581:02.

Fig. 10. Whaling with rockets, a technology developed by Thomas W. Roys and his associates and competitors with trials off Iceland and elsewhere. Note the silhouette of what appears to be either a balaenid or a blue whale, the free-standing shooter, and the line attached to the rocket-launched harpoon. This advertisement was typical of those appearing over the name of Roys or G. A. Lilliendahl during the mid 1860s in the *Whalemen's Shipping List and Merchants' Transcript*, and it reflects the technological innovations leading to subsequent worldwide exploitation of not only the humpback, but all other balaenopterids. (From Smithsonian Institution, reprinted with permission from Schmitt *et al.*, 1980, Fig. 19.)

15 men, made large catches along the south coast of Newfoundland, especially in Hermitage Bay, Bay of Despair, and Fortune Bay, during the late 1790s (Prowse, 1972, pp. 296–9). In 1796, 12 vessels, each manned by 15 men, returned to New England fully loaded (Browne, 1909, pp. 166–7). Yankee whaling continued in Hermitage Bay at least through 1801, but the American fishery apparently ended after about 1810. In that year an American schooner working in St Mary's Bay made a good catch (Prowse, 1972, p. 298).

The *Whalemen's Shipping List* (27(24): 10 August 1869) refers to a letter sent from 'St. Johns, N.F.' by Capt. Chappel of the bark *E. B. Phillips* of New London. He reported having shipped 2,000 gallons of sperm oil to London, 'and would sail for Trinity Bay humpbacking', definite evidence that Yankee sperm whalers hunted humpbacks at Newfoundland during the last half of the nineteenth century.

Prowse (1972, p. 299) referred to a local whale fishery at Hermitage Bay, apparently in the early nineteenth century, that was 'extensive' and 'large scale'. Bonnycastle (1842) gave a confusing characterization of the Newfoundland whale fishery. On the one hand (Vol. II, pp. 181–2): 'The whale fishery is not yet of much note. Some few merchants in St. John's annually send a ship or two to the south shore, or to the Gulf; and the great house

Fig. 11. View of a 46 ft 6 in. (14.2 m) gravid female humpback whale, landed at Snooks Arm, Notre Dame Bay, Newfoundland, on 18 August 1899 (no. 21; True, 1904, p. 212). Note remains of whales to left, including (?) severed snouts awaiting removal of baleen (?) near shed. (Photograph by F. W. True, courtesy of J. G. Mead, USNM neg. 11528)

of Newman and Company keep an establishment at Harbour Britain, where they carry on this fishery to some extent, the kind pursued being chiefly the fin-backed whale.' And (Vol. I, p. 247): '[It is the "true or toothless whales"] which engage the small and irregular whale fishery on the Newfoundland coast, and that principally on the harbour coasts of the south, and in the gulf.' On the other hand, Bonnycastle (1842, Vol. I, p. 239) claimed: 'The coast and gulf whale fishery is now becoming of much value to Newfoundland.' Whatever the magnitude of this early Newfoundland-based fishery, we know little about its pursuit or about the composition of the catch.

We have been unable to document catches of humpbacks around Newfoundland before the advent of modern mechanized whaling, although they probably were taken.

(ii) *1898 to 1902*

The Newfoundland–Labrador catch data for 1898–1902 are given in numbers of whales and total oil production, with no breakdown of species composition (Mitchell, 1974, table 5-5). We have tried to develop plausible estimates of the humpback portion of the catch in these years.

In 1898, only the Snook's Arm station on Notre Dame Bay was in operation (Southwell, 1899). The first whale taken there was killed on June 25 (Millais, 1907, p. 163). At least 46 more whales were taken in that year by the steamer *Cabot*. Southwell (1899) and Tønnessen (1967) indicated a catch in the 1898 season of 92 and 91 whales, respectively, although Mitchell (1974) accepted Millais's lower figure of 47. Twenty whales had been landed by mid-September, all of them finbacks and humpbacks (Tønnessen, 1967), and the season closed in early November (Southwell, 1899). According to True (1904, p. 111), who visited the Snook's Arm station in 1899 (Figs 11, 12 and 13), fin whales and humpbacks were the only species generally captured there. During his three-week stay in August, 25 finbacks and 3 humpbacks were taken, humpbacks being 12 per cent of the catch to date. The whalers told True that finbacks predominated in August but that 'the Humpback arrived in large numbers later in the year' (True, 1904). Considering that less than half the season's harvest in 1898 had been taken prior to mid-September and that whaling continued until early November, we estimate that humpbacks finally comprised 20 per cent of the season's catch. Taking the mid-point of two estimates of the season's catch, 92 and 47, we estimate the season's catch as 69 whales. If 20 per cent were humpbacks, then an estimated 14 humpbacks were taken in 1898.

In 1899, the picture becomes clouded, when a second whaling station – at Balaena on Hermitage Bay – began operations. The blue whale was the principal species caught at Balaena (Tønnessen, 1967). Generally, the *Cabot* would work out of Snook's Arm, on the north coast of Newfoundland, in summer (June–October), and out of Balaena, on the south coast, in winter. From the end of February through March 1899 the *Cabot* took 11 blue whales in Hermitage Bay (Southwell, 1900). Between mid-July and the first week of October, 98 whales were taken in Notre Dame Bay, of which only 9 were humpbacks and the rest finbacks (Southwell, 1900). Southwell's total of 109 whales is somewhat higher than the figure of 95 given by Millais (1907) and accepted by Mitchell (1974). However, the ratio of finbacks to humpbacks taken at Snook's Arm (Southwell's catch data – 9.9 fins to 1 humpback) is close to the ratio in the catch for part of 1899 given by True (1904 – 8.3:1) from first hand observation, and we are inclined to accept Southwell's figures as reliable. Therefore, we estimate 9 humpbacks taken in 1899.

In 1900 the *Cabot* accounted for 111 whales according to Millais (1907), of which 67 were blue whales and 11 were humpbacks taken at Balaena (True, 1904; and see Southwell, 1901). Assuming the remaining 33 were finbacks and humpbacks taken at Snook's Arm after mid-July, in the ratio of 9 finbacks to 1 humpback, then four humpbacks would have been taken at Snook's Arm. Our estimate for the humpback catch in 1900 is, therefore, 15.

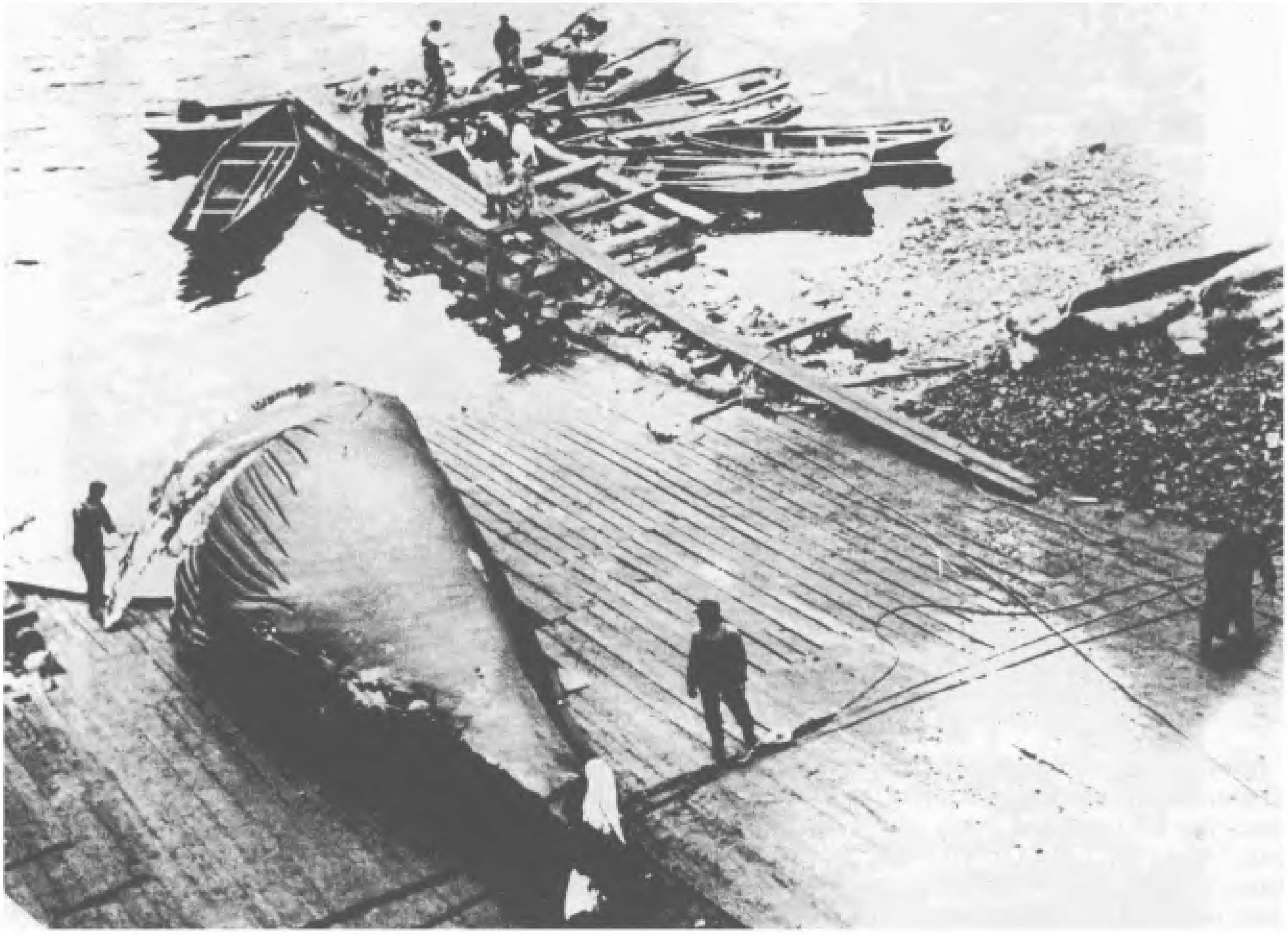

Fig. 12. View of a 45 ft 5 in. (13.8 m) gravid female humpback whale, landed at Snooks Arm, Notre Dame Bay, Newfoundland, on 9 August 1899 (no. 6; True, 1904, p. 212). Note jaws to right of ramp. (Photograph by F. W. True, courtesy of J. G. Mead. USNM neg. 11526)

In 1901 another whaling station was opened on Chaleur Bay just west of Hermitage Bay (Tønnessen, 1967). The total catch by the *Cabot* and the Newfoundland Steam Whaling Company's catcher boat working out of Chaleur Bay was 258 whales (Millais, 1907). There were at least 71 blue whales and 7 humpbacks taken at Balaena (True, 1904). As only 4 per cent of the whales (12 of 297) caught at Chaleur Bay from 1904 to 1906 were humpbacks, it is likely that very few were taken there in 1901. Assuming 4 per cent of Chaleur Bay's 258 whales in 1901 were humpbacks, we estimate 10 humpbacks were taken there. Our estimate for Balaena and Chaleur Bay combined, then, is 17.

In 1902 the total catch was 472 whales (Millais, 1907). In spite of a Newfoundland whaling law that took effect on April 22 of this year requiring payment of a high permit fee ($1,500 per year) and limiting the number of catcher boats to one per station, two new stations opened – one at Rose-au-Rue deep inside Placentia Bay and the other at Aquaforte on the southeast coast of Newfoundland (Risting, 1922; Tønnessen, 1967; Mitchell, 1974, Table 5–4). As 121 of the 353 whales taken (34 per cent) at these two stations in 1904 were humpbacks, we assume the same percentage for 1902. The total catch in 1902 at Aquaforte was 108 whales, or about 37 humpbacks. Guldberg (1904, p. 375; 1981) indicated that about 105 humpbacks were taken in all of Newfoundland this year. We have no reason to question Guldberg's statement, and we accept his estimate of 105 humpbacks taken at Newfoundland in 1902.

A conservative estimate, then, of the humpback catch at Newfoundland between 1898 and 1902 is 160. Tønnessen (1967) observed that 32 per cent of the catch in 1903 was humpbacks, and he considered the 'relative values [to] have probably been similar in previous years though possibly with higher numbers of blue whales' (Tønnessen, 1971, p. 7–8). If we simply were to multiply the total catch by 0.32, following Tønnessen's suggestion, the estimate for humpbacks during 1898–1902 would be 315 whales, or about twice the figure we have used (Table 1).

(iii) *1903–1915*

Data for Newfoundland–Labrador whaling between 1903 and 1915 are given by species for all years except 1907 (Mitchell, 1974). We have little to add or revise in these statistics. Sergeant (1966 MS, Table 8) estimated a catch of 41 humpbacks for 1907 by 'smoothing', and we have no reason to contest this estimate. The Norwegian steamship *Sobraon*, operating as a 'floating cookery' (Tønnessen, 1971, pp. 25–6), worked north along the Labrador coast to Spotted Island during the summer of 1908, taking 47 whales, species unspecified (Tønnessen, 1967). We assume at least a few were humpbacks, but no catch by the *Sobraon* has been included in Table 1.

(iv) *1916–Present*

There was a hiatus in whaling at Newfoundland–Labrador between 1916 and 1922, broken, as far as we know, only by modest catches in 1918 and 1919 (Mitchell, 1974). The

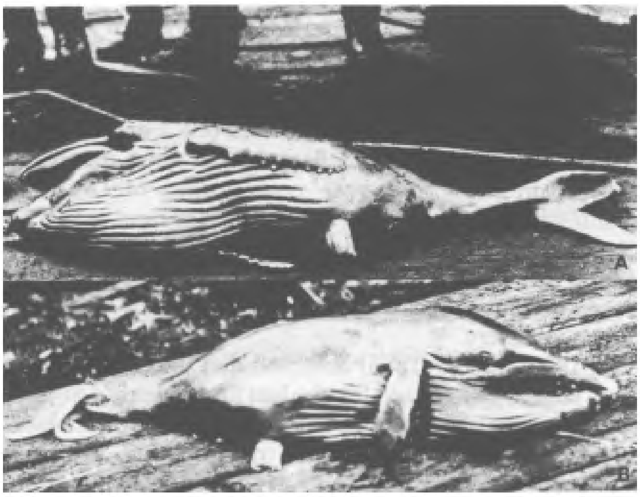

Fig. 13. Fetuses from humpback whales landed at Snooks Arm, Notre Dame Bay, Newfoundland in August 1899. a. (top). – Male fetus 45 in. (114 cm) long, from female humpback no. 21, landed 18 August 1899. b. (bottom) Male fetus 39.5 in. (100 cm) long, from female humpback No. 6, landed 9 August 1899. (Photographs by F. W. True, courtesy J. G. Mead, USNM negs. 11522, 11533, respectively; and see True, 1904, p. 212n)

Fig. 14. Female humpback whale, 46 ft. (13.95 m) long, landed 3 June 1971 at the South Dildo land station, Trinity Bay, Newfoundland, one of a scientific take to recover tags in the Northwest Atlantic population. (EDM photo DR29–71:16A by B. Peers; whale No. D 28–71)

specified catches of humpbacks in the year before (5 in 1915) and the year after (3 in 1923) this period represented 3.6 and 4.3 per cent, respectively, of total catch for those years. The catch in 1918 was 101 whales. We take four per cent (mid-point of 3.6 and 4.3) of this 1918 catch as four humpbacks. The oil production in 1919 was 1,464 bbls. Assuming yield per whale was the same as in 1918 (25 bbls.), then the number of whales caught in 1919 is estimated to be 59. If four percent of these were humpbacks, then two humpbacks are estimated as taken in 1919.

Humpbacks were taken every year between 1923 and 1951 except those in which whaling was suspended – i.e., 1931–34 and 1938. Very little killing of humpbacks is known to have taken place in Newfoundland–Labrador after 1951 (Mitchell, 1974, table 5-5). In 1969–1971, 34 humpbacks were taken at Newfoundland (plus seven at Nova Scotia) under special scientific permit (Mitchell, 1973a; Fig. 14).

(v) *Loss rate in the modern fishery*

The loss rate in the modern Norwegian-type fishery at Newfoundland–Labrador was undoubtedly lower than that in the nineteenth century open-boat fisheries, but there is little information to use as a basis for estimating it.

R. L. Stevenson, a Canadian inspector at the Hawkes Harbour, Labrador, station in 1951, kept a daily record of operations between June 13 and October 20 of that year (Stevenson, 1951 MS). During this time 378 whales were landed at Hawkes Harbour, including 20 humpbacks. Stevenson dutifully reported information he received about lost whales. He mentioned whales 'lost with harpoons in them,' whales 'stolen by killer whales whilst flagged,' and whales lost when their 'tail broke at ship's side in heavy seas.' He estimated that 21 whales were killed and lost during the season, which would represent 5.6 per cent of the landed catch. We calculate the Loss Rate Factor (LRF), by which landings must be multiplied to account for killed but lost whales, as: LRF = (378+21/378), or 1.056.

We assume two things about Stevenson's data. First, they refer to a period relatively late in the fishery, when his very presence indicated some degree of official interest in monitoring the hunt. The loss rate may have been substantially higher during the early years of the fishery. Second, it is not likely that Stevenson heard about every whale that was struck and lost, although we have no reason to think he knowingly under-reported losses. In light of these assumptions, we have rounded the Loss Rate Factor to estimate Fishing Mortality (F) from landed catch of 1.056 upward to 1.06 and applied it to our yearly catch figures for the entire 'modern' fishery, 1898–1971.

IV. Gulf of St Lawrence

(i) *Nineteenth-century Gaspé sailing vessel fishery*

Whaling at least by residents of Gaspé Bay, on the south shore of the St Lawrence, began about 1804 and continued until 1893, interrupted only for a few years during the 1820s when whale oil prices declined and operations were unprofitable (McDougall, 1979; McDougall and McDougall, 1978; 1981). Few details of this fishery, particularly for the first half of the nineteenth century, are available, and available information is fragmentary and sometimes contradictory. According to Lavoie (1876) there were at least a dozen 'fine large schooners' engaged in the fishery during its early years. A 93-year-old Gaspésie told Moussette (1972) that he thought seven schooners was the most ever involved in the fishery at one time, but a contemporary account by Fortin (1856) listed eight vessels active in 1856. Four or five were active in 1832 (Anderson, 1872); seven in 1858 (Dawson, 1858); ten in 1859 (Lavoie, 1874). McDougall (1979; in litt., 1 September 1981) has accounted for nine vessels from Gaspé Bay, two from Percé, and eight from Paspebiac in what he considered the peak year, 1819.

The Gaspé whalers used schooners to reach the whaling grounds, then attacked the whales in rowboats with hand-held harpoons and lances (Perley, 1852, 1859; Fortin, 1856, 1859; Fortin and Tetû, 1868). Their whaling techniques apparently were conservative, and we have no evidence that they used explosives or that they tried out the blubber on board. Fortin (1859) explained that killed whales were towed to the vessel, 'where they cut them up', and McDougall (pers. comm., 20 October 1981) stated that tryworks were set up at convenient sites on shore.

The Gaspé sailing vessel fishery was, at least by the middle 1800's, a humpback fishery primarily (Perley, 1852, 1859; Fortin, 1856, 1859, p. 22; Lavoie, 1876). A contemporary statement from 1826 indicates that humpbacks were 'the most common' whales encountered by the Gaspé whalers at that time (Mountain, 1942, p. 335). Fortin (1859, p. 22) claimed that most female whales entering the Gulf in late May or June were accompanied by calves and that the whalers would avoid taking a calf for fear of the mother's 'furious' attempts to defend it. On the other hand, Lavoie (1879, p. 49) stated 'it was the rule in olden times among Gaspé whalers to kill the calves and spare the dams'.

Balaenids were present in parts of the Gulf of St Lawrence and Strait of Belle Isle, and they undoubtedly would have been hunted in preference to other species. However, by the 1850s the right whale (*Eubalaena glacialis*) was effectively absent (Fortin, 1857, 1865, 1866); a few were seen in the early 1860s (Fortin, 1863). According to a government report (Wakeham *et al.*, 1913) a right whale killed upriver from Manicouagan in 1912 was the first of its kind to have been killed in the Gulf in 60 years. Captain Coffin of Gaspé took two right whales near St Thomas, Quebec, in autumn 1850 (Wakeham *et al.*, 1913). Only a few were killed during the 1850s (Fortin, 1859; McDougall, 1979).

Blue whales and fin whales were struck occasionally by the Gaspé whalers (Dawson, 1858). However, they were considered 'very difficult to take' (Fortin, 1859, p. 22) and generally would not be harpooned until they had been lanced and wounded. This probably resulted in a relatively high loss rate in a fishery with a low take (cf. Lavoie, 1878).

In addition to Gaspé Bay, the schooners worked throughout the Gulf and the lower St Lawrence estuary (Fortin, 1856, 1859), and through the Strait of Belle Isle and along the Labrador coast (Fortin, 1865). Captain Tripp's vessel regularly visited Trinity Bay, Newfoundland, during the 1860s (McDougall, in litt., 1 September 1981). Among the most important grounds were the Mingan Shoals, situated between 'North Cape' on Anticosti Island and the St John River on the north shore; and St John's Shoal, situated in the upper reaches of the Gulf leading to the Strait of Belle Isle, between St John Island and Great Mecatina Island (Fortin, 1859, p. 22). The vessels at least occasionally reached as far up the St Lawrence River as Kamouraska and as far north along the Labrador coast as Hamilton Inlet (McDougall, 1979). During the 1864 season, one vessel worked in St Mary's Bay, Newfoundland, and another along the Atlantic coast of Labrador (Fortin, 1865).

The main whaling season was July through September (McDougall, 1979), although activity usually began about the first of June (Fortin, 1859), and sometimes as early as late May (Fortin, 1865).

The magnitude of the Gaspé whale fishery can be assessed at present only on the basis of the few published statistics, referring principally to the second half of the nineteenth century (summarized in Table 3), and research by McDougall (1979) and McDougall and McDougall (1978; 1981). Based on records for the period 1853–1865, McDougall (1979) conservatively estimated the annual average production to be 'nearly 750 barrels'. He considered 1858 to be the best year on record, when six schooners accounted for 1,624 barrels. Fortin's (1858) statement that the whaling fleet 'had as good success [in 1857] as in any former year' corroborates McDougall's evaluation. The period 1830–1870 was the most active for Gaspé whaling (McDougall and McDougall, 1981). About half the population of 3,000 people living on the shores of Gaspé Bay was involved, directly or indirectly, in this industry.

In 1872, Lavoie (1873) observed that the Gaspé fishery had 'steadily decreased for the last fifteen years,' and the following year he (Lavoie, 1874) complained that whales were 'abandoning the waters of the Gulf in larger numbers every year.' McDougall (1979, Fig. 4), however, found a reasonably close correspondence between the number of Gaspé schooners engaged in the whale fishery and the fluctuating price of whale oil. Thus, he attributed at least some of the decline in catch to the decrease in whale oil prices after 1870 (Table 4). Analysis of oil returns per vessel led McDougall (in litt., 1 September 1981) to believe that the 'optimum' number of whaling schooners was about five. He believes bad years were as often due to bad weather and ice conditions in the Gulf as to a shortage of whales.

To estimate humpback landings by the Gaspé whalers for years after 1857 (Table 3), we assumed that half the oil returned each year was from humpbacks or that half of the whales captured were humpbacks. For years in which data on oil returns or whales caught were missing, we used as an estimate the midpoint of the oil returns in the next documented years before, and after, the one in question. Humpbacks in the Gulf yielded 10–80 barrels (Fortin, 1859). To be conservative, we used 50 barrels or 1,500 gallons as an average yield per whale in our calculations. (Our estimate here is so crude that it does not matter if these are Imperial or American gallons.)

Information on the loss rate in the Gaspé fishery is equivocal. Fortin (1859) claimed that the whalers 'almost always succeed in securing' struck whales. However, in the 1874 season, for example: 'The schooners of Capts. Suddard and Baker would have done as well as Capt. Tripp's had they succeeded in securing all the whales they harpooned; most of them were unfortunately lost, and with them the profits of the season' (Lavoie, 1875, p. 15). Mitchell (1977 MS) used data from the British whaling captain William Scoresby to estimate the secured catch in the bowhead fishery (using non-explosive implements) to be 85 per cent of the actual kill. Bannister *et al.* (1981), in their detailed logbook study of the nineteenth century American sperm whale fishery, derived estimates ranging from 1.20 to 1.61 for the factor necessary to correct catches and estimate total removals. In the absence of detailed information on the loss rate in the Gaspé fishery, and recognizing that balaenopterids sink after being killed more frequently than balaenids and sperm whales do, we used a loss rate factor of 1.20 to account for whales killed but not recovered in the Gaspé fishery (Table 3).

For the years 1853–57 we assumed an annual yield of 750 barrels (after McDougall, 1979), which would represent an estimated nine humpbacks killed per year. Arbitrarily, we estimated five per year from 1850 to 1852. Our conservative estimate of total humpback removals by the Gaspé whalers from 1858 to 1888 is 244.

Table 3

Summary of available information on the nineteenth-century sailing vessel fishery based in Gaspé Bay, Gulf of St Lawrence. Brackets indicate data that have been estimated (see text)

Year	No. of whales	Oil production	Estimated no. of humpbacks killed (Loss Rate Factor of 1.20)	No. of schooners	Sources
1832	—	'about 18,000 gallons' yearly	—	4 or 5	Anderson, 1872
1856	—	—	—	8	Fortin, 1857
1857	—	—	—	8	Fortin, 1858
1858	—	1,624 barrels	[19]	6	Fortin, 1859; McDougall, 1979
1859	—	[1,337 barrels]	[16]	10	Lavoie, 1874
1860	—	[1,337 barrels]	[16]	—	—
1861	—	33,600 gallons	[13]	—	Fortin, 1862, 1866
1862	—	26,000 gallons	[10]	—	Fortin, 1866
1863	At least 6; at least one a humpback	14,400 gallons	1 [+5]	7	Fortin, 1864, 1866
1864	—	25,014 gallons worth $17,500 (65 ¢/gal.)	[10]	—	Fortin, 1865, 1866; Anderson, 1872
1865	—	14,420 gallons or 474 barrels	[6]	7	Fortin, 1866; Fortin and Tétu, 1868
1866	—	12,330 gallons or 411 barrels	[5]	7	Fortin, 1867; Fortin and Tétu, 1868
1867	—	25,890 gallons	[10]	6	Fortin and Tétu, 1868
1868	—	[23,755 gallons]	[10]	—	—
1869	Four of 5 vessels 'made a good voyage'	[23,755 gallons]	[10]	5	Lavoie, 1870
1870	—	21,620 gallons	[9]	1	Lavoie, 1871
1871	—	523 barrels	[6]	4	Lavoie, 1872
1872	'Some' killed in Gaspé Bay, yielding total of 90 barrels	250 barrels	[3]	3	Lavoie, 1873
1873	—	355 barrels	[4]	2	Lavoie, 1874
1874	Most taken in 'north-west portion of the gulf, from Natashquan to Thunder River'	480 barrels worth $9,000	[6]	3	Lavoie, 1875
1875	27; most 'on the coasts of Labrador and in the Strait of Belleisle'; 120 bbls. taken 'within a short distance from Gaspé'	580 barrels (50 ¢/gal.)	[16]	3	Lavoie, 1876, 1877; Clark, 1887a, p. 216
1876	19	290 barrels or 9,368 gallons	[12]	3	Lavoie, 1877, 1878
1877	15 (at least some killed and lost)	277 barrels	[9]	3	Lavoie, 1878
1878	9	5,120 gallons	[5]	1	Lavoie, 1879
1879	13	8,015 gallons	[8]	1	Wakeham, 1880; Anon., 1880
1880	10	8,100 gallons	[6]	1	Wakeham, 1881; Clark, 1887a, p. 216
1881	9	9,785 gallons	[5]	—	Wakeham, 1882
1882	6; 4 at Grosse Water Bay, one at Meccatina, one at Mingan	3,577 or 5,580 gallons	[4]	1	Wakeham, 1883
1883	4; 14 June to 20 September in upper Gulf and Strait of Belle Isle	4,810 gallons	[2]	1	Wakeham, 1884
1884	4; season 'a failure'	2,000 gallons	[2]	1	Wakeham, 1885
1885	7	5,000 gallons	[4]	1	Wakeham, 1886
1886	[7]	[5,000 gallons]	[4]	—	—
1887	7; in Strait of Belle Isle	5,000 gallons (40 ¢/gal.)	[4]	1	Wakeham, 1888
1888	6; Grosse Water Bay	2,272 gallons	[4]	1	Wakeham, 1889

(ii) *Other eighteenth- and nineteenth-century whaling*

The Gaspé whalers were joined, on and off, during parts of the nineteenth century by whalers based in Newfoundland, New England, and possibly other parts of the Gulf of St Lawrence, particularly the north shore (McDougall, 1979). Bonnycastle (1842, p. 247) claimed the Gulf whale fishery 'carried on by the citizens of the United States, and by our [Newfoundland] colonists, is much greater than has been imagined.'

'The extent to which the Whale Fishery is carried on, within the Gulf of St Lawrence, by vessels from Newfoundland, is very little known, nor is its value appreciated' (Perley, 1852, 1859). In about 1840 a local government bounty encouraged several vessels to depart from St. John's to the whaling grounds on 'the western shore' (Browne, 1909, p. 168). As many as 100 whales were said to have been killed in a season. We are not certain that humpbacks were a significant part of the

Table 4

Prices of sperm, whale, and humpback oil, from compilations by Decker (1973) for 1850–67 and Stevenson (1904) for 1868–1902. Except as noted, humpback oil prices are from statements in the annual review of the whale fishery in the *Whalemen's Shipping List and Merchants' Transcript*, published weekly in New Bedford.

Year	Sperm oil, per gallon ($)	Whale oil, per gallon ($)	Humpback oil, per gallon ($)	Year	Sperm oil, per gallon ($)	Whale oil, per gallon ($)	Humpback oil, per gallon ($)
1850	1.207	0.491	—	1880	0.80–1.08	0.45–0.57	(0.43–0.57)[5]
1851	1.27	0.454	—	1881	0.87–1.05	0.50–0.59	(0.42–0.52)[6]
1852	1.24	0.68	—	1882	1.05–1.15	0.57–0.60	—
1853	1.25	0.58	—	1883	1.08–1.15	0.56–0.60	—
1854	1.49	0.60	—	1884	0.87–1.05	0.55–0.63	—
1855	1.77	0.71	—	1885	0.85–1.00	0.42–0.55	—
1856	1.62	0.80	—	1886	0.67–0.85	0.36–0.48	—
1857	1.28	0.73	—	1887	0.57–0.65	0.35–0.36	—
1858	1.21	0.54	—	1888	0.55–0.62	0.37–0.40	0.40–0.45
1859	1.36	0.49	0.41–0.46[1]	1889	0.62–0.68	0.40–0.42	—
1860	1.43	0.50	—	1890	0.58–0.65	0.42–0.50	—
1861	1.32	0.45	—	1891	0.63–0.68	0.50–0.54	—
1862	1.43	0.59	—	1892	0.63–0.65	0.50–0.53	0.35–0.355
1863	1.61	0.95	—	1893	0.62–0.90	0.40–0.48	—
1864	1.90	1.28	—	1894	0.56–0.62	0.38–0.43	0.30
1865	2.26	1.45	—	1895	0.50–0.56	0.36–0.40	—
1866	2.55	1.21	—	1896	0.35–0.45	0.30–0.35	—
1867	2.27	0.74	—	1897	0.36–0.49	0.32–0.38	—
1868	1.75–2.00	0.64–1.13	—	1898	0.38–0.57	0.31–0.39	0.30–0.33
1869	1.59–1.93	0.84–1.13	0.70	1899	0.40–0.61	0.32–0.40	—
1870	1.22–1.55	0.63–0.75	—	1900	0.45–0.60	0.33–0.37	—
1871	1.22–1.57	0.54–0.84	—	1901	0.55–0.68	0.34–0.38	0.38
1872	1.35–1.63	0.62–0.73	0.60–0.625	1902	0.62–0.70	0.34–0.38	—
1873	1.40–1.55	0.52–0.68	0.55–0.60	1903	0.56	0.38	—
1874	1.50–1.66	0.57–0.63	0.54–0.64	1904	0.52	0.36	—
1875	1.48–1.84	0.62–0.70	0.60–0.65	1905	0.46	0.31	—
1876	1.27–1.62	0.55–0.70	(0.51)[2]	1906	0.51	0.34	—
1877	1.03–1.40	0.50–0.70	(0.50–0.60)[3]	1907	0.59	0.37	—
1878	0.81–1.05	0.35–0.52	(0.34–0.55)[4]	1908	0.57	0.32	—
1879	0.71–1.00	0.35–0.57	0.32–0.59	1909	0.59	0.31	—

[1] *WSL* 17: 1859–60.
[2] Humpback oil remained at about 5 cents below the price of whale oil.
[3] Humpback oil was 5–10 cents below Arctic oil, which declined from 70 cents to 60 cents during the year.
[4] Humpback was about 5 cents below Arctic, which began the year at 60 cents and declined to 39 cents.
[5] Humpback and South Sea oil remained within 2–3 cents of Arctic oil.
[6] Humpback and South Sea oil remained within 3 cents of Arctic oil.

catch, but the technology used probably precluded the regular capture of blue and fin whales.

The American presence in the Gulf was sporadic during the eighteenth century. A large contingent of Yankee vessels visited the Gulf and the Strait of Belle Isle during the 1760s (Starbuck, 1878, 1924). In 1765, the fleet of nearly 100 vessels had taken more than 9,000 barrels of oil by August 8. The next year, however, only 20 whales were taken. A few whaling sloops were outfitted from Quebec by British and American merchants in about 1765, and similar activity continued through at least 1780 (McDougall, 1979). Americans apparently continued to visit Gulf waters off western Newfoundland until about 1810 (Prowse, 1972, p. 298).

We assume the right whale was the main target of these whalers, but there is some evidence that humpbacks were taken in the Gulf by American whalers. In September 1849 the Provincetown schooner *Council* arrived home with 130 barrels of humpback oil; her destination upon leaving port in May 1849 had been 'Straits Bellisle' (*WSL* 8(1): 5III1850). The following year the *Council* again visited Belle Isle, reporting 50 barrels of blackfish oil upon her return to port, 18 September 1850 (*WSL* 8(36): 5XI1850). The *Vesta* of Provincetown returned the same day with 80 barrels of humpback oil. The Provincetown schooner *Cadmus* sailed for the Strait of Belle Isle on 4 June 1850.

Two American schooners certainly visited the Gulf during the middle 1850s, and their use of the Congreve rocket gun was criticized by Canadian fisheries protection officials (Fortin, 1856; 1859, p. 22). The Gaspé whalers complained that the Americans, in two years of whaling with the guns, killed 'from thirty to forty whales yearly, and have not succeeded in securing more than six or eight.' As the right whale was by this time nearly absent from the Gulf, it is likely that humpbacks and other balaenopterids bore the brunt of this wasteful episode of whaling.

We have very little information about eighteenth and nineteenth century whaling by Quebec fishermen in parts of the Gulf outside Gaspé. However, some shore-based whaling certainly occurred. In September 1823, for example, a large (42-foot) whale seen off Montreal was killed by 'several enterprising individuals [who] put off in boats with some whale-fishing materials in pursuit of it,' and in August 1871 a 'gun harpoon' was used to shoot whales from shore near Quebec (Anderson, 1872). A report by the fisheries overseer in the Mingan Division (Caron, 1877, p. 176) makes passing reference to fish catches along the north shore 'by the whalers from Thunder, Magpie, and St. John Rivers' in the 1876 season. Whale oil landings for Quebec outside the Gaspé Division in 1868 (Mitchell, 1869), 1880 (Wakeham, 1881), 1881 (Wakeham, 1882), 1882 (Wakeham, 1883), 1883

Table 5

Catch statistics for whaling station at Seven Islands, Gulf of St Lawrence, 1905–15, after Mitchell, 1974, table 5–7, revised. Data mainly from *International Whaling Statistics* and *Annual Reports of the Department of Marine and Fisheries* (Canada), except as noted.

Year	Blue	Fin	Humpback	Sei	Sperm	Other	Total whales[1]	Oil Production
1905	—	—	—	—	—	—	66	—
1906	—	—	—	—	—	—	72	180,000 gals
1907	—	—	—	—	—	—	77	25,000 gals (?)
1908	—	—	—	—	—	—	52	—
1909	—	—	—	—	—	—	—	—
1910	—	—	—	—	—	—	—	—
1911	—	—	(3)[2]	—	—	—	55	2,000 bbls
1912	—	—	—	—	—	—	85–90[3]	3,333 bbls (*IWS*)
1913	—	—	—	—	—	—	90 Bl+F[4]	3,500 bbls
1914	—	—	—	—	—	—	78 unspec.[5]	3,390 bbls
1915	28	56	—	—	—	—	84	3,422 bbls

[1] According to Tønnessen (1971, p. 23) only blue and fin whales, in the ratio 1:2, were caught during the period 1911–15.
[2] Mackenzie, 1948; *IWS* indicates all 55 taken this year were blue and fin.
[3] Sources differ. Mitchell (1974) and *IWS* indicate *ca.* 85 whales, all blue and fin. Wakeham *et al.* (1913) indicate 90 whales, including 1 right which contributed 140 bbls oil. Mackenzie (1948) indicates 88 whales, unspecified.
[4] Wakeham *et al.* (1914) indicate 87 whales yielding 147,560 gals oil.
[5] Wakeham *et al.* (1915) indicate 85 whales yielding 135,600 gals oil.

(Wakeham, 1884), and other years probably resulted from the activities of these whalers.

Because of poor documentation, we have not tried to estimate the number of humpbacks killed by non-Gaspé whalers in the Gulf of St Lawrence before the turn of the twentieth century.[4]

(iii) *Early twentieth-century modern whaling*

Mitchell (1974, table 5-6) indicated a modern whaling station was operating at Seven Islands in the years 1911 to 1915, but the Quebec Steam Whaling Company was active there as early as 1905. The idea of using steam whalers equipped with explosive harpoons had taken root in Quebec by 1904 (Wakeham *et al.*, 1905, p. 143), and in 1905 the station at Seven Islands accounted for 66 whales (Wakeham, 1906). Although we have found no catch records for 1909 and 1910, we assume the station (Townsend, 1910) continued to operate during these years. It was purchased from its Canadian owners by Norwegians in 1911 (Risting, 1922; Tønnessen, 1971, p. 23). Oil was the main product, but several thousand dollars worth of whalebone was marketed per year between 1912 and 1915 (Minville, 1946, p. 515). Whaling at Seven Islands ceased after the 1915 season 'owing to the small number of whales captured. The fishermen notice that whales are becoming scarcer in the gulf each year' (Bernier, 1917). Some statistics for the Seven Islands station between 1905 and 1915 are given in Table 5.

There is no reason to believe large numbers of humpbacks were landed at Seven Islands because modern technology facilitated the capture of blue and fin whales. The capture of a right whale in 1912 (Wakeham *et al.*, 1913) suggests, however, that right and probably humpback whales were killed opportunistically by the Seven Islands whalers.

Until there is better documentation for species composition between 1905 and 1910, we cannot usefully estimate a humpback kill. We have it on Tønnessen's (1971, p. 23) authority that no humpbacks were processed at Seven Islands between 1911 and 1915.

V. New England and eastern United States

(i) *Before 1812*

Shore whaling in New England dates as far back as the early colonial period, i.e., the early 1600's (Clark, 1887a; Allen, 1916). Indians certainly took advantage of drift whales prior to the arrival of Europeans, but it is not known that they hunted the large whales to a significant extent. An informant told Clark (1887a, p. 30) that the earliest account of a whale capture at Nantucket 'was in the year 1608, when a party of Indians killed a humpback whale which got stranded.' There is little doubt that the whaling by Indians, as well as by early settlers, involved right whales more than any other species. However, Dudley (1725) included the humpback among the whales known from New England waters, and his familiarity with it suggests that the humpback, along with the 'scrag whale' (possibly *Eschrichtius robustus*; see Mitchell and Mead, 1977) and the finback, was hunted at least occasionally.

'The Right Whale and less often the Humpback were the only species regularly hunted in our waters [New England] until the introduction of more deadly apparatus than the hand harpoon' (Allen, 1916). Although the right whale was clearly preferred by the whalers, its numbers had been severely reduced in New England by 1725. After this time, short cruises for humpbacks were made more frequently by vessels based at Nantucket or the Cape Cod towns. Such cruises often combined humpbacking with codfishing. The principal grounds were Nantucket Shoals and Georges Bank. Goode (1884, p. 27) stated: 'The shore fishery of Cape Cod, which was quite vigorously prosecuted in the early part of the last century, was probably largely concerned with this species [*M. novaeangliae*].' He believed the number of humpbacks killed by the shore whalers 'must have been very considerable.' Unfortunately, we have little definite information on the number of vessels engaged in humpbacking or the number of whales taken in the early nineteenth century. The only 'definite record' for the 1700s listed by Allen (1916) was of a humpback struck but lost near Yarmouth, Massachusetts, in 1757.

The War of Independence (1776–1781) reduced the

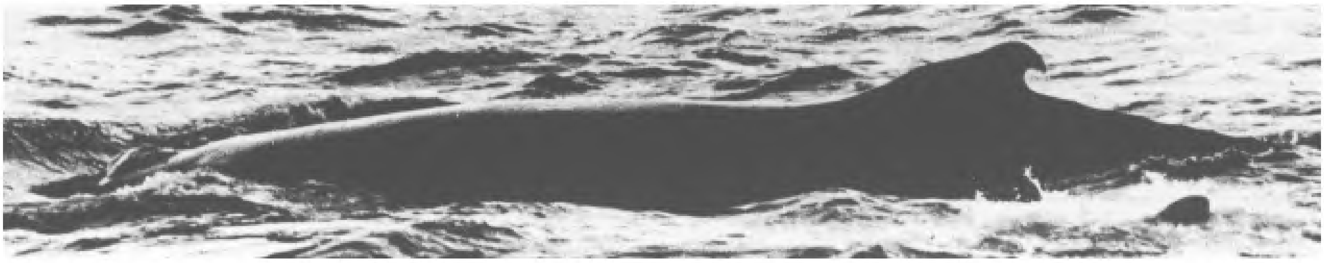

Fig. 15. Humpback whale, *Megaptera novaeangliae*, showing the distinctive 'hump' and a strongly arcuate dorsal fin. (Bermuda, mid April, 1970, EDM photo 807:8)

Yankee pelagic whaling fleet and forced the New England whalers to work closer to home (Allen, 1916). This probably increased the hunting pressure on humpbacks. After the War, the Yankee fleet began to grow again, extending its reach to the Pacific and South Atlantic oceans on a regular basis by the turn of the century (Starbuck, 1878, p. 90–1; Stackpole, 1972). The sperm whale had become a major target, and in the new distant-water grounds there were still large numbers of right whales, the preferred baleen species. Humpbacks were still hunted in New England, however. During the middle 1880's an informant told Clark (1887c, p. 235) that 75–80 years earlier there were four whaling captains, each with a vessel requiring a crew of 14, at Wellfleet, Massachusetts. These whales hunted right whales off Labrador, humpbacks in the Gulf of Maine, and sperm whales [and humpbacks?] in the West Indies.

(ii) *War of 1812 to the end of the Civil War (1865)*

The war with England in 1812 dealt another blow to the New England whaling fleet (Stackpole, 1972), and again humpbacking in local waters augmented the reduced effort in distant-water whaling grounds (Starbuck, 1878, p. 94; Ashley, 1942, p. 32). Many Nantucket vessels, having returned home upon hearing about the outbreak of hostilities, confined their operations to codfishing and humpbacking on nearby shoals (Macy, 1835, p. 174). 'There were about 10 small vessels from Nantucket humpback whaling on the Shoals in 1813. Several made similar voyages in 1814' (Starbuck, 1924, p. 422). In 1815 the *Rover* sailed on September 27 and returned two days later, having 'got two humpback whales in company with sloop *Success*' (Starbuck, 1924, p. 424–5).

When the war ended and the Yankee fleet once more visited distant grounds on a regular basis (Starbuck, 1878, p. 95), some humpbacking in New England continued. '"Humpbacking on the Shoals" was probably the frequent resort of many a Nantucket or Cape Cod fisherman in the years preceding 1850,' and it continued 'in a more or less desultory sort of way' until the American Civil War (Allen, 1916, p. 314). 'A great many' humpbacks were killed by the whalers at Provincetown after 1817 (Goode, 1884, p. 27). Some vessels made cruises specifically for humpbacks (e.g. see *WSL* 8(36): 5XI1850; Starbuck, 1878, p. 473; 1924, p. 481), and occasionally the pelagic whalers interrupted their departure for the grounds when humpbacks were encountered near home (*WSL* 15(15): 23VI1857). References in the *Whalemen's Shipping List* to 'shore and shoals whaling' from Provincetown and Nantucket before 1865 indicate that right whaling and humpbacking off Long Island and Cape Cod were successfully pursued in some years (e.g. *WSL* 11(8): 26IV1853; 17(45): 17I1860; 19(44): 7I1862). Shore whaling in Maine, although poorly documented, lasted from 1810 to at least 1860, and humpbacks 'were undoubtedly the chief object' (Allen, 1916, p. 313; also see Clark, 1887a, p. 41).

(iii) *After the Civil War*

The character of New England shore whaling changed after the Civil War, as explosive projectiles and steam propulsion became more widely used. Not only the humpback, but all balaenopterids, were now available to the whalers. Consequently, it cannot be assumed that 'whales' taken by shore whalers after 1865 were invariably right whales or humpbacks. In fact, fin whales were probably taken or at least attempted at least as often as humpbacks in New England during the 1870s and 1880s (Clark, 1887a, p. 43–4; Allen, 1916, p. 314).

During the 1850s finbacks were 'frequently struck, but rarely killed' by Provincetown whalers (*WSL* 15(42): 29XII1857). After 1865, it could be said that they were frequently struck *and* killed, but rarely landed. Nearly every mention of finback whaling in the *Whalemen's Shipping List* makes reference to the high loss rate (e.g., *WSL* 46(19): 12VI1888; 39(10): 19IV1881; 39(15): 24V1881; 39(8): 5IV1881; 40(10): 18IV1882; 40(13): 9V1882; 40(14): 16V1882; 40(30): 5IX1882; also see Clark, 1887a, p. 41–8). The whales were shot with no intention of getting fast. Those that were bombed successfully were expected to sink to the bottom, then rise and drift ashore or at least to within easy towing distance from a port. Many, of course, were never recovered.

Humpbacks certainly were bomb lanced by the New England shore whalers as readily as were finbacks, and losses were substantial. In 1852 the *Hamilton* of Nantucket took six humpbacks and struck but lost five more on Nantucket Shoals (Allen, 1916, p. 309). Several humpbacks were killed with bomb lances in Provincetown harbor in April 1881, 'going to the bottom as soon as dead' (*WSL* 39(10): 19IV1881); 20 supposedly were shot there in one day in May 1881 (Goode, 1884, p. 27). 'Doubtless others were killed at this time' (Allen, 1916, p. 314). There is ample documentation to support an estimate that at least one humpback or finback was killed and lost for every one landed by the New England shore whalers during the late nineteenth century.

In addition to the balaenopterid whaling carried on in Cape Cod Bay and Massachusetts Bay by Provincetown and Salem whalers during the 1870s and 1880s, several vessels were fitted out especially for humpbacking along the coast of Maine, where humpbacks were still being taken from time to time by local crews 'regularly equipped for whaling' (*WSL* 24(21): 24VII1866; also see Norton, 1930, p. 94–5). The *Brilliant* took at least four humpbacks in the 1879 season (Goode, 1884, p. 27); the

Table 6

Information on humpback whaling and estimated kills in New England, 1850–95. We assumed an average yield of 25 barrels and applied a loss rate factor of 2.0 to account for hunting loss.

Year	Whales or barrelage	Estimated kill	Comments	Sources
1850	80 bbls	6	*Vesta* of Provincetown	Starbuck, 1878, p. 473
	1 whale	2	*Council* of Provincetown	*WSL* 8(36): 5XI1850
1852	6 whales, 130 bbls	12	*Hamilton* of Nantucket	Allen, 1916, p. 307, 314
	60 bbls	4	*Hamilton* of Nantucket	Allen, 1916, p. 314
	1 whale, 40 bbls	2	A Provincetown schooner	Allen, 1916, p. 307
	2 whales (?)	4(?)	*Union* of Provincetown	Allen, 1916, p. 314
1853	4 whales	8	'Shoals whaling'	*WSL* 11(8): 26IV1853
1857	1 whale	2	*Rienzi* of New Bedford	*WSL* 15(15): 23VI1857
1859	180 bbls	14	Provincetown shore whaling	*WSL* 17(45): 17I1860
1861	125 bbls	10	*Samuel Chase* of Nantucket	Starbuck, 1924, p. 481
	474 (minus 125) bbls	28	'Shore and shoals whaling from Prov'town and Nant'et'	*WSL* 19(44): 7I1862
1866	1 whale	1	Chased in harbor, Portland, Maine	*WSL* 24(21): 24VII1866
1875	1 whale	2	Schooner *Starlight*, in Cape Cod Bay	Allen, 1916, p. 314
1878	1 whale	2	Cape Cod, specimen in USNM	True, 1904, p. 232; Allen, 1916, p. 308
	1 whale	2	'Found adrift and towed into Portland Harbor'; 'a harpoon embedded in its back, and...otherwise lacerated'.	Norton, 1930, p. 94–5
1879	2(+1?) whales	4–6	Two killed with bomb lances and a third stranded at Provincetown	True, 1904, p. 232; Allen, 1916, p. 308; Goode, 1884, p. 27
	4 whales, 145 bbls	8	*Brilliant* of Provincetown	Goode, 1884, p. 27
1880	1 whale, 1,200 gals	2	Bass Harbor, Maine	Clark, 1887a, p. 40; Allen, 1916, p. 308
	3 whales	6	Killed with bomb lances, Provincetown	Clark, 1887a, p. 42
1881	2 whales	4	*Bloomer* of Provincetown	*WSL* 39(30): 6IX1881
	'Several' whales	5	All but one killed and sank, Provincetown, before April 11	*WSL* 39(10): 19IV1881
	20 whales	20	Shot with bomb lances, Provincetown, May 14. (For this date, *WSL* 39(15): 24V1881 refers to *ca.* 12 'finbacks' shot in Massachusetts Bay, *ca.* 6 of which died and sank.)	Goode, 1884, p. 27; Allen, 1916, p. 308
1895	1 whale	1	Wounded off Provincetown	Allen, 1916, p. 308

Bloomer, which also hunted finbacks (*WSL* 39(29): 30VIII1881; 38(10): 20IV1880), took at least two humpbacks off the Maine coast in 1881 (*WSL* 39(30): 6IX1881) and at least one in 1882 (*WSL* 40(23): 18VII1882). Although this small fishery in the Gulf of Maine 'proved somewhat successful' (True, 1884, p. 635), the *Brilliant*'s haul, at least, 'was not sufficiently alluring to induce others to follow the example of the owners of the schooner' (Clark, 1887a, p. 162). Shore whaling with small steamers ended in New England after 1895 (Allen, 1916, p. 315).

Because of the erratic documentation of humpbacking in New England during the second half of the nineteenth century, we have not been able to devise an acceptable method of estimating the yearly kill. Even with the assumptions that all oil reported for 'shore and shoals whaling' in the years 1860 and 1862 was from humpbacks, that the average humpback taken by the New England shore whalers only yielded 25 barrels, and that two humpbacks were actually killed for every one secured, our estimates listed in Table 6 are probably very conservative.

VI. Bermuda

The local humpback fishery at Bermuda spanned nearly three centuries. Statements concerning the abundance of whales around the Bermuda Islands appeared as early as 1610, and unsuccessful attempts at capturing whales were made during the 1610s and 1620s (Lefroy, 1877; Verrill, 1907). An abortive attempt to initiate a whale fishery at Bermuda was made in 1619 by the British vessel *Neptune* – 'they could kill none, though they struke many' (*WSL* 44(26): 31 VII 1888). A fishery was finally established in 1663. In the following year, 44 hogsheads of oil and 4 cwt. of baleen were shipped to England (Anon., 1665). Few data on the amount of oil or baleen landed are available. Some statistics, as well as comments concerning whaling activity, are summarized in Table 7.

There has been some uncertainty about the species involved in the Bermuda fishery, although the earliest authoritative account provides an unmistakable description of the humpback as the principal target (Anon., 1665). Jones (1884) interpreted early accounts (e.g. Norwood, 1667) to refer to the right whale, and sperm whales were taken occasionally (e.g. Wilkinson, 1973, p. 656–7). However, we agree with the conclusions of True (1904) and Verrill (1907) that most whales hunted in nearshore waters were humpbacks (cf. Payne and McVay, 1971; Fig. 15). The peak season for the fishery was March to May, and 'females and cubs' were commonly taken. Verrill (1907) believed few humpbacks were born near Bermuda, noting that most 'cubs' taken there were 20 to 30 feet long and 'must have been born in more southern seas.'

One of Verrill's (1907) informants indicated that the average Bermuda humpback yielded 30–33 barrels, very

Table 7

Information on catches of humpback whales at Bermuda, 1664–1907.
(Note: A few right whales and sperm whales may be included in the statistics.)

Date	Evidence	Source
1664	At least 5 whales landed (2 adult females, 3 young); the whalers 'fastened their Weapons a dozen times'; 44 hogsheads oil, 4 cwt. baleen shipped to England	Anon., 1665; True, 1904; Verrill, 1907, p. 273
1665	16 whales landed, yielding 50–60 tons oil; 117 hogsheads or 29 tons oil shipped to England	Anon. 1666; Verrill, 1907; True, 1904
1667	47½ tons oil shipped to England; 'within these two or three years, in the Spring-time and fair weather, they take sometimes one, or two, or three in a day'	Norwood, 1667; Verrill, 1907
1668	'Considerable oil' was 'manufactured' in this year; Stafford claimed to have himself killed many baleen whales at Bermuda in previous years; 13½ tons oil shipped to England	Verrill, 1907, pp. 109–10
1671	Whaling company reorganized	Verrill, 1907
1679	Whaling prohibited, but illegal catching continued on small scale	Verrill, 1907
1685	About 14 whales killed	Verrill, 1907
After 1685	'The whale fishery was carried on with greater activity than before'	Verrill, 1907
1691	Request made by Gov. Richier to Earl of Nottingham for grant to be used in upgrading the whale fishery; 'four large and four small whales have been taken, and three of the large ones escaped owing to bad tackle'	Anon., 1946
After 1700	'More or less whaling was carried on, generally in a local way,...the number of whales constantly decreasing'	Verrill, 1907
1748	'The Bermudians in some years catch 20 of these whales ["fin-backs", but unquestionably meaning humpbacks], not in sloops, but in whale-boats from the shore'	Douglas, 1755, quoted in Goode, 1884, p. 20, footnote 2
Early 1780s	'The local prospects of catching an occasional whale off shore were so poor that the equipment at St. George's was put up for sale'	Wilkinson, 1973, p. 31
ca. 1785	Five whales [probably humpbacks] were taken	Wilkinson, 1973
1797	'All the attempts to establish a regular whale-fishery on the islands have hitherto proved unsuccessful'	Anon., 1972
1833–34	Fishery active; at least one whale landed; in addition, 'One of the boats struck a whale but was pulled out of sight of land and obliged to cut loose but when they were returning they saw two others and struck them'	Gosling, 1952
1851	Two whales taken, each yielding about 30 bbls	Wilkinson, 1973, pp. 656–7
1852	One large whale (humpback?) and a sperm whale caught	Wilkinson, 1973, p. 657
1853	Two adults and a small one caught at East End; stations at Port Royal and Somerset also active; total 12 humpbacks struck, 7 landed, yield 350 barrels total	Wilkinson, 1973, p. 657; Gardner, 1853
1854	A 54 ft. whale caught at Port Royal	Wilkinson, 1973, p. 657
1855–58	'Barren'	Wilkinson, 1973, p. 657
1859	'A revival [of whaling] was tried with two boats...but without reward'	Wilkinson, 1973
1866	33 ft. female taken; yield 40 bbls.; first humpback taken 'for some years'; struck by 3 bombs but only third exploded	Verrill, 1907; Jones, 1884
1871	22 ft. calf taken; yield 5½ bbls.; mother struck but 'warp broke' and she escaped bleeding	Verrill, 1907; Jones, 1884
1884	'Almost every year some of these whales are taken'	Jones, 1884
Near turn of century	Joe Smith and David Burchell were whaling with hand harpoons	Kan, 1933
1907	'For the past fifty years they [humpbacks] have been rarely captured'	Verrill, 1907
1915	Antonio Marshall and Rev. Darrell brought 2 whaleboats and equipment worth £500 from New Bedford for whaling	Kan, 1933
1932	One humpback fastened-to but lost	Kan, 1933
1933	A new start in humpback whaling at Bermuda – one boat, modern equipment	Kan, 1933
1940	One humpback taken	Wheeler, 1941
1942	One humpback taken	Wheeler, 1943

rarely as much as 70 barrels (also see Cotter, 1828). A 22-foot calf yielded only 5.5 barrels (Verrill, 1907, p. 275).

The fishery was prosecuted almost continuously from the 1660's to the turn of the twentieth century (Verrill, 1907). It intensified after 1685, when Bermuda became a crown colony. A special license was required to carry on whaling during most of the eighteenth century (see in particular *Minutes of His Majesty's Council* for Bermuda during the 1730s and 1740s), although this system was discontinued after 1782. Verrill was convinced that the humpback population visiting Bermuda had been overhunted by the middle of the nineteenth century, after which captures became rare. Tucker (*1959, p. 81*) stated, apparently in reference to the 1700s, that 'there were now

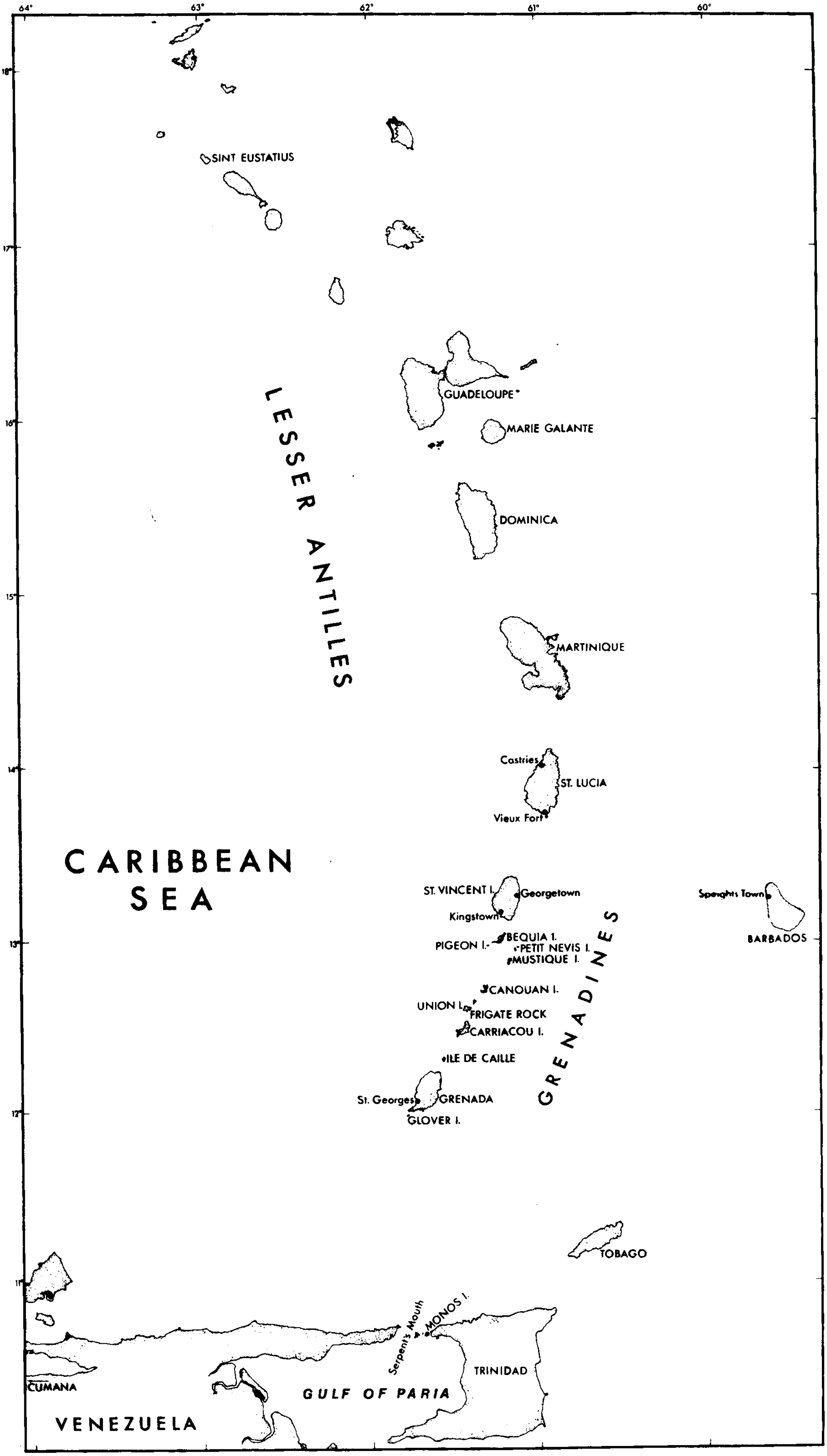

Fig. 16. Chart of the Lesser Antilles, showing some place names mentioned in the text.

so few whales that less than ten could be taken in a whole season.' In earlier years, according to Tucker, as many as two or three were caught 'on any fair spring day.'

An attempt by New Englanders to establish a whale fishery at Bermuda in 1785 was thwarted by an act of the Massachusetts senate forbidding the export of necessary supplies and equipment to the islands (Starbuck, 1878, p. 79; Brown, 1976).

During the 1830s and 1840s the fishery was considered to be in decline, but in one year 'more than a dozen whales were struck, and nearly as many during another season' (Wilkinson, 1973, p. 656). Small, independent whaling enterprises persisted, and in 1851 a newly formed whaling company imported several New England whaleboats in an attempt to rejuvenate and expand the Bermuda fishery. There were three sites on the islands from which whaling was conducted during 1853 (Gardner, 1853). In that year 12 humpbacks were struck, seven of which were recovered, yielding 350 barrels. By about 1860, however, whaling 'had ceased to be of any importance to the colony' (Wilkinson, 1973, p. 657). The whalehouse on Smith's Island, 'the last one to serve its original purpose,' was used as a warehouse during the American Civil War and by 1898 had been converted into a dwelling house (Tucker, 1962). Although the most recent kill noted by Verrill (1907) was in 1871, Jones (1884) implied that as late as the 1880s 'almost every year some of these whales are taken.' Some whaling was being done at the turn of the century (Kan, 1933). An unsuccessful attempt to revive the fishery, with two boats imported from New Bedford, was made in 1915.

In 1933 a whaleboat with modern equipment, including a harpoon cannon mounted on the bow, was in use at Bermuda, but the whalers reported a lack of success (Kan, 1933). One humpback had been fastened-to but lost in the 1932 season. During or shortly before World War II the Bermuda legislature passed an amendment to the Tariff Act waiving the import duty on whaling equipment (Anon., 1945). Several boat owners tried to revive the local shore whaling industry during the war years. The attempt was described as 'a complete failure', with no more than about six humpbacks observed passing the islands in any one year during the 1940s (Anon., 1948). A humpback, supposedly the first landed at Bermuda in more than 40 years, was taken in April 1940 (Wheeler, 1941). An exploding harpoon shot from a cannon mounted on the bow of a motor vessel was used in the capture. The meat was sold locally, and the oil was saved. Another humpback was killed in November 1942 (Wheeler, 1943).

Several factors affecting the kill at Bermuda should be mentioned. First, calves were hunted preferentially, not only because this often made the females easier to catch (Jones, 1884; Cotter, 1828) but also because the meat of young individuals was relished by Bermudans (Verrill, 1907) and some Europeans (Cotter, 1828). Meat was an incentive for the hunt (Gardner, 1853). Smaller animals probably were more easily captured, brought ashore, and processed with the technology of the seventeenth and eighteenth century whalers (e.g. Norwood, 1667). Second, explosives were used to capture whales at Bermuda as early as 1851 (Wilkinson, 1973, p. 656), a factor which probably added to an already high struck-but-lost rate (Jones, 1884; Gosling, 1952; Gardner, 1853). Also, carcasses were often mauled by sharks before they could be towed to shore (Cotter, 1828), so there may have been a tendency for oil production to under-represent the catch of whales.

In Table 1 we did not attempt to estimate kills at Bermuda for years for which we had no definite information on take or effort, and we did not extrapolate from production statistics. As a result, our presentation probably under-represents substantially the actual kill, even though known landed catches have been doubled to account for hunting loss.

VII. West Indies

(i) *Nineteenth-Century pelagic whaling*

There are few published references to this segment of whaling history. We used available information to help define the fishery, then chose two samples of unpublished logbooks and journals to study, in order to make a first approximation of the magnitude of the fishery and of the humpback catch.

A. Selection of logbook/journal samples

Our samples were selected in the following manner. We assumed, judging by a published statement (Atwood in Clark, 1887a, p. 22; *WSL*), that more Provincetown vessels humpbacked in the West Indies in a given year than vessels from any other port. Also, we assumed that vessels whose stated destination was in the Atlantic were more likely to hunt humpbacks at the West Indies (Figure 16) than vessels bound for Pacific, Indian Ocean, or Arctic grounds, although we recognized the possibility that virtually any voyage originating in New England other than those destined to Hudson Bay or Davis Strait could visit the West Indies en route. Provincetown had a known history of humpbacking, and her vessels generally did not participate in fisheries outside the Atlantic Ocean owing to their small size (Clark, 1887a, p. 3; Hohman, 1928, p. 11; Stackpole, 1953, p. 452; *WSL*).

In the two collections, we began by locating and reading all available Provincetown logbooks or journals. This yielded a sample of 19 documents, including 43 separate voyages, in the two collections combined. These 19 logbooks and journals, covering 43 voyages, are our record nos. 3–5, 9, 11–12, 14, 20–23, 28, 30–33, 56a, 56b, 58a, and 66 in Table 8.

A second sample of logbooks and journals was selected on the basis of destination and timing of visits to the West Indies. All voyages to the Arctic, Pacific, or Indian Ocean were disregarded, leaving only voyages said to be bound for the Atlantic. Priority was given to 'North Atlantic' voyages sailing in fall or winter (Oct.–Mar.) on the supposition that such voyages were more likely to visit the West Indies (at least in the first year out) than those which began at other times. Cruises beginning in April or later and returning before the following January were omitted. Sampling decisions were also influenced by data in Starbuck (1878) and Hegarty (1959). For example, humpback oil is occasionally mentioned in the lists of returns; and voyages meeting our destination and timing criteria sometimes returned with 'whale' oil and no 'bone', suggesting, particularly in later years as right whale baleen increased in value, that humpbacks were taken. Subsequent to our reading and analysis of the logbook/journal sample, we found statements in the *Whalemen's Shipping List* indicating that blackfish oil, which was taken in large quantities on some cruises, accounted for some of the 'whale oil' listed in the returns. For example it was reported in October 1865 that since July 1864, 20 of 26 Provincetown schooners had arrived with 3,414 barrels of sperm and 2,932 barrels of blackfish oil, the latter selling for 49¢ per barrel compared to 70¢ for sperm (*WSL* 23(35): 31 X 1865).

North Atlantic documents in the Nicholson Collection (PPL) were selected with no further screening, and the time constraint is all that prevented complete coverage. Twenty of 151 or about 13 per cent of the non-Provincetown logbooks and journals in this collection, having a North (or North and South) Atlantic destination, were examined. Cumpston's abstracts facilitated an additional screening step for ODHS documents. A judgment was made after reading each itinerary, and priority was given to voyages known to have visited the West Indies between January and June, as this was the humpbacking season there. Documents were then read in descending order of priority. Approximately 75 documents were examined at ODHS, of which 58 were read and carded. These non-Provincetown data are our record nos. 1–2, 6–8, 10, 13, 15–19, 24–27, 29, 34–56, 57–58, 59–65, and 67–80 in Table 8

A given logbook or journal was scanned rapidly to learn the itineraries of voyages and to determine whether vessels visited the West Indies at a season when humpbacking was likely to occur there, i.e. January–May. Sections covering activities in the West Indies were read carefully. Sightings, lowerings, strikes, captures, and any other pertinent comments about humpbacking were noted on file cards. The names of other vessels mentioned as seen in the West Indies and any information on their activities were also recorded.

Although we undoubtedly overlooked some data on humpbacking in the West Indies, we believe our coverage of these two major collections was adequate.

Since selecting and reading our sample, we have learned from our own research and the comments of Martin (1981 MS) that, in addition to Provincetown, Sippican, Rochester, Dartmouth, Sandwich, Westport, Edgartown, Fairhaven and other minor ports originated voyages that included some North Atlantic humpbacking. New Bedford sent vessels around the world, including cruises to the North Atlantic, that humpbacked. By contrast, Nantucket 'maintained a stubborn preference for sperm oil' and specialized in long-distance voyages (Hohman, 1928, p. 11), and Sag Harbor voyages were nearly always destined for grounds outside the Atlantic (Schmitt, 1971). We did include known kills by non-Provincetown vessels as we encountered them, but in extrapolating to estimate total kills by the Yankee fleet in the West Indies, we extrapolated only with Provincetown voyages and ignored non-Provincetown oil returns. This decision ensured that our estimate would be conservative, even though some of the Provincetown oil included in the extrapolation came from blackfish or Cape Verdes humpbacks. We assumed the overestimation caused by inclusion of blackfish and Cape Verdes humpback oil in our Provincetown extrapolations was counterbalanced by the West Indies humpback catches made by non-Provincetown vessels.

Relevant data from all voyages that visited the West Indies during the humpbacking season are presented in Table 8. For comparative purposes, discussed below, we also included in the table data from several voyages that did not visit the West Indies but humpbacked exclusively at the Cape Verdes. Table 9 contains relevant data, used in our discussions, on West Indies humpbacking from the Townsend worksheets (Townsend and Watson, n.d. MS), from Martin (1981 MS), and from one humpbacking/sperm whaling voyage off the west coast of South America (Fig. 17).

B. Identity of the humpbackers

We have not identified any individual whaling masters, owners/agents, or vessels that specialized in North Atlantic humpbacking. However, some generalizations can be made. For instance, we have no evidence that vessels heading for destinations outside the Atlantic stopped regularly in the West Indies to hunt humpbacks. All West Indies humpbackers we identified were Atlantic sperm whalers. In our logbook sample, including vessels identified as humpbackers from statements in other vessels' logbooks (Table 11), the mean vessel size ($n = 46$) was 102 tons for those that lowered for humpbacks more than twice in a voyage on the North Atlantic winter grounds. Thirty-six (78%) of these vessels were schooners, seven were brigs, and three were barks. Although we tried to select New Bedford voyages on the basis of a high likelihood that they humpbacked, only four of 60 (7%) of those whose logbooks we examined did humpback. In contrast, 18 of 43 (42%) of the Provincetown voyages humpbacked. Some of the logbooks from smaller ports, such as Sippican, Westport, Fairhaven, Edgartown, Mattapoisett, Boston, Wellfleet, and New York, contained evidence of humpbacking.

C. Period of greatest humpbacking activity

Provincetown did not enter the high-seas sperm whale fishery until 1820, when a scarcity of cod on the Grand Bank led shipowners there to look for new fields of enterprise (Atwood in Clark, 1887a, pp. 144–5). During the first two years (1820–1821) the small fleet of 12 vessels visited the Western Islands Grounds around the Azores. In 1822, one of the 18 Provincetown vessels engaged in the whale fishery, the *Laurel*, went to the West Indies in the fall rather than returning home directly from the Azores. She remained until early 1823, arriving in Provincetown in March (Atwood in Clark, 1887a). We do not know how much, if any, humpbacking was done on this cruise.

There followed a six-year hiatus in Provincetown whaling. It resumed in 1830, but not until 1835 did another Provincetown vessel go to the Caribbean region. In that year the *Imogene* went to the Western Islands (Azores) and the Gulf of Mexico, probably getting mostly sperm whales. However, the next year (1836) the fleet of four vessels went directly to the West Indies, 'where they got some humpback whales,' before visiting the Gulf of Mexico and the Western Islands (Atwood in Clark, 1887a, p. 144). After this time, humpbacking visits to the West Indies became an ordinary feature in the itineraries of Provincetown whalers.

West Indies humpbacking was not limited to the Provincetown fleet. As early as 1772 Nantucket whalers visited the West Indies, but we do not know whether they captured any humpbacks (Anon., 1794). In 1822 the brig *Industry* of Westport visited St Lucia after whaling on the Western Islands and Brazil Grounds (*Industry*, 1821–1822; our Table 8, Entry 39). She spent the period March 13–April 3 humpbacking and blackfishing

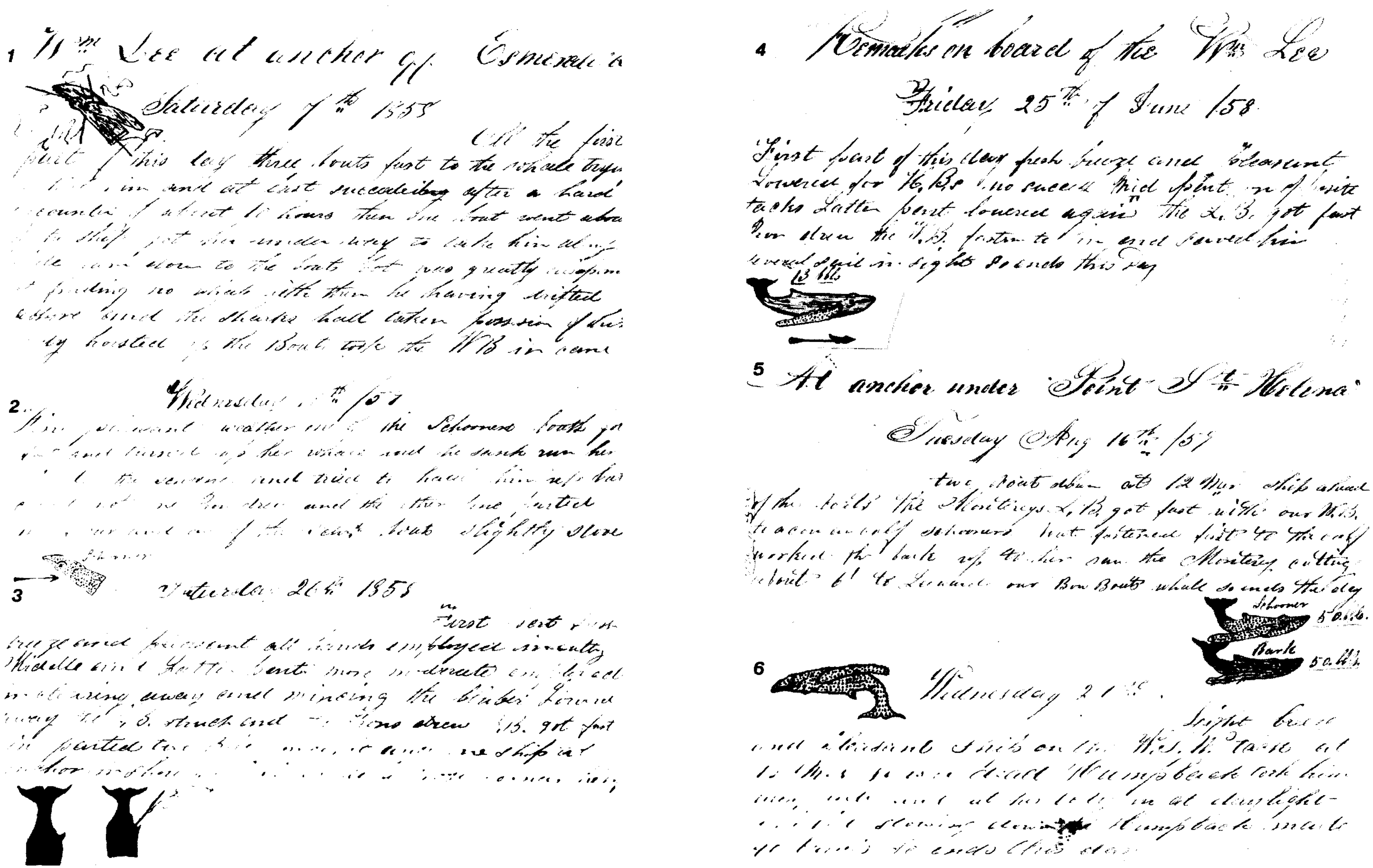

Fig. 17. Some daily entries from the journal of Josiah Robinson, kept on the bark *William Lee*, William Slocum, Master, out of Newport, Rhode Island, 17 September 1856 – 17 May 1860, showing particularly detailed drawings on a wide-ranging sperm whaling and humpbacking cruise in the Pacific.

1. – Entry for Saturday, 7th August 1858, describing an attempt on a humpback, fraught with disaster. Three boats got fast and spent 10 hours trying to kill the whale. Finally, the dead whale drifted ashore; before the carcass could be salvaged, 'the sharks had taken possession' of it. Note at least four irons apparently made fast to this whale.

2. – Entry for Wednesday, 10th August 1859, showing a humpback killed but lost when it sank. Two boats were slightly stove in the unsuccessful attempt to raise the sunk whale; an iron drew and a line parted. Note the double-flued harpoon.

3. – Entry for Saturday, 26th June 1858, indicating that on this date two humpbacks were struck. In one case the irons drew; in the other, the line parted.

4. – Entry for Friday, 25th June 1858, showing a 13-barrel humpback taken by the *Lee*. The whale was harpooned once, but the iron drew. A second boat got fast and made the catch. Note the single-flued toggle harpoon.

5. – Entry for Tuesday, 16th August 1859, showing two humpbacks taken, each yielding 50 barrels of oil. At least one of them was a cow whose calf was struck first in order to facilitate the whalers' approach to the cow. Note that the journal artist apparently recognized pigmentation differences among individual humpbacks and attempted to illustrate them.

6. – Entry for Wednesday, 21st October 1857, showing a dead 40-barrel humpback found floating and

between St Lucia and Guadeloupe, with little success. While on the humpbacking grounds, the *Industry* gammed with the schooner *Liza* of Falmouth. The *Annawan* of Rochester was humpbacking in the West Indies in 1837 (Martin, 1981 MS; our Table 9, Entry 4).

Thomas Welcome Roys, during his voyage of experimentation on the *William F. Safford*, visited Tobago, apparently in early January 1859, and 'took several humpbacks' while testing his rocket-harpoons (Schmitt *et al.*, 1980, p. 75). The following winter he returned to the West Indies on the *Pacific* of Sag Harbor, which had been modified to navigate the Serpent's Mouth between Trinidad and Venezuela, 'where the whales were' (Schmitt *et al.*, 1980, p. 76).

The Yankee whalers also lowered for humpbacks occasionally while cruising for sperm whales on grounds outside the West Indies (see Table 8). The bark *Exchange* of New Bedford, heading for the Pacific in 1847, took a humpback at 43° 20′ N, 52° 40′ W in June; the bark *John Dawson* of New Bedford took one at 41° 52′ N, 35° 40′ W in June 1862 during an Atlantic voyage (Townsend and Watson, n.d. MS).

Martin (1981 MS) believed that humpbacking became an important activity in the Yankee fleet after 1850. He cited as evidence the fact that almost 85 per cent of the 2,883 humpback kills plotted by Townsend (1935) occurred in 1850–1890, and Martin's own sample had 96 per cent of the humpback kills in that period. Our data are generally consistent with those of Townsend and Martin, although our logbook sample gave no coverage of the Provincetown fleet for the period 1857–1865. (Also, we should caution that Townsend's (1935) sample of logbooks, while covering the period 1761–1920, might not be a representative or random sample.) To investigate further the question of when humpbacking was at its peak, we examined the whalemen's inward manifests for the port of New Bedford, 1818–1906 (Brown *et al.*, 1936). Humpback and blackfish oil are listed separately for some voyages, although for many it is lumped with other 'whale' (ie. non-sperm) oil. The amount specified as from humpbacks is plotted in Fig. 18. There is a clear peak in humpback oil production in New Bedford between 1833 and 1887. Data and statements in the *Whalemen's Shipping List* confirm that humpbacking remained an important activity of the Yankee fleet only through the 1880s.

As the Civil War ended in 1865, the Provincetown fleet expanded rapidly (Fig. 19), and as it did, North Atlantic humpbacking appears to have become a more regular part of the industry. As Gray (1874, p. 186) stated in 1874: 'The American whalers are now in the habit of catching humpbacked whales off the coast of San Domingo and in other parts of the Caribbean seas' (also see Van Beneden, 1887, p. 24). Imports of whale oil at Provincetown, the port we consider the most active in West Indies humpbacking, became negligible after 1888 (Hegarty, 1959). By the 1890s virtually the entire US fleet was committed to securing sperm oil and (mainly balaenid) whalebone, baleen whale oil having become relatively unimportant (Tower, 1907).

The *Whalemen's Shipping List* began mentioning the price of humpback oil as a separate entity as early as 1850, and from 1872 through 1881 it was given in each annual review of the fishery (Table 4). After this, humpback oil was listed sporadically through 1901. In January 1868 the *WSL* stated: 'The Provincetown fleet make Winter cruises around the West Indies and Cape de Verde Islands, humpbacking' (*WSL*, 25(46): 14I 1868). At this time about one-fourth of New Bedford's 'whale oil' was said to come from humpbacks, elephant seals (*Mirounga* spp.) and right whales (*Eubalaena*) (*WSL* 25(46): 14I 1868). A special report on humpbacking was often included in the annual review during the early 1870s. For example, in 1872, when 'humpbacking [had] been successfully carried on everywhere', the review noted that 2,000 barrels of humpback oil had been taken 'around the West Indies' (*WSL* 30(50): 4II 1873). This represented less than 10 per cent of world humpback oil landings (totaling 22,000 bbls.) which were 'equal to the entire Arctic catch' (*WSL* 30(50): 4II 1873).

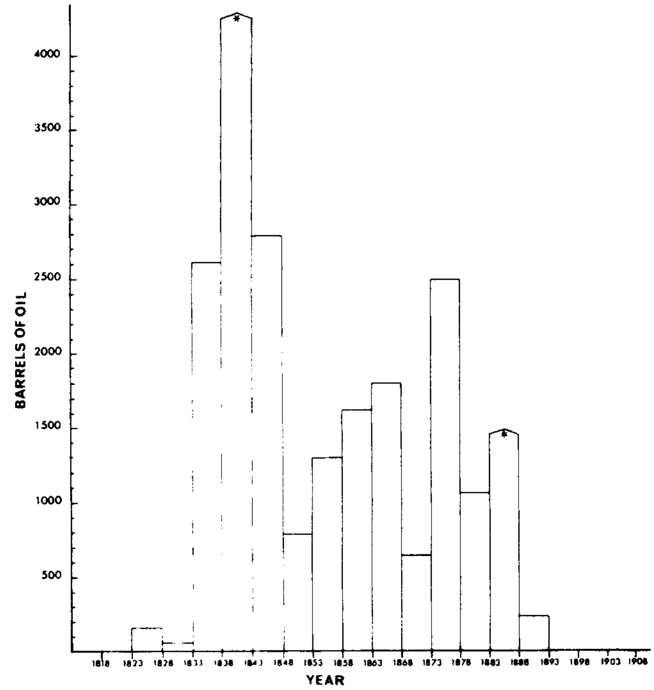

Fig. 18. Humpback oil landings in New Bedford between 1818 and 1908. (Data from Brown *et al.*, 1936; asterisks denote minimum figures.) The amount actually landed was certainly greater in many years than plotted here, since humpback whale oil was not always distinguished in the returns from 'whale' (mainly balaenid) oil.

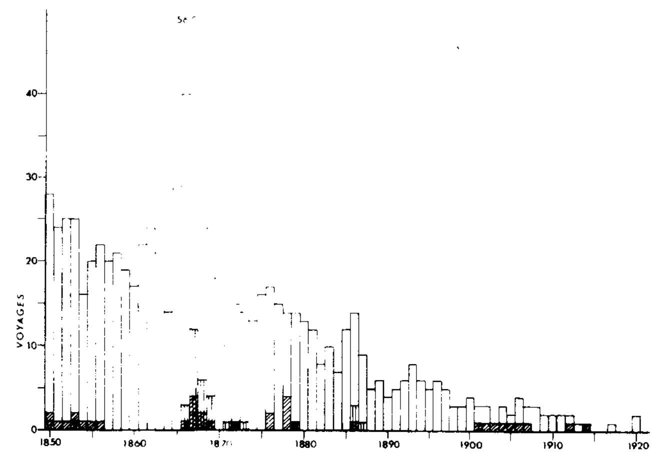

Fig. 19. Number of Atlantic voyages by Provincetown fleet, by year, showing portion known to have humpbacked in West Indies and portion sampled by reading logbook or journal. Coding: white bars = voyages made, oblique shading = voyages read, vertical shading = voyages known to have humpbacked in West Indies.

(continued on p. 186)

Data from a sample of whaling logbooks and journals, supplemented by information in Starbuck (1878) and Hegarty (1959). Vessel names are as spelled in the logbooks and journals. Port, rig, tonnage, master, owner/agent, dates sailed and returned, and destination are taken from Starbuck and Hegarty, with no attempt to reconcile inconsistencies between their tables and the logbooks and journals.

Record no.	Vessel	Port	Rig	Tons	Master	Owner or agent	Sailed	Returned	Destination (SA = South Atlantic, NA = North Atlantic)	Period in West Indies	Other vessels seen in West Indies (take of humpbacks)	Comments	Humpbacks struck or taken[1] in West Indies (except as noted): Landed	Known killed but not landed	Struck but escaped: Unspecified	Struck but escaped: Iron 'drew'	Struck but escaped: Line parted or cut; escaped with gear in it	Calves orphaned but not known to have been struck
Providence Public Library																		
1	*Sally Anne*	New Bedford	Ship	311	D. Flanders	—	13V1835	15IV1836	SA	—	—	—	—	—	—	—	—	—
2	*Seine*	New Bedford	Bark	281	D. Flanders	Crane & French	10VIII1837	1IX1838	SA	—	—	—	—	—	—	—	—	—
3a	*Medford*	Provincetown	Schooner	105	Cook	P. Cook	VIII1846	25IX1847	A	V '47	—	—	—	—	—	—	—	—
3b	"	"	"	"	Dyer	P. Cook	12V1848	19X1848	A	—	—	Sightings: 40° N, 39° W, 2VI; 35° N, 43° W, 30VIII	—	—	—	—	—	—
3c	"	"	"	"	Dyer	P. Cook	6II1849	30IX1849	A	III–IV	—	Many sightings in West Indies	Lowered twice for humpbacks					
3d	"	"	Brig	107	Dyer	E. Cook	10IV1850	26VI1851	A	II–III '51	*Loisa* + 7 others	—	Lowered at least 3 times for humpbacks					
4a	*Walter Irving*	Provincetown	Schooner	130	Nickerson	A. Nickerson	23IV1850	19IX1850	A	—	—	—	—	—	—	—	—	—
4b	"	"	"	"	—	"	?1851	1XII1851	A	—	—	—	—	—	—	—	—	—
4c	"	"	"	"	Nickerson	"	22III1852	1II1853	A	—	—	—	—	—	—	—	—	—
4d	"	"	"	"	"	"	27IV1853	4I1854	A	—	—	Spoke *Sylph*, 32 months out with 700 sperm, 150 humpback	—	—	—	—	—	—
4e	"	"	"	133	"	S. Soper	21IV1854	19X1854	A	—	—	—	—	—	—	—	—	—
4f	"	"	"	"	Paine	S. Soper	9XI1855	16IX1856	A	—	—	Right whaling at Cintra Bay with several other vessels; at least 15 right whales taken; 150 whale (Starbuck).	—	—	—	—	—	—
4g	"	"	"	"	Holmes	S. Soper	1856	1857	A	III–IV '57	*Parker Cook*, *Lady Suffolk*, *Antarctic*, *Lewis Bruce*	Right whaling at Cintra Bay late xii '56 – early i '57 with several other vessels; at least 3 right whales taken; Cape Verdes humpbacking; 50 whale (Starbuck)	Lowered for humpbacks in desultory way in vicinity of Samana Bay					
5	*E. Nickerson* (journal of E. E. Jennings)	Provincetown	Schooner	131	Soper	Nickerson	8III1853 (Starbuck data much different from journal)	25IX1853	A	—	—	Humpbacking at Sal, Cape Verdes; *September* humpbacking there; 100 whale (Starbuck)	17	8	6 (Cape Verdes)	8	7	2
6	*Solon*	New Bedford	Bark	129	C. Barstow	J. & W. R. Wing	23X1863	24VI1865	A	—	—	—	—	—	—	—	—	—
7	*Admiral Blake*	Sippican	Schooner	120	Hathaway	"	2V1865	21VIII1865	A	—	—	—	—	—	—	—	—	—
					Hammond	A. Hadley	28XII1865	4XI1866		—	—	—	—	—	—	—	—	—
8	*Marcella* (journal of H. B. Chase)	New Bedford	Bark	210	H. Chase	C. R. Tucker	25IV1865	13IV1867	A			Sightings: 39° N, 47° W, 25V; 41° N, 43° W, 27V						
9a	*Arthur Clifford*	Provincetown	Schooner	118	Dyer	H. & S. Cook Co.	6II1866	1IX1866	A	III–V	*G. W. Lewis*	Humpbacking out of Castries, St Lucia, Canouan, Union; 140 whale (Starbuck)	7	1	2	1	1	—
9b	"	"	"	"	"	"	3I1867	18VIII1867	A	I–V	*Dyer*; *St. Hilger* (?) also humpbacking	Humpbacking in same area as previous year; 200 whale (Starbuck)	9	2	2	—	3	—
													Also at least 3 landed and 1 killed but lost by other vessels					
9c	"	"	"	"	"	"	26XII1867	31X1868	A	I–V'68	—	Left St Vincent Jan. 20 'bound down to the keys a humpbacking'; 132 whale (Starbuck)	5	No notation of struck and lost				
9d	"	"	"	85	"	"	21XII1868	IX1870	A	I–V'69	*Nellie Putnam*	Sent ashore 1,100 gals at St Vincent	2	1	—	1	1	—
										I–V'70	*Rising Sun*; *Grace Parker* (1 s/l); Geo Dyer (7+1); *L. J. Bigelow*; *Thriver*; *Alleghania* (1 s/l); *Sparks* (1 s/l); *Sassacus* (2); *N. J. Knight* (1+1)	236 whale (Starbuck) saved at least some whalebone; log ends April 30 with vessels still humpbacking	8	1	2	—	1	1
													Minimum catch by other vessels: 11 landed, 4 known killed and lost, 5 struck but lost					
10a	*Mattapoisett*	Westport	Bark	150	A. C. Davis	H. Smith	13XI1866	25VIII1868	A	II–III'68	*Winged Racer* with 50 bbls humpback oil, 50 days out on March 19; *Oxford*	Did not humpback; 30 whale (Starbuck)	—	—	—	—	—	—
10b	"	"	"	110	W. S. Tripp	"	22IV1869	2XI1870	A	II–III'70	—	Did not humpback; 7 whale (Starbuck)	—	—	—	—	—	—
11	*Quickstep* (journal of T. Nickerson)	Provincetown	Schooner	119	Nickerson	E. & E. K. Cook	24XI1867	28VIII1869	A	II–V'68	*Estella* [*Snow*] and at least one other vessel humpbacking	Anchored at Castries and Pigeon Island; landed 135 gals. hump. oil at St. Vincent for 'port charges'; 175 whale (Starbuck)	4	2	2	1	—	—

[1] Calves known to have been struck are assumed to have died, even if no attempt was made to secure them. They are scored as 'known killed but not landed'.

Table 8 (*continued*)

Record no.	Vessel	Port	Rig	Tons	Master	Owner or agent	Sailed	Returned	Destination (SA = South Atlantic, NA = North Atlantic, A = Atlantic)	Period in West Indies	Other vessels seen in West Indies (take of humpbacks)	Comments	Humpbacks struck or taken[1] in West Indies (except as noted): Landed	Known killed but not landed	Struck but escaped: Unspecified	Struck but escaped: Iron 'Drew'	Struck but escaped: Line parted or cut; escaped with gear in it	Calves orphaned but not known to have been struck
12	*E. H. Hatfield*	Provincetown	Schooner	125	Keith	E. & E. K. Cook	22 I 1867	15 IX 1868	A	V'67	*C. H. Cook*, *Walter Irving*, *William Martin*	Visited Cape Verdes first; reported seeing humpbacks at both Cape Verdes and West Indies but did not lower; reported 'several sails and plenty of Humpbacks' between Martinique and Dominica; sighting at 12° N, 38° W, 29 II	—	—	—	—	—	—
13	*Star Castle*	Fairhaven	Brig	116	H. Clay	Damon & Judd	13 V 1867	lost 1869	A	IV'68	*E. H. Adams*	—	—	—	—	—	—	—
										I–V'68	—	Began 1868 season at Cape Verdes but did no humpbacking until reaching St Eustatius Jan. 21; reported 160 bbls. hump. oil upon leaving W.I.; Starbuck reported 150 bbls. humpback 'sent home'; 20 bbls. off-loaded at Barbados	9	1	— (Not clear that all strikes reported)	1	1	—
14a	*Nellie S. Putnam*	Provincetown	Schooner	—	Tilson	H. & S. Cook	31 V 1867	6 VIII 1868	A	II'67–V'68	*D. C. Smith* (1), *G. H. Phillips* (1), *J. Taylor*, *Arizona* all humpbacking	Detailed legible log; began voyage at Azores and Cape Verdes; humpbacking in Grenadines; lowered many times without success; no whale (Starbuck)	—	—	— (Minimum catch by other vessels: 2 landed, 1 struck and lost)	—	3	—
14b	,,	,,	,,	87	Dyer	,,	12 XI 1868	27 VII 1869	A	XII'68–V'69	*A. M. Dyer*; *A. Clifford* and *G. W. Lewis* humpbacking	300 whale (Starbuck); lowered for humpbacks at least 34 times	8	1	3	1	2	1
14c	,,	,,	,,	,,	Atkins	,,	1869	[1870]	A	—	—	Humpbacking at Cape Verdes	6	2	1 (Cape Verdes)	—	1	—
15	*Ocean Steed* (journal of G. B. Borden)	New York	Bark	258	G. Borden	L. Peirce	27 IV 1868	29 XI 1869	A	—	—	Detailed, legible log; sightings: 30° N, 63° W, 23 I; 33° N, 50° W, 1 V; 40° N, 36° W, 22 V; 35° N, 35° W, 24 V; 48° N, 23° W, 21 VI; 49° N, 21° W, 24 VI; lowered unsuccessfully for humpbacks at: 49° N, 24° W, 16 VII; 35° N, 50° W, 28 IV; 38° N, 51° W, 8 V; 20 whale (Starbuck)	—	—	—	—	—	—
16	*Globe* (journal of C. A. White)	New Bedford	Bark	200	A. Tripp	C. Tucker	6 III 1869	20 V 1872	A	—	—	—	—	—	—	—	—	—
17	*Ocean Steed* (journal of M. Sylvia?)	New Bedford	Bark	258	E. Russell	L. Peirce	4 V 1870	[1872]	A	—	—	—	—	—	—	—	—	—
18	*Union*	New Bedford	Schooner	66	P. H. Reed	P. H. Reed	10 IV 1873	26 IX 1873	A	—	—	Sightings: 23° N, 53° W, 5 V; 23° N, 57° W, 8 V; 18° N, 55° W, 14 IV; 21° N, 58° W, 16 IV; lowered for humpbacks: 26° N, 50° W, 28 IV; 19° N, 56° W, 15 IV; humpbacked opportunistically on way home from sperming in east Atlantic	—	—	—	—	—	—
19	*Pioneer*	New Bedford	Bark	228	A. Tripp	G. Allen & Son	10 IV 1875	10 XI 1878	A	V'76	—	—	—	—	—	—	—	—
20a	*Clara L. Sparks*	Provincetown	Schooner	96	H. Sparks	D. Conwell	1 V 1876	20 VIII 1877	A	—	—	Humpbacked at Cape Verdes, I–III'77; 200 whale (Starbuck)	4	—	— (Cape Verdes; losses not detailed)	—	1	—
20b	,,	,,	,,	,,	,,	,,	3 V 1878	5 VI 1879	A	—	—	—	—	—	—	—	—	—
20c	,,	,,	,,	,,	,,	,,	11 VII 1879	12 IX 1880	A	III–IV'80	*Fanny Byrnes*, several others, all humpbacking	Legibility poor; seems to have off-loaded oil in Barbados 21 IV; no whale (Starbuck)	+	1	+ (Other vessels took at least 1)	?	?	?

[1] Calves known to have been struck are assumed to have died, even if no attempt was made to secure them. They are scored as 'known killed but not landed'.

Table 8 (*continued*)

Record no.	Vessel	Port	Rig	Tons	Master	Owner of agent	Sailed	Returned	Destination (SA = South Atlantic, NA = North Atlantic, A = Atlantic)	Period in West Indies	Other vessels seen in West Indies (take of humpbacks)	Comments	Humpbacks struck or taken[1] in West Indies (except as noted): Landed	Known killed but not landed	Struck but escaped: Unspecified	Iron 'drew'	Line parted or cut; escaped with gear in it	Calves orphaned but not known to have been struck
21a	*E. H. Hatfield*	Provincetown	Schooner	89	Kirkconnell	E. & E. K. Cook	22 I 1876	29 VIII 1876	A	II–III	*Sarah E. Lewis, Quickstep*	Sperm whaling in Greater Antilles; lowered once unsuccessfully for humpbacks in Samana Bay	—	—	—	—	—	—
21b	,,	,,	—	—	—	—	[XII 1876]	[1878]	[NA]	VI'77 III–V'78	— —	— Visited Bequia, St Vincent, but did not humpback	— —	— —	— —	— —	— —	— —
21c	,,	,,	,,	,,	B. Higgins	,,	6 VII 1878	18 IX 1878	A	—	—	—	—	—	—	—	—	—
22a	*Gage Phillips*	Provincetown	Schooner	107	J. Nickerson	S. Cook	25 IV 1878	30 VIII 1880	A	IV'79 IV'80	— —	Sperm whaling ,,	— —	— —	— —	— —	— —	— —
22b	,,	,,	,,	,,	,,	,,	11 V 1881	11 IX 1883	A	V–VI'82	—	Showed no interest in humpbacks; 20 whale (Starbuck)	—	—	—	—	—	—
23	*Express*	Provincetown	Schooner	70	R. Smith	E. & E. K. Cook	14 III 1878	10 IX 1878	A	—	—	Legibility poor; humpbacked at Cape Verdes (?); 200 whale (Starbuck)	—	—	—	—	—	—
24	*Bertha*	New Bedford	Bark	177	W. Robinson	J. Tucker	15 I 1878	26 XI 1881	A	IV–V'78, V'79	—	Lowered once for a humpback; 550 whale (Starbuck)	—	—	—	—	—	—
25a	*E. H. Hatfield*	Edgartown	Schooner	89	F. Cornell	S. Osborne	15 VI 1880	27 X 1880	A	—	—	Sperm whaling	—	—	—	—	—	—
25b	,,	,,	,,	,,	,,	,,	30 XI 1880	18 VIII 1882	A	V'82	—	Right whaled along coast between N. Carolina and Georgia II–IV'81; II–III '82 humpbacked casually at Cape Verdes; 10 whale (Starbuck)	1	—	— (Cape Verdes)	—	1	—
26	*Hattie Smith*	Edgartown	Schooner	107	F. Taber	S. Osborne	1 X 1885	23 VIII 1887	A	V'86	—	No humpbacking; sightings: 31° N, 58° W, 18 II; 26° N, 46° W, 23 II	—	—	—	—	—	—
27a	*Adelia Chase*	New Bedford	Schooner	85	A. Senna	A. Sylvia	30 X 1901	10 IX 1902	A	—	—	Sperm whaling	—	—	—	—	—	—
27b	,,	,,	,,	,,	,,	,,	3 XI 1902	20 VIII 1904	A	IV'04	—	Sperm whaling	—	—	—	—	—	—
27c	,,	,,	,,	,,	,,	,,	15 X 1904	11 X 1905	A	IV'05	—	Sperm whaling	—	—	—	—	—	—
28a	*Wm. A. Grozier*	Provincetown	Schooner	117	J. Dunham	J. Dunham	7 V 1901	31 VIII 1901	A	—	—	Sperm whaling	—	—	—	—	—	—
28b	,,	,,	,,	,,	,,	,,	18 III 1902	26 VIII 1902	A	IV	*Greyhound; Carrie Knowles*	Lowered once for humpbacks	—	—	—	—	—	—
28c	,,	,,	,,	,,	,,	,,	25 III 1903	4 VIII 1903	A	IV	*C. Knowles*	Saw but did not lower for humpbacks	—	—	—	—	—	—
28d	,,	,,	,,	,,	G. Dunham	,,	4 IV 1904	31 VII 1904	A	IV–V	*Greyhound, Laura, A. R. Tucker, Bertha, A. Chase*	Sperm whaling	—	—	—	—	—	—
29	*Bertha*	New Bedford	Bark	117	M. Gomes	H. Clay	1 X 1901	31 VIII 1904	A	IV'02, '03 '04		No humpbacking	—	—	—	—	—	—
30a	*Wm. A. Grozier*	Provincetown	Schooner	117	G. Dunham	J. Dunham	2 V 1905	26 VII 1905	A			Sperm whaling	—	—	—	—	—	—
30b	,,	,,	,,	,,	,,	,,	28 IV 1906	15 VII 1906	A			,,	—	—	—	—	—	—
31	*John R. Manta*	Provincetown	Schooner	147	Edwards	Manta	15 VII 1907	4 IX 1908	A	IV–V'08	—	Sperm whaling	—	—	—	—	—	—
32	*Ellen A. Swift*	Provincetown	Schooner	132	G. Dunham	J. Dunham	11 III 1912	3 VIII 1912	A	IV	*Imogene*	Sperm whaling	—	—	—	—	—	—
33	*John R. Manta*	Provincetown	Schooner	147	Santos	Manta	25 IV 1914	11 VIII 1914	A	—	—	Sperm whaling	—	—	—	—	—	—
34	*A. E. Whyland*	New Bedford	Schooner	130	Lopes	Cleveland	16 III 1915	1 IX 1915	A	IV	—	Sperm whaling	—	—	—	—	—	—
35	*Wanderer*	New Bedford	Bark	303	Edwards	Avery	18 VIII 1917	9 VI 1918	A	IV'18	—	Sighting: 25° N, 63° W, 23 IV	—	—	—	—	—	—
36	*A. M. Nicholson*	New Bedford	Schooner	136	Cleveland	Cleveland	29 X 1919	[1920]	A	XI'19	—	Legibility poor; cruising in West Indies for sperm whales	—	—	—	—	—	—
Old Dartmouth Historical Society																		
37	*Manufactor*	Dartmouth	—	—	—	—	1756	1756	[NA]	—	—	Sperm whaling offshore	—	—	—	—	—	—
38	*Koziah*	New Bedford	—	—	—	—	1789	1790	Gulf of Mexico	—	—	Sperm whaling	—	—	—	—	—	—
39	*Industry*	Westport	Brig	—	Cory	—	1821	24 III 1822	Cape Verdes	III–IV'22	*Liza* of Falmouth	Humpbacked for 3 weeks near Dominica, Martinique, and Guadeloupe without success; no *Liza* in Starbuck for this period	—	—	—	—	—	—
40	*Industry*	Westport	Brig	—	Bennett	—	1823	11 XI 1824	Africa	XII'23–II'24	*Dove, Amy, Columbus*	Saw but did not lower for humpbacks	—	—	—	—	—	—
41a	*Industry*	Westport	Brig	94	O. Wilber	—	16 I 1827	13 IX 1827	West Indies	II–III	—	Saw humpbacks, but only sperming	—	—	—	—	—	—
41b	,,	,,	,,	,,	M. Mayhew	—	4 I 1828	14 VII 1829	West Indies	I–III'28	Several other sails in sight	Humpbacked opportunistically; primarily sperming and blackfishing	1	—	1	—	—	—
										I–II'29	—	Lowered unsuccessfully for humpbacks at least once; mainly sperming	—	—	—	—	—	—

Record no.	Vessel	Port	Rig	Tons	Master	Owner or agent	Sailed	Returned	Destination (SA = South Atlantic, NA = North Atlantic, A = Atlantic)	Period in West Indies	Other vessels seen in West Indies (take of humpbacks)	Comments	Humpbacks struck or taken[1] in West Indies (except as noted): Landed	Known killed but not landed	Struck but escaped: Unspecified	Struck but escaped: Iron 'Drew'	Struck but escaped: Line parted or cut; escaped with gear in it	Calves orphaned but not known to have been struck
42	*Juno*	New Bedford	Brig	123	Brownell	A. H. Seabury & Bro.	14IV1838	29V1839	A	I–II'39	—	Reported seeing humpbacks but did not lower; 14 whale (Starbuck)	—	—	—	—	—	—
43	*Thos. Winslow*	Westport	Brig	136	Manchester	T. Mayhew	12XI1841	30IX1842	A	III'42	—	Sperm whaling; 7 whale (Starbuck)	—	—	—	—	—	—
44	*Mattapoisett*	Mattapoisett	Brig	150	Brightman	Hammond	26III1841	5IX1842	A	II–III'42	*Emigrant*	Sperm whaling	—	—	—	—	—	—
45	*Theophilus Chase*	Westport	Bark	168	Baker	H. Wilcox	26XII1842	26VIII1844	A	I–III'44	*Fairy, Gem*	Lowered once for humpbacks in company with *Fairy*	—	—	—	—	—	—
46	*Barclay*	Westport	Bark	167	King	A. Corey	1VI1849	1IX1850	A	II–III'50	*Peru, Gov. Hopkins, Mexico*	Sperm whaling	—	—	—	—	—	—
47	*Barclay*	Westport	Bark	167	Tripp	A. Corey	4XII1850	26V1852	A	II–III'51	*Solon*	Saw humpbacks, but did not lower	—	—	—	—	—	—
48a	*Solon*	Westport	Brig	129	Smith	H. Smith	2V1850	21X1851	A	I'52	—	—	—	—	—	—	—	—
48b	,,	,,	Bark	129	J. Smith	,,	9VII1852	15X1853	A	— I–IV'53	*S. R. Soper, September* (2), two other humpbackers reported	Winter 1852–3 sailed from Cape Verdes to Barbados, then to Trinidad, Tobago, and Venezuela for humpbacking; reported at least 2 humpbacks taken at Monos Is. shore station; using bomb lance; 40 whale (Starbuck)	1	1	2	1	1	—
													At least 4 others taken by other vessels and at land station					
49	*Orray Taft*	New Bedford	Bark	176	P. Cornell	A. Lucas	20XI1854	25VIII1856	A	III–IV'55	—	Legibility poor, no humpbacking	—	—	—	—	—	—
50	*Solon*	Westport	Bark	129	Smith	H. Smith	6IV1854	15IV1856	A & I	III–IV'56 IV'55	— —	Saw humpbacks at Bermuda in April and May; sperming and right whaling	— —	— —	— —	— —	— —	— —
51	*Willis*	Mattapoisett	Bark	164	J. King	R. Barstow	3VI1857	21IX1858	A	II–IV'58	*Amelia* with 140 bbls humpback and blackfish	Lowered for humpbacks at Barbados; 'after chasing them a dozen times without success gave it up as a bad job'	—	—	—	—	—	—
52	*A. R. Tucker*	New Bedford	Bark	218	A. Grinnell	J. & W. R. Wing	29V1861	4V1864	A	V'63	—	Struck/lost a humpback while at anchor in Barbados	—	—	1	—	—	—
53	*Tekoa*	Fairhaven	Schooner	143	V. C. Long	Damon & Judd	29VI1863	20XI1863	A	—	—		—	—	—	—	—	—
54a	*Mattapoisett*	Westport	Bark	150	G. Beebe	H. Smith	20V1862	14IV1864	A	II–III'64	4 other schooners	Got 29 bbl humpback after it had sunk for 2+ days; 20 whale (Starbuck)	1	—	—	—	—	—
54b	,,	,,	,,	,,	W. Tripp	H. Smith	3X1864	5VIII1866	A	III'65 II–III'66	—	No mention of humpbacks	—	—	—	—	—	—
55	*Draco*	New Bedford	Bark	258	Braley	J. Bourne, Jr.	7IV1866	15VII1868	A	—	—	Saw humpbacks in May at Bermuda	—	—	—	—	—	—
56	*Edith May* (journal, personal)	Wellfleet	Schooner	135	Gross	R. Freeman	11XII1867	26IX1869	A	IV'68	—	Visited Cape Verdes; 85 whale (Starbuck)	—	—	—	—	—	—
56a	*Charles H. Cook*	Provincetown	Schooner	149	Gelett	S. Cook	22X1867	18V1868	A	—	—	—	—	—	—	—	—	—
56b	,,	,,	,,	114	Crowell	,,	3VI1868	25XI1868	A	—	—	—	—	—	—	—	—	—
57	*Wave*	New Bedford	Bark	150	E. Cannon 2nd	T. Knowles	6V1867	25IV1869	A	V–VI'68	—	*Walter Irving* spoken at 33° N, 51° W on 25VI'57, 3 months out with 100 whale, 25 sperm	—	—	—	—	—	—
58	*Washington Freeman*	Fairhaven	Schooner	96	L. Braley	O. Hitch	23XI1868	30IX1870	A	IV'69	—	Humpbacking off W. Africa; 312 whale (Starbuck) probably from there	—	—	—	—	—	—
58a	*Allie B. Dyer*	Provincetown	Schooner	—	O. Tripp	—	4VIII1868	?	A	—	—	—	—	—	—	—	—	—
59a	*Thriver*	Boston	Schooner	69	Cook	R. Soper	3I1870	22VIII1870	A	XII'70–	*Geo J. Jones*	Still humpbacking off Cumana 10IV when log ends	2	1	1	—	1	—
59b	,,						1870 lost at Aux Cayes	3II1873	A	IV'71								
60	*Union*	New Bedford	Schooner	66	Barstow	P. H. Reed	8VI1875	12IX1876	[A]	III'76	*Antarctic*	Saw humpbacks near St Lucia; did not lower	—	—	—	—	—	—
61	*Arnolda*	New Bedford	Bark	340	I. Howland	L. Snow	6VII1876	2XII1880	A	VI'77	—	—	—	—	—	—	—	—
62a	*Golden City*	New Bedford	Schooner	84	W. A. Martin	H. Clay	29XI1878	18III1880	A	—	—	Right whaling off Georgia, II'79	—	—	—	—	—	—
62b	,,	,,	,,	,,	Avery	,,	2VI1880	23VIII1881	A	—	—	Right whaling off Georgia, II1881	—	—	—	—	—	—
62c	,,	,,	,,	,,	Frates	,,	13X1881	18IX1882	A	III–IV'82	—	No humpbacking; killed a right whale off Brunswick, Ga.	—	—	—	—	—	—

[1] Calves known to have been struck are assumed to have died, even if no attempt was made to secure them. They are scored as 'known killed but not landed'.

Table 8 (*continued*)

Record no.	Vessel	Port	Rig	Tons	Master	Owner or agent	Sailed	Returned	Destination (SA = South Atlantic, NA = North Atlantic, A = Atlantic)	Period in West Indies	Other vessels seen in West Indies (take of humpbacks)	Comments	Humpbacks struck or taken[1] in West Indies (except as noted): Landed	Known killed but not landed	Struck but escaped: Unspecified	Struck but escaped: Iron 'drew'	Struck but escaped: Line parted or cut; escaped with gear in it	Calves orphaned but not known to have been struck
62d	,,	,,	,,	,,	Bourne	,,	23 X 1882	19 VIII 1884	A	V'83	*Quickstep, Ellen Rizpah*	Humpbacking at Cape Verdes; *Admiral Blake* (+) and *Crown Point* (ca. 4) also humpbacking at Cape Verdes; no whale (Starbuck)	3	—	1	—	1	—
													(Cape Verdes) other vessels there took at least 4 and struck/lost 2					
										IV–V'84	*Conwell*	—	—	—	—	—	—	—
63	*Union*	New Bedford	Schooner	66	Foster	H. Clay	30 I 1882	16 IX 1883	A	II–V'82	—	Humpbacked near St Lucia; went to Cape Verdes and NW Africa between seasons; 170 whale (Starbuck)	4	3	1	1	1	2
										I–VI'83	*Franklin, Bloomer* humpbacking	—	3	—	—	—	—	2
64a	*E. B. Conwell*	New Bedford	Schooner	91	Costa	H. Clay	11 IV 1883	18 VIII 1884	A	IV–V'84	*Golden City*	Sperm whaling	—	—	—	—	—	—
64b	,,	,,	,,	,,	,,	,,	7 X 1884	6 IV 1885	A	II–III'85	—	Sightings: 18° N, 60° W, 8 III; 21° N, 59° W, 15 III	—	—	—	—	—	—
64c	,,	,,	,,	,,	Foster	,,	28 IV 1885	10 IX 1885	A	—	—	—	—	—	—	—	—	—
64d	,,	,,	,,	,,	,,	,,	22 X 1885	10 VIII 1887	A	I–III'86	*Antarctic*	Lowered once for humpbacks near St Lucia	—	—	—	—	—	—
65	*Franklin*	New Bedford	Schooner	77	Mandly	H. Clay	5 X 1885	13 VII 1887	A	I–VI'86	*F. A. Barstow, W. A. Grozier, Adelia Chase*	Humpbacking near St Lucia; spent 2nd winter in Greater Antilles sperming; 230 whale (Starbuck)	9	4	3	—	—	2
66	*D. A. Small*	Provincetown	Brig	119	Winslow	Macool	1 II 1886	29 V 1888	A	II–V'86	*Quickstep* (2), *E. Rizpah* (1) definitely humpbacking; *Franklin, Mary E. Simmons, Alcyone, Rosa Baker*	Humpbacked 3 consecutive seasons at West Indies; 240 whale (Starbuck)	8	5	2	—	1	2
															At least 3 taken by other vessels			
										III–V'87	*Alcyone* (2) definitely humpbacking; *Baltic, Rising Sun*	—	2	—	—	—	—	1
										III–V'88	—	—	2	—	—	—	—	2
67a	*E. B. Conwell*	New Bedford	Schooner	91	Foster	H. Clay	3 X 1887	5 X 1888	A	V–VI'88	—	—	—	—	—	—	—	—
67b	,,	,,	,,	,,	Avery	,,	30 IV 1889	31 VII 1890	A	II–III'90	*Carrie Knowles*	Sightings: 19° N, 63° W, 21 II; 20° N, 63° W, 22 II; 26° N, 72° W, 3 IV	—	—	—	—	—	—
68	*Golden City*	New Bedford	Schooner	84	Mandly	H. Clay	30 IV 1888	30 VII 1889	A	I'89	*Franklin, Wm. Martin*	—	—	—	—	—	—	—
69	*Frances Allyn*	New Bedford	Schooner	106	Foster	Luce	11 VI 1889	4 VIII 1890	A	II–III'90	*Carrie D. Knowles*	—	—	—	—	—	—	—
70	*Golden City*	New Bedford	Schooner	84	Mandly	Luce	28 X 1889	24 VII 1891	A	XII'89–IV'90	*Alcyone, Franklin, Rising Sun, President, Chas. W. Morse, Wm. A. Grozier*	Sperm whaling; lowered once for humpbacks 'thinking it was sperm whales'	—	—	—	—	—	—
										XII'90–IV'91	*Carrie Knowles, Baltic, Alcyone, Wm. A. Grozier*	Sperm whaling; took a humpback cow (with calf) while working up sperms in Samana Bay; 10 whale (Starbuck)	1	—	—	—	—	1
71	*Franklin*	New Bedford	Schooner	77	Rose	H. Clay	3 X 1889	31 VII 1891	A	XI'89–III'90	*Baltic, Alcyone, Golden City, Rising Sun*	Sperm whaling and blackfishing	—	—	—	—	—	—
										XII'90–III'91	*Carrie Knowles, Alcyone Golden City, Baltic, E. B. Conwell, Rising Sun*	—	—	—	—	—	—	—
72	*E. B. Conwell*	New Bedford	Schooner	91	Avery	H. Clay & Co.	15 X 1890	16 IX 1892	A	I–II'91	*Franklin*	Saw humpbacks but did not lower	—	—	—	—	—	—
										II–III'92	*Carrie Knowles, Golden City*	,,	—	—	—	—	—	—
73	*Antarctic*	New Bedford	Schooner	101	Fisher	Luce	2 XII 1890	14 VIII 1892	A	V–VI'91	*Mary Simmons, Adelia Chase*	Saw humpbacks at Cape Verdes but did not lower	—	—	—	—	—	—
										IV–V'92	—	Saw humpbacks in West Indies but did not lower	—	—	—	—	—	—
74	*Pearl Nelson*	New Bedford	Schooner	123	Mandly	Luce	17 VI 1900	31 VIII 1902	A	II–IV'00, IV'01	*Carrie D. Knowles*	Sperm whaling	—	—	—	—	—	—
75a	*Golden City*	New Bedford	Schooner	84	Gonsalves	H. Clay	15 X 1901	23 VIII 1903	A	I–III'02	*Carrie D. Knowles*	Sperm whaling, lowered once for humpbacks in company with *Knowles*; sightings: 16° N, 56° W, 10 I; 16° N, 58° W, 11 I	—	—	—	—	—	—
										III–V'03	—	—	—	—	—	—	—	—

[1] Calves known to have been struck are assumed to have died, even if no attempt was made to secure them. They are scored as 'known killed but not landed'.

Table 8 (*continued*)

Record no.	Vessel	Port	Rig	Tons	Master	Owner or agent	Sailed	Returned	Destination (SA = South Atlantic, NA = North Atlantic, A = Atlantic)	Period in West Indies	Other vessels seen in West Indies (take of humpbacks)	Comments	Humpbacks struck or taken[1] in West Indies (except as noted): Landed	Known killed but not landed	Struck but escaped: Unspecified	Struck but escaped: Iron 'drew'	Struck but escaped: Line parted or cut; escaped with gear in it	Calves orphaned but not known to have been struck
75b	"	"	"		Santos	Avery	27IX1904	7VIII1905	A	III–IV'05	*Adelia Chase*	Sperm whaling	—	—	—	—	—	—
76	*Mary E. Simmons*	New Bedford	Schooner	105	Mandly	Luce	21V1903	22VII1904	A	—	—	—	—	—	—	—	—	—
77	*A. V. S. Woodruff*	New Bedford	Schooner	193	—	Tilton	5XI1910	21IX1911	A	—	—	—	—	—	—	—	—	—
78	*A. M. Nicholson*	New Bedford	Schooner	136	Smith	Smith	13II1913	8VIII1913	A	II'13	*Ellen A. Swift, Mystic, Bertha, D. Nickerson Margarett*	—	—	—	—	—	—	—
79a	*John R. Manta*	New Bedford	Schooner	147	Mandly	Manta	1V1918	29VII1918	A	IV	—	Only brief visits to Dominica and St Eustatius during sperm whaling cruises	—	—	—	—	—	—
79b	"	"	"	"	"	"	6II1919	19VII1919	A	II–III	—	—	—	—	—	—	—	—
79c	"	"	"	98	"	"	27III1920	4VIII1920	A	IV	—	—	—	—	—	—	—	—
79d	"	"	"	"	"	"	15III1921	9VIII1921	A	IV	—	—	—	—	—	—	—	—
79e	"	"	"	"	"	"	28II1923	16VIII1923	A	V	—	—	—	—	—	—	—	—
79f	"	"	"	"	"	Mandly	2V1925	20VIII1925	A	—	—	—	—	—	—	—	—	—
80a	*Wanderer*	New Bedford	Bark	303	Edwards	Edwards	15III1921	13IV1922	A	—	—	—	—	—	—	—	—	—
80b	"	"	"	"	"	"	25VIII1922	26IX1923	A	V'23	—	—	—	—	—	—	—	—

[1] Calves known to have been struck are assumed to have died, even if no attempt was made to secure them. They are scored as 'known killed but not landed'.

Table 9

Logbook data from various sources, presented here to supplement the data in our own logbook sample (Table 8) and, in the case of Record No. 8, to use for comparison.

Record no.	Vessel	Port	Rig	Tons	Master	Owner or agent	Sailed	Returned	Destination	Period in West Indies	Other vessels seen in West Indies (take of humpbacks)	Comments	Humpbacks struck or taken in West Indies (except as noted): Landed	Known killed but not landed	Struck but escaped: Unspecified	Struck but escaped: Iron 'drew'	Struck but escaped: Line parted or cut; escaped with gear in it	Calves orphaned but not known to have been struck
C. H. Townsend Worksheets (Townsend and Watson, n.d. MS)																		
1	*Aurora*	Edgartown	Schooner	89	Reynolds	Osborne	22X1884	2XI1885	Atlantic	II–III'85	—	No whale (Hegarty)	3	—	—	—	—	—
2	*Cicero*	New Bedford	Bark	226	H. Clay	Loum Snow & Son	9V1870	24X1873	Atlantic	I–III'72	—	85 whale (Starbuck); sent home 290 whale, 1,300 lb. bone	6	—	—	—	—	—
										1873	—		2	—	—	—	—	—
K. Martin (1981 MS)																		
3	*Rainbow*	Dartmouth	Schooner	48	Eldridge	Potter	13XII1866	17VIII1867	Atlantic	III'67	—	Humpbacking at Trinidad	?	1	?	?	?	?
4	*Annawan*	Rochester	Brig	148	Hammond	Barstow	16XII1836	19VI1837	Atlantic	I–II'37	—	Humpbacking; 20 whale (Starbuck)	?	?	?	?	?	?
5	*Franklin*	New Bedford	Schooner	77	Avery	Clay	9X1883	24VIII1885	Atlantic	III'84; III'85	At least 2 other vessels humpbacking in 1885	Humpbacking at St Lucia; at least 6 cow–calf pairs taken; 'many strikings'	7	—	+	—	—	6(?)
6a	*Agate*	Provincetown	Schooner	81	Atkins	Atkins	8II1869	15VII1870	Atlantic	III–IV	At least 5 other vessels humpbacking	Starbuck listed 130 bbls. whales plus 'sent home 167 humpback'						
6b	"	"	"		Atkins	Atkins	I1871	24IX1871	Atlantic	III–IV	—	100 whale (Starbuck)	Took at least 14–15 cow–calf pairs in 4 seasons					
6c	"	"	"		Atkins	Atkins	31I1872	21IX1872	Atlantic	III–IV	—	221 whale (Starbuck)						
6d	"	"	"		Atkins	Atkins	5II1873	15IX1873	Atlantic	III-IV	—	86 whale (Starbuck). Four consecutive seasons humpbacking at Grenada, Carriacou, Union						
7a	*J. Taylor*	Provincetown	Schooner	174	Smith	Atwood	28II1866	28VI1867	Atlantic	I–III'66; I–III'67	—	Humpbacking and black-fishing at Bequia and Mustique; 120 whale, sent home 60 whale (Starbuck)	Took 5 in 3 seasons					
7b	"	"	"		"	"	20VIII1867	24VIII1869		I–III'68	9 other vessels	No whale (Starbuck)						
EDM Collection																		
8	*William Lee*	Newport	Bark	311	Slocum	Monroe	1856	1860	Pacific Ocean	—	—	Humpbacked 3 seasons off western South America; detailed and legible so loss rate should be accurate	1(+one floater)	—	—	—	—	—
													7	2	9	1	1	—
													5	3	—	—	—	—
													(Pacific)					

D. Difficulties and methods of capturing humpback

Although the humpback was the only large baleen whale other than the right whale (and the gray whale in early colonial times) that could be successfully hunted with premodern technology (i.e. in open boats propelled by hand or sail and using hand-thrown harpoons and hand lances) in coastal waters of eastern North America, it was not easy to capture. On its summer grounds or during migration, the humpback was 'very wary, hard to approach, and very hard to kill; as well as being a swift traveler' (Edwards and Rattray, 1932, p. 115). 'When this species...is met with at sea, it is seldom thought worth lowering after, for the reason that it is exceedingly hard to kill, runs to windward at great speed on being struck, and generally sinks when killed. When a dead fish sinks at sea...he is of course lost' (Nordhoff, 1857, 1895, pp. 175–6). Bullen (1901, p. 255) referred to 'the almost impossibility of competing with him [the humpback] in the open sea.'

On their winter grounds, humpbacks could often be hunted 'on soundings', i.e. in shoal water where the sinking problem was obviated to some extent (Davis, 1874, p. 388). 'The [sunk] whale is anchored, and a large buoy is left to mark his place under water. The progress of decay evolves certain gasses in his body, which being lighter than the water, raise the body to the surface; and once there, it is again taken possession of by its captors' (Nordhoff, 1857, 1895, pp. 175–6; also see Scammon, 1874, pp. 45–6). A large harpoon called the 'humpback-iron' was often thrown into the whale's 'neck' or the area near the blowholes before it died (Brown, 1887, p. 270–1; Brown, 1883, p. 312). It this were not done immediately, the humpback-iron could be rigged with weights and driven into the carcass at rest on the bottom (cf. our Fig. 20).

There were still difficulties in humpbacking, even on tropical banks. The whales, especially males, tended to run along the bottom, once struck, and their tendency to spend little time at the surface made it hard to administer the killing lances (Nordhoff, 1857; Ferguson, 1936, p. 130–1; Gray, 1874, p. 186). The whalers avoided 'bulls', if they had a choice. As Bullen (1901, p. 269) put it, 'our ill-success on tackling bulls was not at all in consequence of our clumsiness, these agile animals being always a handful.' Bulls produced less oil for their size than cows (Nordhoff, 1857, p. 180–1).

Humpbacking could also be a dangerous activity. Stove boats were commonplace, and crewmen were sometimes killed or badly injured after being fouled in the harpoon line (Bullen, 1901, pp. 264–5; Balcomb, 1981). Loss to sharks, even in shoal water where a sunken whale could be seen resting on the bottom, was a constant problem (Ferguson, 1936, pp. 131–2). Whales could remain on the bottom for a few hours or for two or three days (Scammon, 1874, p. 46). If shark damage were to be avoided, they had to be raised as soon as possible, then often towed many miles before a land station or a whaleship at anchor near shore could be reached. 'An immense amount of labor was required in attempting to hoist the carcass to the surface and to tow it back to the ship' (Hohman, 1928, p. 148). Nordhoff (1857, p. 209) and his fellow crew members departed their Madagascar humpbacking grounds 'with a hearty determination never to return.'

As with other mysticetes, female humpbacks are

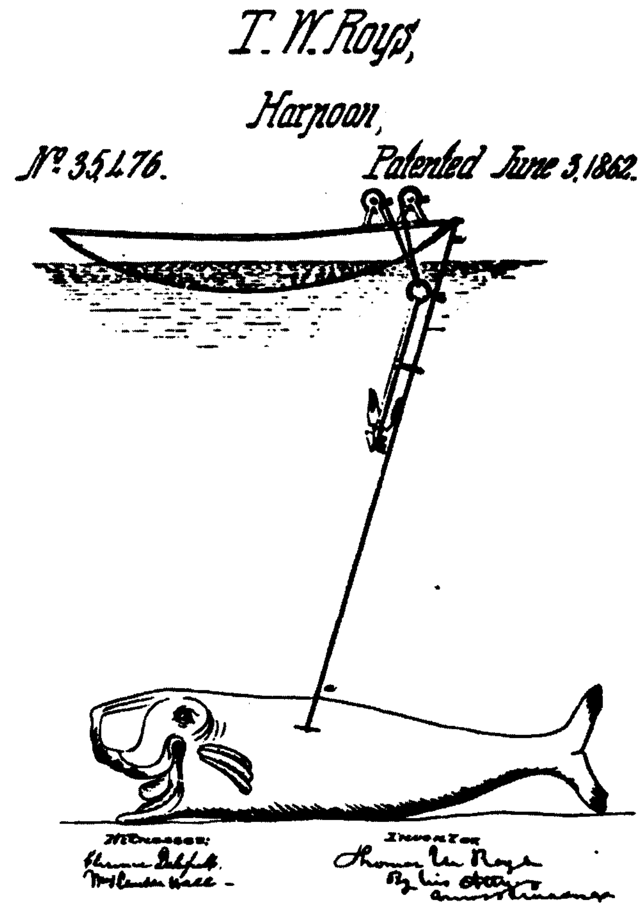

Fig. 20. Roys' whale-raiser, developed to retrieve sunken rorquals. The heavily weighted, 10 ft long 'whale raiser' was sent down the foregoer into the carcass, affording a better purchase sufficient for the ship's windlass to be used on the attached hawser. (Roys' patent 35,476 of 3 June 1862; reproduced here from Schmitt *et al.*, 1980, fig. 17, with permission.)

extremely solicitous of their calves. Whalers regularly took advantage of this devotion by fastening to the calf with a 'drug-iron' (drogue?), then attacking the cow, which would not abandon the calf as long as it remained alive (Brown, 1887, p. 268). Often the calf was not saved. As Nordhoff (1857, p. 191) noted, the calves 'were not yet old enough to get their own living, and would most likely starve to death.' It is reasonable to assume that every time a nursing humpback was killed in the tropics, her calf starved if the whalers did not bother to secure it.

E. Products and markets

Dudley (1725) wrote: 'The Bone...is not worth much, tho' somewhat better than the Finback's.' The humpback's baleen was said to be 'specially suitable for corsets' (Clark, 1887a, p. 5), and despite its shortness and lack of elasticity, it sold for up to 6¼¢ a pound (Goode, 1884, p. 27). These claims notwithstanding, an authoritative source (Stevenson, 1907) stated:

> The baleen from the humpback whale is even shorter and of poorer quality than that from the finback; its low value and the small quantity that may be obtained from an individual do not warrant the trouble of saving it.

Indeed, in at least one instance it was judged

> so short as to be not worth the trouble of curing, so, with the exception of such pieces as were useful to the 'scrimshoners' for ornamenting their nicknacks, it was not preserved (Bullen, 1901, p. 253).

Nevertheless, there is some evidence that humpback baleen was occasionally marketed. The domestic stock of whalebone in 1866 totaled 193,200 pounds; of this, 6,000 pounds or 3 per cent was from humpbacks (*WSL* 23(48) 30 I 1866). The year 1872 was an unusually successful one for humpbacking worldwide; a total of 22 tons of humpback baleen was imported, with a stock of 27 tons on hand as of 1 January 1873 (*WSL* 30(50): 4 II 1873). In 1880 'a few hundred weight of small whalebone' (likely from humpbacks) was sold by the Gaspé whalers of the St Lawrence for $10 per cwt. (Clark, 1887a, p. 216).

Hohman (1928, p. 148) referred to the 'inferior quality' of humpback oil as insurance of the humpback's 'comparative safety from the harpoons of the whaleman except in dull seasons.' Goode (1884, p. 27) attributed to Bennett the claim that humpback oil is 'superior' to right whale oil and only a little less valuable than sperm oil. Judging by prices quoted in the *Whalemen's Shipping List*, however, humpback oil was consistently priced well below sperm oil and slightly below Arctic whale oil. It was equivalent in value to South Sea, or right whale, oil (Table 4).

The reason for the difference in price between Arctic (bowhead) whale oil and humpback or South Seas (right whale) oil is that oil taken in high latitudes gave much less foots or stearin than oil taken in the tropics (Stevenson, 1904). Humpback oil is somewhat lighter (i.e. has a lower specific gravity) than right whale oil and has a slightly higher percentage of carbon and hydrogen.

Oil prices influenced the itineraries and preferences of the whalers. For example, in 1878 'many vessels were humpbacking during the year on account of the unusually low price of sperm oil' (*WSL* 36(48): 14 I 1879). The following year humpbacking was 'in better favor on account of the high price of the oil' (*WSL* 37(47): 6 I 1880); more whalers turned to humpbacking in 1880 because of 'the high price compared with other oils' (*WSL* 38(48): 11 I 1881).

Some consideration had to be given to the problem of mixing oils if a whaler hunted more than one species. A cask that held whale or humpback oil had to be thoroughly cleansed before sperm oil was to be stored in it; whereas, a cask emptied of sperm oil did not need to be washed before receiving whale or humpback oil (Stevenson, 1904). There are basic differences between physeterid waxy esters and mysticete oils. Right whale and humpback oil have a greater gumming tendency than sperm oil, and they consequently require more scrubbing along with the administration of strong lye to effect their removal (Brown, 1887, pp. 287–8).

F. Itinerary considerations

As the Yankee whalers learned more about where and when to find their prey, and about the logistic requirements for reaching the grounds in a timely fashion, they developed predictable itineraries. Such itineraries were influenced by the whalers' preferences for different species; the seasonal and geographic availability of the whales; vessel size and capabilities; the need for water, wood, and victuals; and considerations of current, wind, and weather.

In the North Pacific from 1855 to 1865, for example, 'Whaling masters from the northern summer grounds...were attracted to the coastal gray-whale fishery because winters were mild and because the capture of even a few gray backs, before returning to the more profitable summer bowhead and right whaling, made the off-season worthwhile' (Henderson, 1972, p. 160). It was, at any rate, 'more financially attractive than spending the season in port in Hawaii or California or in sailing all the way to the South Pacific Ocean for sperm and southern right whales.' Henderson (p. 82) suggested that one of the early gray whaling grounds in the Pacific, Magdalena Bay, was discovered by sperm and humpback whalers who gathered there in winter 'to cooper their oil and chase sperm whales outside the bay' and to pursue 'the familiar humpback whales which frequented that bay with their calves in spring.'

In the North Atlantic, where gray whales had been extirpated and right whales had become scarce by the beginning of the eighteenth century, humpbacks were the only large baleen whales available that could be taken by the Yankee sperm whalers during their off-season. Barbados, Dominica, Marie-Galante, St Thomas, St Eustatius, Santo Domingo (Hispaniola), and other Caribbean islands were favorite sites for assembling, trading, victualing, sending and receiving mail, 'wooding', and 'watering'. Some whalers ignored the humpbacks while visiting the islands, or at least their logs show no evidence of an interest. Others humpbacked in a desultory manner; for example, the *Willis* of Mattapoissett took a 55-barrel humpback 'while lying in port' at Barbados (*WSL* 22(16): 21 VI 1864). Although humpbacking was for some vessels merely an opportunistic pursuit, others sailed purposefully for the humpbacking grounds. For example, the schooner *Petrel* of New Bedford was sold to a Westport captain in 1871 and 'fitted for a humpback cruise' (*WSL* 29(4): 21 III 1871). A few vessels clearly considered Caribbean humpbacking a part of their itinerary, frequently returning to the same grounds at the same time in successive years.

Atwood's (in Clark, 1887a, p. 22) summary of the itinerary of Provincetown humpbackers is generally consistent with what we found in reading logbooks and journals:

> They sail from port about the middle or last of January and go direct to the West Indies, where they whale near the shores of these islands for humpbacks. Their whaling-ground for this species is from Tobago, latitude 11° 20′ north, longitude 60° 27′ west, thence northward around the shores of the islands as far as the Island of Mariegulante [Marie-Galante], in latitude 15° 52′ north, longitude 61° 18′ west. These vessels stop there until the latter part of April or early in May, when they leave for the Western, Charleston, or Hatteras grounds in pursuit of sperm whales, and usually return home in September. Another favorite ground is around the Cape Verde Islands, where these vessels cruise near the shore for the humpback during the winter months and then go north to the sperm whale grounds.

However, we found that some vessels began a cruise at the sperm whaling grounds on either side of the North Atlantic, then visited the West Indies or Cape Verdes humpbacking grounds in winter before sperm whaling again the following summer (e.g. record no. 14a, Table 8).

To a degree, humpbacks were probably hunted simply because of their proximity to tropical islands and continental ports visited by whalers in winter. Nordhoff (1857, pp. 168–9) implied that an inability to find sperm whales at least contributed to the decision to go whaling for humpbacks. Moreover, a visit to the humpbacking grounds held out the welcome prospect of 'an occasional run on shore'. The pleasant weather, change of diet, and presence of drink and women compensated the whalers for whatever misery had to be endured chasing humpbacks. As Bullen (1901) remarked concerning a season's humpbacking in the Friendly Islands, 'Profitable, in a pecuniary sense, the season had certainly failed to be, but that was the merest trifle compared with the real happiness and peace enjoyed during our stay.'

G. Estimation of Loss Rate Factor

Losses were high in the West Indies humpback fishery for a variety of reasons (see Section VII (ii) below). Logbook data were used to quantify the loss rate and to calculate an appropriate loss rate factor for correcting figures on secured catch. We used 13 West Indies humpbacking vessel-seasons between 1866 and 1888 for which we judged losses to have been reported consistently in the logbook or journal. Lost whales were divided into five categories:

- s – known killed but not recovered, usually due to sinking (often followed by shark mutilation);
- u – known struck and escaped, but with no indication as to the severity of wounding ('unspecified');
- d – struck and lost when the iron drew;
- p – struck and lost when the line parted or was cut, the whale presumably escaping with whaling gear still imbedded and/or attached to it;
- c – calves whose mothers were definitely killed but whose fate was not indicated.

We made a series of assumptions about these data. Calves known to have been struck but whose fate was not mentioned were scored as 'known killed but not landed', our assumption being that a sucking calf no more than two or three months old has little chance of recovering from a harpoon or lance wound. We assumed that whales struck and lost but scored as 'unspecified', as well as those from which the iron drew, had some chance of recovery and survival. Arbitrarily, we assumed 50 per cent mortality of these whales. Whales that escaped with gear in them are assumed to have died soon after of their wounds. In the absence of evidence that sucklings are adopted by females whose own calf has died, orphaned sucklings are all assumed to have died.

For comparison, we applied the same assumptions to the three Cape Verdes humpbacking voyages whose logbooks were read and for which we consider the notation of losses to be reasonably complete. For further comparison, we used data in the logbook of the *William Lee* of Newport, which humpbacked for two seasons in the eastern Pacific in 1856–60.

To calculate a Loss Rate Factor (LRF), we used the following equation:

$$\text{LRF} = \frac{T+s+0.5(u)+0.5(d)+p+c}{T}$$

where

T = number of humpbacks tried out
s = number of humpbacks killed but lost
u = number of humpbacks struck and lost but 'unspecified'
d = number of humpbacks struck and lost because the iron drew
p = number of humpbacks struck and lost carrying whaling gear
c = number of calves orphaned.

The three sets of data yield Loss Rate Factors of 1.86, 2.12, and 1.92, respectively (Table 10). To be conservative, we used an LRF of 1.85 to correct estimated catches in the West Indies fishery.

H. Estimate of total kill

We have used our logbook sample and other available data to estimate the total kill of humpbacks in the West Indies by the Yankee pelagic whalers. In addition to the reliable information on catches obtained by reading logbooks, we examined the tables in Starbuck (1878) and Hegarty (1959). Two procedures for extrapolation from these tables were considered. One involves the use of oil returns for selected voyages to estimate their whale landings; the other relies on the application to selected voyages of the average known catch by voyages in our logbook sample.

1. *Rationale for estimate from 'oil yield'.* To estimate the yield per whale landed in the West Indies we consulted several authoritative sources. Scammon (1874) stated that large Pacific humpbacks yield 40 barrels, although he knew of a 73-barrel female taken in the tropics. One of the largest humpbacks we know about was an 85-barrel specimen from the coast of Africa (*WSL* 26(37): 10 XI 1868). Bullen (1901) expected a lactating female to yield 50 barrels. True (1884) gave a range of 35 to 60 barrels for adult Atlantic humpbacks. Allen (1916, p. 315) referred to Clark's (1887a, p. 41) estimate of 25–30 barrels for humpbacks taken along the Maine coast as being low because only the blubber was tried out; the modern method, according to Allen, involves the boiling of the entire carcass. Allen gave 33.3 barrels as the average yield of 14 humpbacks taken in New England, but he did not specify whether they were tried out by the 'old' or the 'modern' method.

We made an independent estimate of yield per whale landed in the West Indies based on logbook data. The whalers in our sample rarely mentioned the amount of oil recovered from the humpbacks they caught. However, some did, and our West Indies sample included 34 humpbacks that yielded 859 barrels, or about 25 barrels per whale. Our Cape Verdes sample included 13 whales yielding 364 barrels, or about 28 barrels per whale. For 13 humpbacks taken by the *Lee* in the eastern Pacific during winter, the yield was 416 barrels or 32 barrels per whale. Individual yields ranged from 75 barrels in one Cape Verdes animal to 5 barrels in a West Indies calf.

Another method of estimating average yield is by summing Starbuck's and Hegarty's whale oil returns for voyages whose landings of humpbacks are known. We used the 11 West Indies voyages from Table 8 for which Starbuck or Hegarty gives whale oil returns and for which we believe the logbook tally of landed humpbacks in the West Indies to be complete. These result in a yield per whale of 24.9 barrels.

Although 25 barrels is the low end of the range for humpback yields given in most published accounts, we consider it an appropriate figure to use in our estimation procedure. There is no reason to believe the Yankee pelagic whalers achieved full utilization of humpback carcasses. They sometimes took calves and other undersized whales and often lost blubber to sharks. The two methods we used to estimate mean yield, from West Indies data, support the decision to use 25 barrels.

2. *Rationale for estimate from 'catch-per-season' statistics.* We used 16 vessel-seasons in the West Indies for which we felt the logbook data were complete (Table 8) to calculate the mean humpback catch per vessel-season.

Table 10

Loss Rate Factor (LRF) to correct secured catch and to estimate total fishing mortality of humpback whales in nineteenth-century Yankee pelagic fishery. For detailed information on the voyages, see Tables 8 and 9.

Vessel	Year	No. tried out (T)	No. known killed but lost (s)	No. struck and lost, unspecified (u)	No. struck and lost because iron drew (d)	No. struck and lost carrying gear (p)	No. of calves whose mothers were known killed (c)	Loss Rate Factor, $LRF = \frac{T+s+\frac{1}{2}u+\frac{1}{2}d+p+c}{T}$
				West Indies Humpbacking				
Arthur Clifford	1866	7	1	2	1	1	0	1.50
Arthur Clifford	1867	9	2	2	0	3	0	1.67
Arthur Clifford	1869	2	1	0	1	1	0	2.25
Arthur Clifford	1870	8	1	2	0	1	1	1.50
Quickstep	1868	4	2	2	1	0	0	1.86
Nellie S. Putnam	1869	8	1	3	1	2	1	1.75
Solon	1853	1	1	2	1	1	0	4.50
Union	1882	4	3	1	1	1	2	2.75
Union	1883	3	0	0	0	0	2	1.67
Franklin	1886	9	4	3	0	0	2	1.83
D. A. Small	1886	8	5	2	0	1	2	2.13
D. A. Small	1887	2	0	0	0	0	1	1.50
D. A. Small	1888	2	0	0	0	0	2	2.00
Totals		67	21	19	6	11	13	1.86
				Cape Verdes Humpbacking				
Golden City	1883	3	0	1	0	1	0	1.50
Nellie S. Putnam	1870	6	2	1	0	1	0	1.58
E. Nickerson	1853	17	8	6	8	7	2	2.41
Totals		26	10	8	8	9	2	2.12
				Eastern South Pacific Humpbacking				
William Lee	1858	7	2	9	1	1	—	2.14
William Lee	1859	5	3	0	0	0	0	1.60
Totals		12	5	9	1	1	0	1.92

The resulting estimate is 7.36. For comparison, we averaged the known catch of seven vessel-seasons at the Cape Verdes (Table 8). These resulted in a mean catch of seven whales per vessel-season. For our 'catch-per-season' calculations, we used a mean catch of seven humpbacks.

3. *Fishing mortality for 'read sample' and 'sighted sample'*. To estimate the total kill of humpbacks in the West Indies by the Yankee pelagic whalers, we followed this procedure. First, we summed known landings from the sample of logbooks we read (called 'read sample' hereafter) and added known losses, including lost whales known to have been killed, all orphaned calves, all whales that escaped with gear in them, and half of those from which the iron drew or for which we had no details about the nature of the strike and loss (Tables 8, 12).

To this we added the estimated catch by vessels we knew from statements in other vessels' logbooks or journals, were humpbacking in the West Indies in a given year (called 'sighted sample' hereafter) (Table 11). This catch was estimated two different ways: (1) by dividing the number of barrels of whale oil listed by Starbuck (1878) and Hegarty (1959) for those voyages by 25 (our estimated oil yield per humpback) – the 'oil yield estimate'; and (2) by attributing to each vessel-season in the West Indies the mean catch per vessel-season from our logbook data – the 'catch-per-season estimate'. The estimated catch was multiplied by the Loss Rate Factor, 1.85, to obtain total fishing mortality (Table 12).

4. *Fishing mortality for 'extrapolation sample'*. There certainly were more West Indies humpbacking voyages than we have accounted for in the above estimate. To account for a higher percentage of the actual kill, we devised the following procedure for selecting an 'extrapolation sample':

First, we identified a period during which we knew Provincetown vessels were humpbacking regularly in the West Indies. As suggested above, the period 1850–1890 is when most of the humpbacking by Yankee pelagic whalers is believed to have occurred worldwide (Townsend, 1935; Martin, 1981 MS; statements in the *Whalemen's Shipping List*). Our sample (including data from Martin 1981 MS and Townsend and Watson, n.d. MS) indicates that between 1866 and 1877 there were at least 33 humpbacking voyages to the West Indies by Provincetown vessels, and we have accounted for (by reading logbooks and journals) only 40 of 385 Provincetown Atlantic voyages during this period (Fig. 19). Three of the seven voyages that did not humpback in the West Indies humpbacked at the Cape Verdes. It is reasonable to assume that most of the baleen whale oil brought or sent home by Provincetown vessels between 1866 and 1887 was from North Atlantic humpbacks. Although there was a market for humpback baleen and we know that it was saved by some whalers, to be conservative we have not included in our extrapolation, voyages for which 'bone' of any kind is listed in the returns. There were still some right whales in the North Atlantic, and there is no reason to think Provincetown whalers would have neglected to catch them opportunistically. Rather than assuming that all Provincetown vessels reporting whale oil between 1866 and 1877 were humpbacking, we applied a further selection before identifying our extrapolation sample. We assume that a winter sailing date, coupled with an arrival date the following summer or fall, contributes to the likelihood that a given vessel went to the West Indies for a season

Table 11

Vessels known to have been humpbacking at the West Indies, based on statements in logbooks or journals of other voyages (see Table 8). This is our 'sighted sample'. Data are from Starbuck (1878) and Hegarty (1959).

Vessel and year of departure	Port	Rig	Tons	Master	Owner or agent	Season in West Indies	Comments
September – 1852	Boston	Brig	115	Heath	Fluker	1853	150 bbls whale; known to have taken at least 2 humpbacks off Venezuela
S. R. Soper – 1853	Provincetown	Schooner	130	Soper	Soper	1853	100 bbls whale
Amelia – 1856	Mattapoisett	Brig	127	Kempton	L. Meigs	1858	Uncertain whether the 140 bbls humpback oil on board in West Indies in 1858 or 87 bbls whale oil listed by Starbuck was from West Indies animals; Starbuck indicated off coast of Africa in 1857
G. W. Lewis – 1866	Provincetown	Schooner	110	Carlow	Rich	1866	140 bbls whale
Arizona – 1867	Provincetown	Schooner	115	Goodspeed	S. Cook	1868	190 bbls whale
Ada M. Dyer – 1867	Provincetown	Schooner	119	Dyer	A. Cook	1867	Definitely one and probably both humpbacking; 200 bbls whale each
Alice B. Dyer	Provincetown	Schooner	129	J. S. Dyer	D. Conwell	1867	
Estella [*Snow*] – 1867	Provincetown	Schooner	94	Snow	J. E. & G. Bowley	1868	139 bbls whale (180 acc. to *WSL*)
G. H. Phillips – 1867	Provincetown	Schooner	130	Taylor	S. Cook	1868	Took at least one humpback, 78 bbls whale (220 acc. to *WSL*)
D. C. Smith – 1867	Provincetown	Schooner	67	Kenney	John Atwood	1868	Took at least one humpback; 3 bbls whale
J. Taylor – 1867	Provincetown	Schooner	174	A. Smith	J. Atwood, Jr.	1868	No whale oil indicated
L. J. Bigelow – 1868	Provincetown	Brig	130	J. Cook	B. A. Lewis	1870	No whale oil indicated
Ada M. Dyer – 1868	Provincetown	Schooner	87	Dyer	A. Cook	1869	185 bbls whale
G. W. Lewis – 1868	Provincetown	Schooner	65	Stid	J. Lewis	1869	95 bbls whale
Winged Racer – 1868	Provincetown	Schooner	80	Young	H. & S. Cook	1868	40 bbls whale but had 50 bbls humpback oil by March 19
N. J. Knight – 1869	Provincetown	Schooner	70	Dyer	D. Conwell	1870	Took at least one humpback and struck/lost another; returned with 150 bbls whale and sent home 80 bbls whale
C. L. Sparks – 1869	Provincetown	Schooner	96	Roberts	D. Conwell	1870	Struck/lost at least one humpback; sent home 176 bbls whale
Allie B. Dyer – 1869	Provincetown	Schooner	87	Tripp	D. Conwell	1870	One of the *Dyers* took at least 7 humpbacks and struck/lost another; *Ada M.* returned with 189 bbls whale and sent home 100; *Allie B.* returned with 224
Ada M. Dyer – 1870 (one or both *Dyers* were there)	Provincetown	Schooner	87	Dyer	A. Cook	1870	
Alleghania – 1870	Provincetown	Schooner	70	Snow	Daniel C. Cook	1870	Struck/lost at least one humpback; sent home 15 bbls whale
Gracie M. Parker – 1870	Provincetown	Schooner	82	Dyer	A. Cook	1870	182 bbls whale; sent home 100 bbls whale; struck/lost at least one humpback
Rising Sun – 1870	Provincetown	Schooner	69	Freeman	A. Nickerson	1870	130 bbls whale
Sassacus – 1870	Provincetown	Schooner	110	Nickerson	E. & E. K. Cook	1870	Took at least 2 humpbacks; sent home 50 bbls whale
Thriver – 1870	Boston	Schooner	69	Cook	R. Soper & Son	1870	69 bbls whale; sent home 150 bbls whale
Franklin – 1882	New Bedford	Schooner	77	Avery	H. Clay	1883	4 whale
Bloomer – 1883	Provincetown	Schooner	74	Smith	Smith	1883	100 bbls whale
Ellen Rizpah – 1886	Provincetown	Schooner	67	Dyer	G. Knowles	1886	Took at least one humpback; 200 bbls whale
Quickstep – 1886	Provincetown	Schooner	94	Marston	G. Knowles	1886	Took at least 2 humpbacks; 200 bbls whale
Alcyone – 1887	Provincetown	Schooner	92	Dunham	G. Knowles	1887	Took at least 2 humpbacks; 15 bbls whale

Table 12

Estimates of humpback kills by Yankee pelagic whalers in the West Indies, 1866–87. The year indicated is not necessarily the year in which the kills were made; rather it is the year in which the voyages that resulted in the kills departed from New England. In all cases, the estimates are based on the assumption that all orphaned calves, struck calves, and non-calves that escaped with gear in them ultimately died because of the encounter with whalers. Also, 50 per cent of the whales that escaped after the iron drew or that were struck and lost in an 'unspecified' manner are assumed ultimately to have died of their wounds. Estimated catches by the 'sighted sample' and the 'extrapolation sample' have been multiplied by 1.85 to account for dead and moribund losses. For definitions of terms in the headings, see text.

		Estimated kill by 'sighted sample'		Estimated kill by 'extrapolation sample'		
Year sailed	Known kill by 'read sample'	'Oil yield estimate'[1]	'Catch-per-voyage estimate'[2]	'Oil yield estimate'[1]	'Catch-per-voyage estimate'[2]	Total for year sailed (midpoint of the range in estimates)
1866	14	10	13	150	246	174–273 (224)
1867	37	60	91	144	246	241–374 (307)
1868	31	24	52	51	78	106–161 (133)
1869	7	47	39	50	104	104–150 (127)
1870	13	73	78	64	117	150–208 (179)
1871	7	0	0	59	91	66–98 (82)
1872	7	0	0	126	117	133–124 (129)
1873	7	0	0	94	91	101–98 (100)
1874	0	0	0	111	104	111–104 (108)
1875	0	0	0	69	65	69–65 (67)
1876	0	0	0	104	117	104–117 (111)
1877	0	0	0	93	91	93–91 (92)
1878	0	0	0	87	65	87–65 (76)
1879	0	0	0	94	78	94–78 (86)
1880	0	0	0	88	91	88–91 (90)
1881	0	0	0	64	78	64–78 (71)
1882	16	1	13	53	65	70–94 (82)
1883	0	7	13	76	91	83–104 (94)
1884	3	0	0	63	65	66–68 (67)
1885	30	0	0	100	78	130–108 (119)
1886	24	30	26	14	13	68–63 (66)
1887	0	2	13	1	13	3–26 (15)
	196	261	338	1755	2104	2205–2638 (2421)

[1] Assumes 25 barrels/whale; oil totals from Starbuck (1878) and Hegarty (1959).
[2] Assumes a catch of 7 humpbacks per vessel-season.

of humpbacking. Therefore, we selected for extrapolation only those voyages with departure dates between October and March (inclusive) and with arrival dates before the following winter.

Some humpbacking voyages to the Cape Verdes are probably included in our 'extrapolation sample', and some of the 'whale oil' used to estimate the catch of humpbacks is actually blackfish (pilot whale) oil. However, given the conservatism of our selection procedure, we believe that Cape Verdes kills and blackfish oil mistakenly attributed to humpbacks are offset by: (1) Provincetown West Indies humpbacking voyages that were not included in our 'extrapolation sample' because of the presence of 'bone' in the lists of returns, the absence of whale oil in the lists of returns, or failure to meet our conditions concerning sailing and arrival dates; and (2) the voyages from ports other than Provincetown that involved West Indies humpbacking.

To the 'extrapolation sample' we applied the same estimation procedures as were used for the other two samples ('read' and 'sighted'). Results are in Table 12.

5. *Combined total fishing mortality.* The total estimated humpback kill by Yankee pelagic whalers in the West Indies between 1866 and 1887, inclusive, is 2,421.

6. *Checks on accuracy of extrapolation procedures.* A check on the accuracy of our 'oil yield estimate' can be made by comparing our estimated oil production for the 1872 season with the statement in the *Whalemen's Shipping List* (30(50): 4II 1873) that 2,000 barrels of humpback oil from the West Indies were shipped in that year. No voyages in our 'read sample' or 'sighted sample' are known to have been on the West Indies grounds in 1872. Summing all the oil listed for our 'extrapolation sample' and that of one of Martin's (1981 MS) West Indies voyages (Table 9), the estimated total is 1,926 barrels for 1872 – very close to the figure from the *WSL*.

We can also compare our kill estimate of 119 whales for 1885 (Table 12) with a report by the Provincetown schooner *Alcyone* that over 1,600 barrels of humpback oil were secured by the fleet operating on the 'West Indies Ground' that season (*WSL* 43(21): 30VI 1885). Using 25 barrels per whale and a loss rate factor of 1.85, 1,600 barrels represents total removals of about 118 humpbacks – almost identical to our estimate in Table 12.

In general, our perusal of letters, memoranda, and lists in the *WSL*, an exercise completed *after* the calculations of total fishing mortality in Table 12 had been made, supported our assumptions and confirmed that our estimates were conservative.

Adams (1970, 1971), who examined the St Vincent *Bluebooks*, reported that more than 6,702 barrels, or 250,000 gallons, of whale oil were shipped from St Vincent and its dependencies from 1867 to 1870, inclusive. He explained: 'The oil processed was from whales caught by American vessels operating in St Vincent territorial waters and was probably subject to export tax.' We therefore assume, in the absence of other evidence, that the figures refer to American gallons and standard American barrels of 31.5 gallons, even though some of the oil may have been shipped to Great Britain or British dependencies. Balcomb (1981) and Price (1981 MS) have cited these same figures and derived from them estimates of 250 and 200 whales taken, respectively. Using 25 barrels as mean oil yield per humpback (and assuming that all 6,702 barrels were from humpbacks), the estimated catch would be 268 whales. Because we have not examined the *Bluebooks* ourselves, and none of the above authors has explained adequately the nature of the data and the reason for attributing all the oil to humpbacks caught locally, we are reluctant to follow their lead. However, we have noted that our own independent estimate for the four-year period 1867–1870, using known catches for the 'read sample' and estimated catches for the 'sighted' and 'extrapolation' samples, is 330 whales. One explanation for our higher estimate may be that it includes humpbacks taken outside St Vincent territorial waters, i.e. at Trinidad, Tobago, and Venezuela, near Barbados, and on grounds north of St Lucia. [See note on St Vincent *Bluebooks* added in proof.][1]

Whale oil exports from a given island do not necessarily represent local catches. The products from whales taken far from the Caribbean frequently passed through West Indies ports, thereby confounding attempts to estimate the local humpback kill by use of oil export records alone. Also, there may be confusion of US gallons (at 31.5 gals per barrel) and imperial gallons. Many Yankee sperm whalers anchored at Dominica in late spring to ship oil, refit, and take on provisions before returning to the sperm whaling grounds (Grieve, 1906). The oil transferred from the whaleships to supply vessels in Portsmouth harbor, then carried to the United States, was recorded in the export returns of Dominica. For example, in 1904 there are 63,474 gallons listed; in 1905, 32,708 (Grieve, 1906). This should not be interpreted as representative of landings in the West Indies. Rather, most of it was probably transshipped sperm or whale oil, taken on distant grounds.

Similary, whale oil export figures for Barbados probably would not be a reliable record of whale landings there. Yankee vessels that worked grounds in the South Atlantic frequently offloaded their cargo to steamers or other whalers in Barbados, paying an export tax for this convenience (John Adams, pers. comm., 5 February 1981; our reading of logbooks; eg., advertisement in *WSL* 24(24): 14 VIII 1866). The Yankee pelagic whalers certainly took humpbacks around Barbados (*WSL* XXII (16): 21 VI 1864; 24(18): 3 VII 1866; also entries 51 and 52, Table 8), but there is no evidence that they did so on a major scale.

(ii) *Nineteenth-century shore whaling*

'A whale (Grampus) was taken near Maycock's Bay [Barbados]' in April 1813 (Schomburgk, 1848 (1971), p. 682). Total length of the whale was 22 feet 6 inches (6.86 m); the 'fin' (= flipper) measured 7 feet 4 inches (2.23 m). These dimensions indicate that it was a young humpback, and this is the earliest record we have found of shore-based humpback whaling in the West Indies. The meat was eaten, but the animal was judged 'too young to afford any oil'.

The killing of whales by local inhabitants probably was sporadic and not of great consequence prior to the 1860s, although there was a humpback whaling station in operation on Monos Island, near Trinidad, as early as 1852–3 (log of *Solon*, Entry no. 48b, Table 8). In approximately 1867 A. S. Archer established a permanent whaling station at Barbados (Clark, 1887a, pp. 214–15; Lindeman, 1880, pp. 84–6, transl. in True, 1904, p. 61; Bolau, 1885, p. 362). There is no question about the species involved, for as Archer put it: 'Right whales and sperm whales are never seen in these waters.'

Shore stations for humpback whaling proliferated in the Lesser Antilles during the ensuing decades. In 1875 or 1876 William Wallace founded the first whaling concern at Bequia (Adams, 1970, 1971). Thereafter, 'at least a score of whaling stations were started in the south Windward Islands and Trinidad.' We have found reference to stations at Palm Island, Canouan Island (2), and Frigate Rock, near Union Island (Adams, 1971); Ile de Caille (Fenger, 1913); St George's, Grenada; Pigeon Island, near St Lucia; and Monos Island (Brown, 1945); as well as Barbados (Fig. 21) and Bequia. There was a shore whaling station at Salt Cay in the Turks and Caicos Islands, near Mouchoir Bank, during the nineteenth century, but we know very little about it. 'Whaling operations ended in the 1880s, but enough remains at the site for a marker to be erected explaining that the industry had once flourished there' (Buissert and Clark, 1974). During the second decade of the twentieth century there were six whaling stations in the Grenadines, each with three to five whaleboats, employing upwards of 100 men (Adams, 1971). Fenger's chart shows a total of five stations active between St Vincent and Grenada in *ca.* 1911 or 1912.

Because it is one of the few first-hand contemporary accounts available, Archer's (1881) description of the economics involved in West Indian humpback whaling is worth summarizing. In the early years of the fishery he found a ready market for whale oil at Demerara (i.e. Georgetown, Guyana). It was used locally for lubrication and burning. After a short time this market dried up, as kerosene and lard oil replaced whale oil. Archer then began selling his oil to Trinidad, but this market soon became glutted by 'the great influx of oil from Grenada, St Vincent, etc.'. He hoped that the newly developed market for fertilizer made from the carcasses, together with the oil and meager amount of low-quality baleen obtained from humpbacks, would allow him to continue operating at a profit. Humpback meat was relished by residents of Barbados.

By 1913 the character of product markets had changed somewhat. Barbados humpback oil was selling for £13–£18 per ton, and fresh whale meat was still in demand locally (Sambon, 1923). Much of the flesh, however, was dried and ground, then used as fertilizer or as an additive to cattle feed. An attempt was made to introduce canned whale meat to gourmet shops in Paris and New York. The baleen was said to be used for making 'coarse brooms' (Sambon, 1923).

Fenger (1913), who spent a season (*ca.* 1911–12) at the Ile de Caille station, and Skinner (*in* Sinckler, 1913), who was actively whaling at Barbados in 1913 (Sambon, 1923), described a fishery in the early 1900s that was essentially unchanged from that described by Archer (1881). Sail and hand were the sole means of propulsion, although small steamers were sometimes used for towing. Equipment included hand harpoons and lances as well as bomb lances (darting guns) and shoulder guns. Humpbacks were usually harpooned first, the lance and shoulder gun being reserved for finishing off the whales. Effort was directed preferentially at calves and their mothers, 'bulls' generally being considered dangerous and difficult to

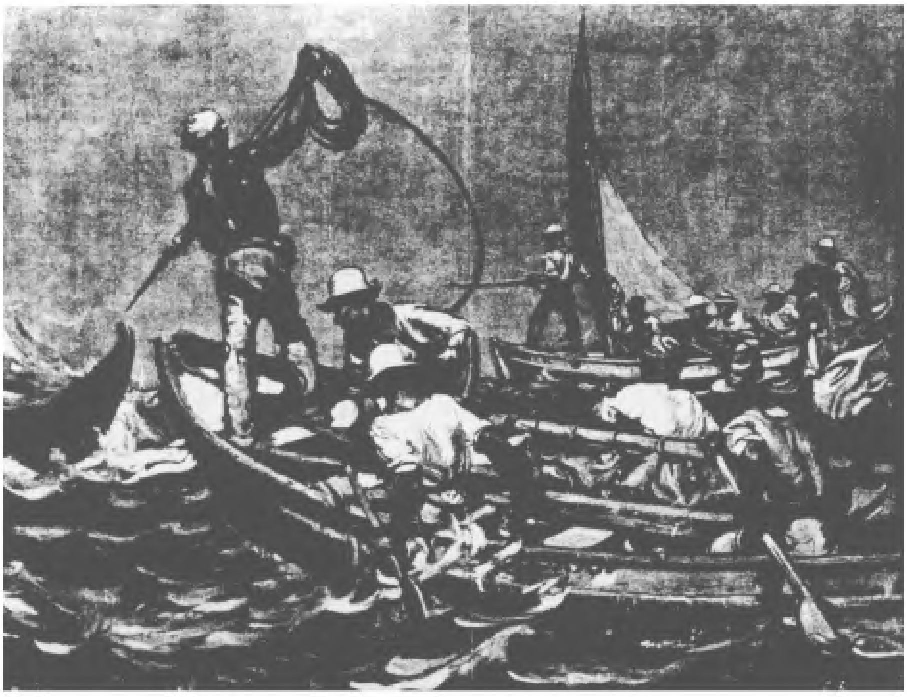

Fig. 21. 'Whale hunt off Barbadoes; harpooning a monster.' Illustration from the *Graphic*, drawn by Frank Brangwyn, 1900. (Reproduced here from a copy in the New Bedford Free Public Library, courtesy of Paul Cyr; mentioned by Tripp, 1920, p. 24.) Whaling around Barbados consisted of an offshore fishery for sperm whales and an inshore fishery for humpbacks, illustrated here.

approach. As Archer put it, 'We always strike the calf first if there is one.' Having tethered the calf, the whalers were better able to approach the cow, which would not abandon the calf as long as the latter was alive. Once the cow was secured, the calf was often cut free.

The loss rate in this fishery was substantial. Fenger stated that 'the humpbacker loses many whales through the parting of his line.' Of the four whales mentioned as having been struck during his stay at Ile de Caille, one (a 'bull') escaped with a harpoon 'deep into the flesh aft of the fin'. In addition, an adult female that was finally landed after a chase covering 30 miles, had been stripped by sharks of much blubber and flesh before reaching shore. Fenger indicated that local people relished the meat and that the low price of oil gave little incentive to extract it efficiently. In fact, the Ile de Caille whalers even 'burned [the oil] in the trying'.

Archer made no mention of the loss rate *per se*, but he did admit to needing 'some sixteen bomb lances' to kill one particularly active adult female. The struggle lasted for an entire day, and the whale had to be brought to shore and processed at Martinique, more than 150 km from Archer's station. The problem of towing killed humpbacks was a major one for the shore whalers, and it resulted in considerable loss. 'A killed whale sinks as soon as the lungs fill with water, and it becomes too heavy for the whalers to support; it has then to be cut adrift' (Brown, 1945). Referring generally to the Grenadine shore fisheries, Adams (1971) claimed: 'On many occasions...the whale had to be cut loose.' Also '...probably at least one-third of the whales killed and taken in tow did not reach shore.'

There is little evidence that whales struck and lost were eventually recovered as floating or stranded carcasses, although this undoubtedly happened occasionally. Some struck humpbacks undoubtedly survived. Price (1979, 1981 MS) mentioned one uncorroborated recovery of a marked harpoon head at Bequia. Nevertheless, we believe the frequent failure to land whales taken in tow, mutilation by sharks during towing, and under-reporting of oil due to inefficiency or domestic consumption, added to those wounded whales that escaped but died of their wounds, warrant use of a Loss Rate Factor of 1.85, the same as applied to the pelagic whalers in the West Indies, for correcting reported or estimated catches.

A. Fishing mortality – Barbados

Archer (1881; *in* Clark, 1887a, p. 215) provided a table of oil production at Barbados from 1869 to 1878. From this, we have estimated the number of humpbacks killed in these years (Table 13). Archer claimed to have been whaling for 14 years and indicated no intention of quitting. We assume that his operation lasted at least through 1881 and probably longer.

The Barbados fishery actually may have expanded after 1881, as there were said to be eight boats (Archer employed only four) in operation 'just before the turn of the century' when the fishery was 'at its height' (Brown, 1942). We used 20, the estimated kill for 1878, as an estimate of the annual kill between 1879 and 1902 (Table 1), considered by Brown as the last successful season at Barbados. Our estimate of 20 whales per year is not inconsistent with Brown's statement that 15 to 20 humpbacks plus an occasional sperm whale (*contra* Archer's claim that this species never occurs at Barbados) were killed annually through 1902.

Although Brown's (1942) informant, an old whaler, recalled that the Barbados fishery collapsed at the turn of the century due to stock depletion, A. Skinner, an active whaler, stated in 1913 that whales were still plentiful near Barbados (Sinckler, 1913). His two boats, manned by 14 men, landed four humpbacks and killed but lost two others in the 1912 season. Skinner was visited in 1913 and apparently informed Sambon (1923) that 'as

Table 13

Catch and estimated kill of humpback whales at Barbados, 1869–1878, by A. S. Archer and company (from Archer, 1881). Archer provided the data in tuns of whale oil landed, by year. A tun is equivalent to 252 'wine' or American gallons. We converted Archer's figures to barrels by using the stated 252 gallons per tun, and 31.5 gallons per barrel. Using 30 barrels per whale as average yield, the humpback catch was estimated for each year.

Year	Tuns whale oil	Estimated barrels whale oil	Estimated whales landed	Estimated whales killed, using correction factor of 1.85 to account for dead and moribund fishing loss; see text
1869	10	80	2.67	4.9
1870	5	40	1.33	2.5
1871	80	640	21.33	39.5
1872	50	400	13.33	24.7
1873	47	376	12.53	23.2
1874	65	520	17.33	32.0
1875	60	480	16.00	29.6
1876	55	440	14.67	27.1
1877	60	480	16.00	29.6
1878	40	320	10.67	19.7
Total	472	3776	125.86	232.8

many as fourteen whales have been killed in a season, giving a yield of 870 barrels of oil.' Two or three boats were active in 1913.

Based on Skinner's reported kill of six humpbacks in 1912 (Sinckler, 1913), an unexceptional year as far as we know, we estimate six killed per year from 1903 to 1913, the last year we can be sure the Barbados fishery was active.

B. Fishing mortality – Grenadines

In the absence of catch records for Grenadine whaling stations during the nineteenth and early twentieth centuries, it is necessary to make estimates based on available figures of oil production and export and on general statements in the literature. Adams (1971) claimed: 'A whaling concern, consisting of four or five boats, was fortunate to dispatch more than six or seven whales in a season.' Later, he observed (Adams, 1975): 'In 1900, a Grenadinian whaling concern had no difficulty in dispatching four or more whales per season, but 20 years later it was hard-pressed to capture even one.' Adams (1970, 1971) concluded from reading the St Vincent *Bluebooks* that 25,000 (Imperial?) gallons of whale oil per year (almost all of it from humpbacks) were exported from the Grenadines between 1893 and 1903. A conservative interpretation of such a yield would be that it represented about 17 secured humpbacks per year (at 1,500 gallons per whale). Elsewhere, Adams (1975) estimated that close to 500,000 (Imperial?) gallons of whale oil were exported from the Grenadines between 1890 and 1925, most of it going to England, Trinidad, and Barbados. Another source (Bulkeley, 1889) indicated that only 'some five thousand gallons' were exported annually from the Grenadines, apparently during the 1880s. This would imply a catch of only about three or four whales, which seems unrealistically low in light of Adams's statements.

Considering Adams's (1971) reference to at least 20 Grenadine whaling stations being in operation for some part of the period 1875–1920 and the fact that there were six still active after 1910, we think it probable that at least six were active at any given time between 1880 and 1913. If each station secured four humpbacks per season, an estimate of total annual kill, including a loss rate factor of 1.85, would be 44 whales. We assume only one station was active from 1876 to 1879, with an estimated total kill of seven whales per year. Assuming a reduced effort after 1913, we estimate that only three stations were active between 1913 and 1920 and that each killed an average of three whales per year, or a total of nine per year for the Grenadines as a whole.

We assume that St Vincent returns do not include oil from Barbados, Trinidad, Tobago, or St Lucia northward, but that they do include oil from stations at Palm, Canouan, and Union Islands, Ile de Caille, and Grenada as well as Bequia. Too little information is available on catches or oil landings outside Barbados and the Grenadines to make meaningful estimates of the kill there. Our failure to account for non-Barbados, non-Grenadine catches in the West Indies should make our estimates of total fishing mortality in the West Indies conservative.[5]

(iii) *Modern Norwegian whaling at Grenada*

A brief episode of modern whaling occurred at Grenada in 1925–1926 (Tønnessen, 1969, vol. 3, pp. 232–3). C. Horne, a local entrepreneur, had constructed a whaling station at Glover Island, off the southwest corner of Grenada, in the early 1920s (Anon., 1928). Catches were small, amounting to 160 gals of oil in 1921; 2,110 in 1923; and 800 in 1924 (Anon., 1926–7). We have converted these production statistics to estimates of 1 humpback killed in 1921, 5 in 1923, and 1 in 1924 (Table 1; and see Table 14, note *a*). Frustrated by the large number of whales seen and the inadequacy of his whaling equipment, Horne petitioned representatives of the Norwegian whaling industry for assistance. Captain Otto Sverdrup visited the island and became satisfied that there were enough whales in nearby waters to support a modern whaling station (Ferguson, 1925; Jacobsen, 1981). Two catcher boats arrived in December 1924, and the Whaling Co. (Grenada) Ltd. began operations in January 1924 (Marsland, 1925). The factory produced both whale oil and 'guano' fertilizer; some of the meat was sold for human consumption.

The season lasted from January to April, coincident with the appearance of wintering humpbacks. The catch consisted almost entirely of humpbacks, although two

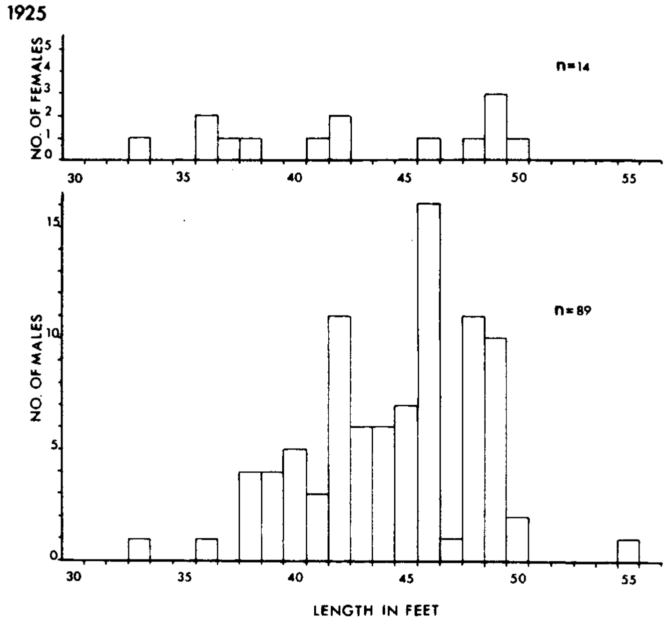

Fig. 22. Length frequency data for the catch of 103 humpback whales landed at Glover Island, Grenada, during 15 January to 4 April 1925 by the whale catchers *Veslemarit* and *Veslefrik*. (Data from British Museum (Natural History) 'Report on Whales...' forms in S. F. Harmer files, B.M. (N.H.), Dept. of Zoology archives.)

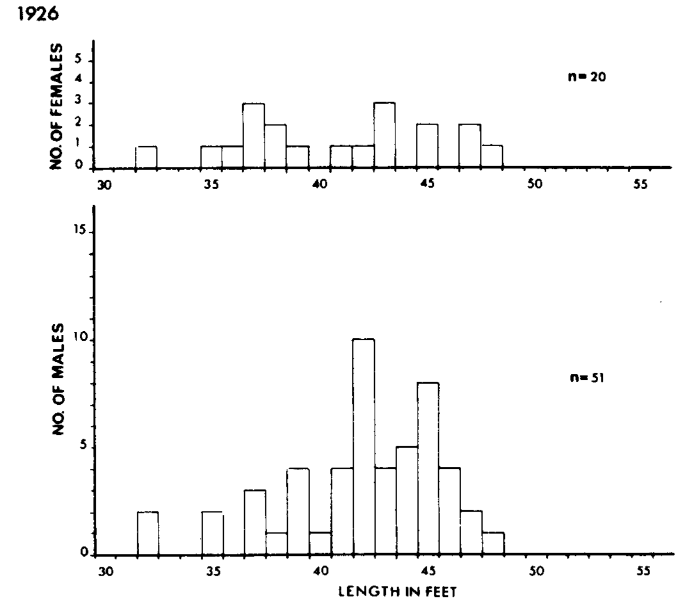

Fig. 23. Length frequency data for a catch of 71 humpback whales landed at Glover Island, Grenada, during 10 January to 30 April 1926 by the whale catchers *Veslemarit*, *Veslefrik*, and *Veslegut*. (Data from British Museum (Natural History) 'Report on Whales...' forms in S. F. Harmer files, B.M. (N.H.), Dept. of Zoology archives.)

Bryde's whales (*Balaenoptera edeni*) were taken in 1924 and one in 1926 (Ferguson, 1929). Published catch statistics are confusing (Ferguson, 1926, 1927, 1929; *IWS*), but the total of humpbacks caught in the two years of operation was 174. In 1925, 105 whales yielded 2,780 barrels of oil; 70 whales yielded 2,500 barrels in 1926 (Tønnessen, 1969, vol. 3, p. 233). The reduced catch in the second season occurred despite the addition of a third catcher boat. By all accounts the fishery was abandoned due to a scarcity of whales.

The humpback catch in this fishery consisted primarily of males (80 per cent), and none of the 34 females taken was reported to be pregnant or accompanied by a calf. We take this to mean either: (1) females accompanied by calves were not hunted by the Norwegians, (2) preferential catching of adult females by West Indies shore whalers had by this time skewed the local population to be mainly males, (3) humpbacks segregate by sex and/or reproductive condition while in Grenadine waters, or (4) no observer was present to examine killed whales. Length frequencies declined from the first year to the second, from a mean of 44.38 feet to 41.91 feet for males and from 42.46 feet to 40.48 feet for females (Figs 22 and 23).

(iv) *Bequia whaling since 1920*

Bequia is the only Caribbean island known to have maintained a humpback whaling tradition since the early 1920s (Adams, 1971; Figs 24 and 25). However, even at Bequia the enthusiasm for whaling flagged for several decades because whales had become extremely scarce. Only three or four boats were kept in readiness during the 1920s, 1930s, and 1940s. 'Few' humpbacks were caught during this period, and none at all was taken between 1949 and 1957 (Table 14).

Available statistics on the Grenadine humpback fishery from 1922 to the beginning of World War II are given in gallons, which we assume to be imperial gallons (Table 14). Brown (1945) stated that the Bequia whalers got 'anything from 400 gallons (small), 800 (medium) to 1,500 gallons from a very large whale.' Adams (1971) gave the same range in yield (400–1,500 gallons), adding the 'average' is 'slightly over 1,000 gallons.' We have accordingly used 1,000 gallons as average yield in estimating whales caught (Table 14).

A catch of three humpbacks in 1958 gave renewed impetus to the fishery (Adams, 1971). Two boats were added to the whaling fleet, making a total of six, and a pact among boatowners assured coordinated effort and equal sharing of the catch. In 1961 a new processing plant was built at Petit Nevis. Aside from the adoption of the darting gun for making the first strike, hunting methods have remained essentially unchanged. 'Nineteenth-century style boats, gear, and methods of hunting are still employed' (Adams, 1975; also see Balcomb, 1981). Balcomb's description of the fishery indicated that by 1981 only two boats were involved. He predicted that 'Bequia whaling will probably end with Athneal [Olliviere]'. (Olliviere is the grandson of one of the men who founded whaling at Bequia in the 1880s).

Price (1979, table 1; 1981 MS, table 1) listed catches at Bequia since 1958, based on conversations with Louis Olliviere, a 70-plus year old whaler. Unfortunately, there are inconsistencies between Price's data and the sparse information found in published sources (Table 14). For example, Coffin (1970) apparently was in Bequia during 1970, for which year she reported a catch of 5 humpbacks, compared to one landed and one struck-but-lost according to Price. Winn *et al.* (1975), investigators with extensive first-hand experience in the West Indies, claimed that the catch at Bequia was 'from zero to six whales per season'; the highest one-year catch of humpbacks reported by Price is four. We cannot account for the discrepancies. As far as we know, Price's records came from Olliviere's personal recollection and not from a written source.

Although we consider Price's data at least slightly suspect, his breakdown of species composition and loss

Table 14

Reported landed catch and estimated kill of humpback whales at Bequia, 1922–78.
Number of whales in parentheses are as reported in reference in parentheses.

Year	Number of whales[a]	Production of whale oil[b] (imperial? gallons)	Sources
1922	9	5,454	R. V. Walker, in litt.[c]
1923	3	1,195 (1,271)	Walter, 1928[(d)]
1924	11	6,672	Walter, 1928
1925	1	280	Walter, 1928
1926	3	1,964	Walter, 1928
1927	1	132	Walter, 1928
1928	5	2,755	Peebles, 1931
1929	3	1,076	Peebles, 1931
1930	1	399	Peebles, 1931
1931	3	1,591	Peebles, 1932
1932	3	1,385	Anonymous, 1933
1933	1	797	Anonymous, 1934
1934	1	912	Anonymous, 1935
1935	3	1,675	R. V. Walker, in litt.[e]
1936	1	278	R. V. Walker, in litt.[e]
1937	1	694	R. V. Walker, in litt.[e]
1938	1	177	R. V. Walker, in litt.[e]
1939	3	1,198 (0)	Brown, 1945; (R. V. Walker, in litt.)[f]
1940	—	(1,198)	(R. V. Walker, in litt.)[f]
1941	1	584 (0)	R. V. Walker, in litt.[f]; (Brown, 1945)
1942	0	0	Brown, 1945
1943	0	0	Brown, 1945
1944	0	0	Brown, 1945
1945	0	0	Brown, 1945
1946	0	0	R. V. Walker, in litt.[g]
1947	1 calf	—	Brown, 1947
1948	3	1,200	R. V. Walker, in litt.[d]
1949	0	0	Adams, 1970, 1971, 1975
1950	0	0	Adams, 1970, 1971, 1975
1951	0	0	Adams, 1970, 1971, 1975
1952	0	0	Adams, 1970, 1971, 1975
1953	0	0	Adams, 1970, 1971, 1975
1954	0	0	Adams, 1970, 1971, 1975
1955	0	0	Adams, 1970, 1971, 1975
1956	0	0	Adams, 1970, 1971, 1975
1957	0	0	Adams, 1970, 1971, 1975
1958	5 (3?)	—	Adams, 1970, 1971, 1975; (Price, 1979)
1959	5	—	Price, 1979
1960	1	—	Price, 1979
1961	0	—	Price, 1979
1962	0	—	Price, 1979
1963	3	—	Price, 1979
1964	1	—	Price, 1979
1965	1	—	Price, 1979
1966	0 (3?)	—	Adams, 1971; (Price, 1979)
1967	3	—	Price, 1979
1968	3	—	Price, 1979
1969	3	—	Price, 1979
1970	8 (1?)	—	Coffin, 1970; (Price, 1979)
1971	3	—	Price, 1979
1972	6	—	Price, 1979
1973	1	—	Price, 1979
1974	5 (3?)	—	Price, 1979; (*IWS*)
1975	3 (0)	—	Price, 1979; (*IWS*)
1976	1 (3)	—	Price, 1979; (*IWS*)
1977	0	—	Price, 1979; *IWS*
1978	1	—	Price, 1979; *IWS*

[a] Crude estimates for 1922–41 based on oil production, assuming average yield of 1,000 gallons and rounding all estimates to the next highest integer. Considering statements by Brown (1945), Adams (1971), and Price (1981 MS) (see text) and the fact that orphaned calves are not taken into account in Price's estimate of a 27.8 per cent loss rate, we estimate one of every three whales struck was killed, mortally wounded, or orphaned but not recovered. Thus, a loss rate factor of 1.5 has been used to correct all landings or estimated landings.

[b] These figures may under-represent the kill, as they probably do not include the oil consumed domestically, the oil from small calves, and the oil lost to sharks.

[c] Source: Administration Report, Public Records Office, Kew, U.K.

[d] Source: Agriculture Annual Report, St Vincent, Public Library or Ministry of Agriculture.

[e] Source: Colonial Report, University of Texas.

[f] Source: Blue Book, Public Records Office, Kew, U.K.

[g] Source: Blue Book, St Vincent.

Fig. 24. Two scenes of humpback whaling at Bequia. (A) Crews of two whaleboats unload rock ballast before beaching the vessels in Friendship Bay, March 1966. Men at the stern steady the boats with a steering oar. For details concerning whaling methods at Bequia, see Adams (1970, 1971). (B) A small humpback, said by the photographer to be a 30-ft female, being butchered by the Bequia whalemen. (Photographs by J. E. Adams)

rate may be instructive. Of 39 whales reportedly landed between 1958 and 1980 (Price, 1981 MS), four (10%) were sperm whales (at least one of them a stranded calf). Respecting humpbacks, 18 adult females and 19 calves were struck, but 28% of the adult females and 5% of the calves were lost. One of five (20%) struck yearlings was lost. Adams (1971) stated: '...the majority of the crew members are inexperienced at whaling, resulting in a high loss of whales through poor judgment and the lack of skill.' This was evident in the 1945 season when eight to ten whales were sighted, three were struck, and none was landed (Brown, 1945). One large female was 'all but brought ashore and then lost.' Judging by these accounts, the vast majority of humpbacks landed in recent years at Bequia have been adult females and calves or 'yearlings'. If we combine Price's humpback 'yearlings', females, and calves (omitting the 4 sperm whales reportedly taken), then 7 of 42 (17 per cent) struck humpbacks were lost. Price's (1981 MS) own assessment of the current Bequia fishery is: 'Usually only one female and calf are harpooned each year with a loss rate of 27.8%.'

Meat is said to have been the most important product from humpback whaling at Bequia in recent years (Adams, 1975; Price, 1979). It was selling locally for US $1.50–2.00 per pound in 1980 (Delves, 1981). Much of the meat is consumed fresh by local residents; the rest is 'corned' for export to St Vincent. Adams (1971) believed the meat from three or four humpbacks per

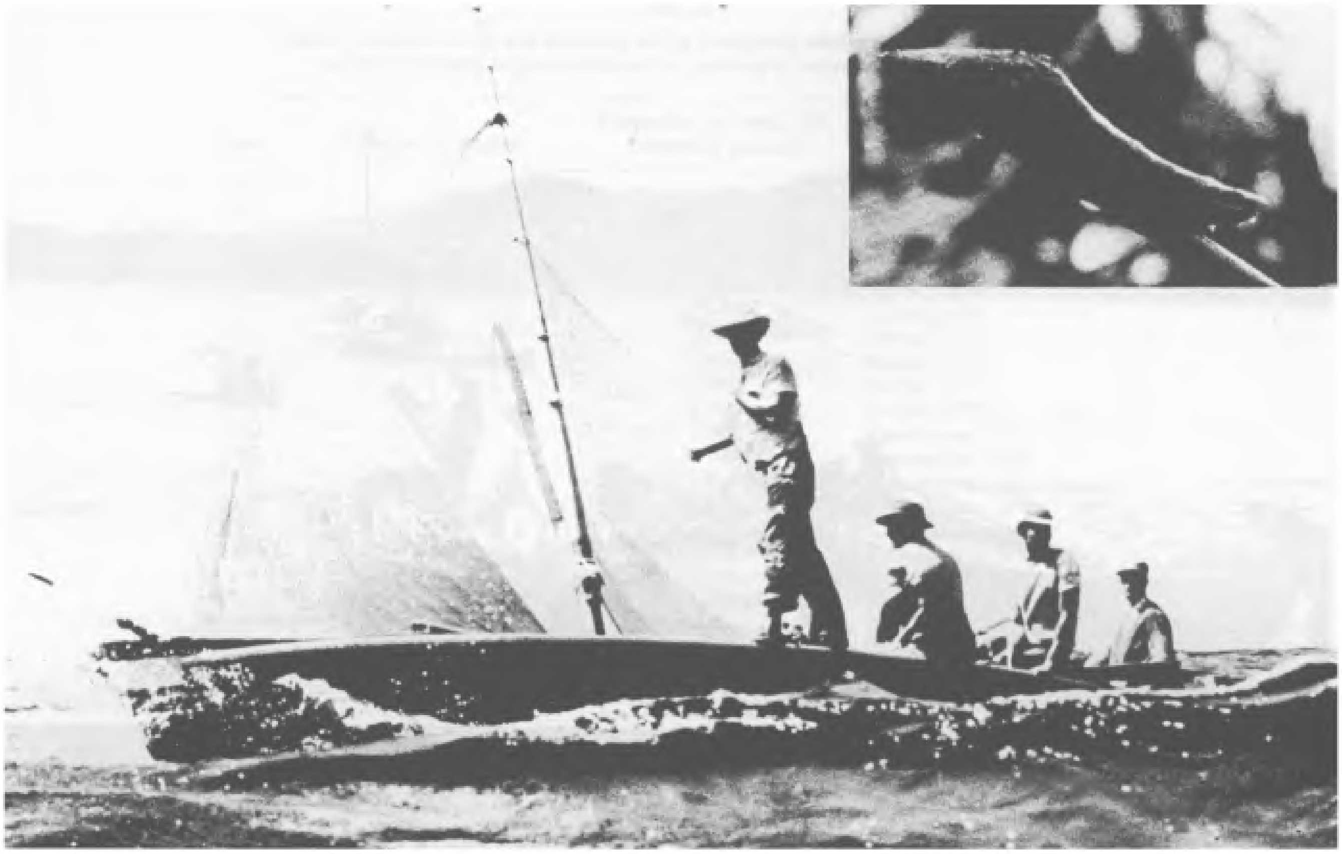

Fig. 25. Humpback whaling in Friendship Bay, Bequia, in January 1970, showing vessel in pursuit within 100 m of a whale (P. Beamish, *in litt.*, 20 January 1892). Standard practice at this time was to sail across the bay, searching. When a whale was 'raised', the lead vessel approached by sail but readily converted to oar power as necessary. The sheets in the foreground are part of the mainsail of a second, identical vessel. [Inset: shows a harpoon head, photographed after the boats were hauled up on the beach.] (Photographs by P. Beamish)

season could be 'absorbed' by the Kingstown (St Vincent) market. Although much of the oil from adult humpbacks is saved, the market for it has been limited in recent years. Some is used locally for cooking and as a medicament (see Delves, 1981); most of the surplus is exported to Trinidad for use in cooking (Caldwell and Caldwell, 1975) or in the manufacture of soap and candles. A recent development is the sale of humpback bones to tourists (Price, 1979). Also, a small amount of whale bone is used by local craftsmen to make belt buckles, which are in turn sold to tourists.

(v) *Recent humpback whaling outside Bequia*

There are several other small whaling concerns in the West Indies, in addition to the one at Bequia, that have continued to operate until the present time. All sources indicate that the humpback is not regularly involved in any of these other fisheries (Morice, 1958; Anon., 1961, 1967; Rathjen and Sullivan, 1970; Caldwell and Caldwell, 1975; Gaskin and Smith, 1977; J. Adams, in litt., 20 October 1981).

In December 1970 a large (48 foot) humpback was killed by Cuban fishermen (Cubillas, 1971). The kill apparently was made opportunistically, the whale having been shot with about 200 *proyectiles* (bullets?) before finally stranding. At least part of the carcass was flensed and used. This capture was considered unusual.

CUMULATIVE CATCH ESTIMATE

It is important to stress that, as in the case of the eastern Pacific population of gray whales which had been hunted by aborigines for decades before it began to be exploited by commercial whalers (Mitchell, 1979b), the western North Atlantic humpback population already had a long history of exploitation by West Greenlanders, coastal whalers in Bermuda and New England, and early pelagic sailing vessel whalers in the Gulf of St Lawrence and the Caribbean Sea, by 1865. Therefore, our estimate of population size in 1865 (see below) is probably not only conservative but substantially below the 'virgin' population size (cf. Anon., 1982, regarding 'true "initial" level' of the western Arctic bowhead stock).

Rather than experiencing a single, short, well documented period of intensive exploitation, the humpback population in the western North Atlantic has been subjected to several centuries of hunting marked by at least three well documented peaks. The first of these began about 1850 and continued through the 1880s. During these four decades, humpbacks were hunted by West Greenlanders in Davis Strait; by Yankee and other whalers experimenting with innovative capture methods around Iceland, in the Gulf of St Lawrence, and in the Caribbean; by Gaspé whalers in the Gulf of St Lawrence and Strait of Belle Isle; by New Englanders along their own coast; by residents of Bermuda, locally; by Yankee sperm whalers principally in the West Indies; and from shore stations in the West Indies manned by local residents. Although documentation is adequate for all these fisheries to demonstrate that they were active during this period, we have few actual catch statistics.

Using kill estimates summarized in Table 1 we identified five decades during which large catches were made and for which there is adequate documentation.

During Decade I (1866–1875) and Decade II (1876–1885) the largest catches were made in the West Indies by Yankee pelagic whalers and various shore stations. Also, the Gaspé fishery in the Gulf of St Lawrence was active during this time.

By the beginning of the twentieth century, the Yankee pelagic fishery was no longer a factor, the Gaspé sail fishery was defunct, and the New England and Bermuda shore fisheries were inconsequential. Humpbacking continued in West Greenland, and we have some statistics for the fishery there after 1885 (Kapel, 1979). Shore whaling in the West Indies persisted at several stations through the first two decades of the century. Although the Barbados fishery had declined by 1902 (Brown, 1942), a few humpbacks were still being caught there through at least 1913 (Sinckler, 1913). Grenadine shore stations remained active between 1890 and 1925 (Adams, 1971).

The most important development at the turn of the century was the introduction of modern whaling in Newfoundland and Labrador and in Iceland. The resulting high catches are well documented. Sergeant (1966) summed the Newfoundland–Labrador catches over 13 years (1903–1915) and concluded that they gave 'a cumulative total very close to that for blue whales, namely about 1500 whales.' (However, the actual total from Sergeant's Table 8 is 1,080.) Allen (1970) performed a similar exercise with the same data but gave a cumulative catch of 938 for the period 1903–1915. Sergeant's figure has been cited as the only estimate of initial population size for the western North Atlantic humpback population (Mitchell, 1973a, 1974; Winn *et al.*, 1975; Balcomb and Nichols, 1978).

We defined the period 1893–1902 as decade III; 1903–1912 as decade IV.

A third peak of exploitation occurred during the 1920s. Norwegian floating factories were active in Davis Strait, Danish catcher boats were catching whales in Davis Strait on behalf of West Greenlanders, the Newfoundland–Labrador shore stations were taking substantial numbers of humpbacks, a modern shore station was operating at Grenada, and the Bequia shore fishery was still alive. The period 1922–1931 is our decade V.

Our estimates of total fishing mortality in the five decades are as follows (see Table 1):

decade I (1866–1875)	– 1,740	(1,754 including Iceland)
decade II (1876–1885)	– 1,549	
decade III (1893–1902)	– 923	(1,802 including Iceland)
decade IV (1903–1912)	– 1,686	(1,701 including Iceland)
decade V (1922–1931)	– 873	

Although hunting was relatively light from 1913 to 1921, it was sufficient to offset some of the net recruitment that occurred during these nine years, and enough whales obviously survived after 1931 to sustain continued exploitation, including the kill of 873 in decade V, and to generate the present population of more than 1,500 (see below). We conclude that at least 1,000 humpbacks were still alive in the western North Atlantic in 1913 (following decade IV). Adding 1,000 to our estimate of cumulative catch for decade IV (1,686 without Iceland; 1,701 with Iceland), we estimate there were at least 2,686 whales in the population in 1902 (2,701 including Iceland).

To account for two peak decades in a fishery, it is possible to add the cumulative kills together for a crude estimate of initial population size, as long as the assumed net recruitment during the interval between the two peaks has been subtracted from the second peak's total (Mitchell, 1977 MS; Breiwick *et al.*, 1981). We have back calculated from a population of 2,686 in 1902, assuming a net recruitment rate of 0.046 (from Chittleborough, 1965) and accounting for estimated fishing mortality (Table 1). This procedure results in an estimate of 2,661 whales (or 2,945 including Iceland) in 1876. Adding this figure to our estimate of 1,740 killed during decade I gives an estimate of 4,401 whales in the population in 1865. If the Iceland whales are considered part of the western North Atlantic stock, then the estimate is about 4,685.

Because we have made conservative assumptions for all our kill estimates, 4,400 (or 4,700) should be regarded as a minimum estimate of population size in 1865.

PRESENT POPULATION SIZE

Published estimates

Mitchell (1973a) estimated 1,259, based on strip census analysis of shipboard sightings made in summer months between 1966 and 1969. He considered this figure to be 'undoubtedly high'. Although Mitchell's cruises widely sampled the western and central North Atlantic, humpbacks were seen only in five areas – Nova Scotia, Labrador, West Greenland, East Greenland, and the Gulf Stream. This is the only estimate of the entire stock based on summer surveys.

Winn *et al.* (1975) estimated the total population as 785 to 1,157 '(average 1,018)', based on a combination of visual and acoustic shipboard censuses made in the West Indies in January–February 1972 and February 1973. They regarded this estimate as 'conservative'.

Balcomb and Nichols (1978) gave a 'rough estimate' of 1,000 to 1,500, based on strip census estimates of 809 whales on Silver Bank and 96 on Navidad Bank in early March 1977.

Gaskin and Smith (1979) referred to an estimate by Price of the total population – 417 animals, 'following extensive survey'. However, Price's (1979) final report gave an estimate of 611 whales 'in the area of the Turks Islands and offshore banks', based on shipboard and aerial surveys.

Scott and Winn (1980) estimated the abundance of humpbacks on Silver and Navidad Banks in early March 1978, using shipboard and aerial visual and aerial photographic techniques. Their best estimate for the two areas combined was 1,375–1,747. Using Winn *et al.*'s (1975) assumption that these two banks contain 85 per cent of the humpback population wintering in the West Indies, they suggested a total of more than 2,055 individuals. The apparent increase since 1972–73 was attributed to '(1) an average annual increase of 8.5% over the 5 year period that separated the surveys, (2) sampling during different phases of the seasonal abundance cycle on the Banks, or (3) a combination of the above effects.'

Work in progress

A document was tabled at the 1978 meeting of the IWC Sub-Committee on Protected Stocks in which an estimate of 2,300 was made (Anonymous, 1979, p. 85). This paper was not accepted for publication, as certain sub-committee members felt that 'some of the assumptions are not well founded and the resulting estimate is high.' A document tabled at the 1979 IWC meeting estimated 3,000 humpbacks for Silver, Navidad, and Mouchoir Banks in winter 1977–78 (Anonymous, 1980d, p. 106). It was not accepted for publication.

Results of more recent field studies were presented at a workshop on humpback whales of the western North Atlantic held at the New England Aquarium, Boston, Massachusetts, 17–21 November 1980 (Prescott *et al.*, 1981 MS). Balcomb (1981 MS) and Balcomb and Nichols (1981 MS) conducted 70 shipboard strip censuses on Silver and Navidad Banks in January, February, and March 1980. For these banks alone they calculated by extrapolation a population of 2,600 (Balcomb, 1981 MS) or 1,923 (Balcomb and Nichols, 1981 MS). Whitehead (1981 MS) presented an analysis of different data collected on the same platform, the R.V. *Regina Maris*, as was used by Balcomb and Nichols. His estimate of 2,000–3,500 for Silver and Navidad Banks and 2,300–4,500 for the western North Atlantic population are higher than any other estimates made to date. Workshop participants evaluated these new estimates in a conservative manner, concluding that 'the West Indies population...is probably closer to 2,000 than 1,000,' with a 'possibility that it is considerably higher.'

Conclusion

A useful lower boundary for current population estimates is suggested by the 1,010 humpbacks considered to be different individuals on the basis of fluke photographs (Katona *et al.*, 1980). It is unlikely that all the humpbacks in the western North Atlantic have had their flukes adequately photographed for cataloguing, so we can assume that the total population is more than 1,000. However, not all whales photographed are necessarily still alive, and natural mortality must be taken into account in using these fluke catalogue data for estimates of minimum population.

If a forward calculation is made from Mitchell's estimate of 1,259 made in 1969, using an annual net recruitment rate of 0.046 (Chittleborough, 1965) and accounting for documented fishing mortality, it results in an estimate of 1,827 for 1980. Until more information becomes available, we consider the total humpback population in the western North Atlantic to be of the order of 1,500 to 2,000 animals. We arbitrarily choose 1,800 for purposes of our comparison, below.

PRESENT STATUS

If present population size is approximately 1,800 and there were 4,400 whales in the population in 1865, then the stock is at approximately 41 per cent of '1865 initial' (or 38 per cent if Iceland is included). If our estimate of present population proves too conservative, it should be stressed that our estimate of initial stock size is probably conservative as well. In any case, we think the population has recovered to approximately half its initial or 'virgin' size.

RECOMMENDATIONS

The following research recommendations are presented *in order of priority:*

1. A coordinated effort, already under way, to improve our understanding of stock identity should be continued and expanded (see Katona and Whitehead, 1981).

(a) The whaling industry in Iceland and elsewhere should be encouraged to tag humpbacks with Discovery tags whenever possible, participate in the development of visual tags that could be applied to humpbacks on the whaling grounds, and facilitate more radiotagging work involving humpbacks. The photographing of humpback flukes in Icelandic waters should be encouraged. Because of the concentrated activity of investigators in the West Indies, the chances of a whale bearing a visual tag or radio transmitter being resighted are good. Discovery tags applied in Iceland could be recovered by the fishery at Bequia or West Greenland or by researchers examining carcasses of whales killed incidentally in fishing gear around Newfoundland or stranded on east coast beaches. The broadly based effort at photographing flukes also should mean that even a small number of photographs from Iceland will be useful.

(b) Fluke photographs are needed in all areas, but particularly Iceland, Davis Strait (West Greenland), Gulf of St Lawrence, Windward Islands, and the northeast coast of South America. Any opportunity to get fluke photographs in the eastern North Atlantic, including the Barents and Norwegian seas, should be used, and the photographs should be compared to those in existing catalogues and added to any future compilations covering western North Atlantic animals.

(c) Any carcass of a humpback, whether it has been killed in a direct or incidental fishery or simply washed onto the beach, should be examined for the presence of a tag; and an attempt should be made to photograph the underside of its flukes.

(d) Further consideration should be given to the possibility that extended schools of humpbacks comprise population units that are in fact biological or fishable stocks. A first step might be to have the existing large series of fluke photographs examined by a geneticist.

(e) The possibility of using vocal dialects to discriminate between putative stocks should continue to be explored. To this end, additional recordings should be made at the Cape Verdes.

2. All humpbacks landed in shore fisheries at West Greenland and Bequia, entangled in fishing gear off eastern North America and Newfoundland, and stranded on east coast beaches should be examined and sampled thoroughly. Basic statistics on the number of whales killed or wounded should be collected for the three 'fisheries'. A protocol involving standard measurements, determination of sex, collection of age- and reproduction-related biological specimens, and examination and sampling of stomach contents should be followed routinely. A critical aspect of every contact with a dead humpback should be to insure that an attempt is made to photograph the undersides of the flukes. Copies of such photographs should be made available to all interested investigators.

3. During field studies, more attention should be given to the determination of size (age) composition of humpback aggregations. Most field surveys to date have resulted mainly in estimates of population size. Net production, as evidenced by the ratios of calves, juveniles, and adults observed, can tell as much about the recovery rate of the population as can apparent absolute population size.

4. Most recent humpback censuses in the western North Atlantic have involved intensive surveys of relatively small areas. Such surveys fail to sample

adequately either the entire known summer or winter range of the putative stock. Although resource limitations frequently make range-wide surveys impractical, it is important that at least the entire range of the component of the stock under study (as defined by the researcher) be sampled thoroughly. We are particularly concerned about surveys of what might be called the 'Newfoundland–Labrador summer population' or the 'West Indies winter population', when the precise limits of the 'population's' range have not been defined and taken into account fully in the sampling design.

5. The value of logbook research for answering certain questions of immediate biological and management importance for humpbacks has been demonstrated in this study. We believe further work of this kind on humpbacks in the North Atlantic would be useful, as would similar studies on other species and other areas. Such research can provide not only estimates of catch levels and loss rates but also information on historic distribution and abundance. We believe the zoogeographic pattern of mysticete distribution in the North Atlantic may include (or have included) mid-Atlantic stocks of some species, among them the humpback, centered on the Mid-Atlantic Ridge. It is unlikely that the intensive search of this area by nineteenth century whalers will be replicated today, but properly designed logbook research can test hypotheses using the sighting and kill records of these early, well trained observers.

Historical sources other than whaling logbooks should be consulted more closely for information on North Atlantic humpbacks. The *Bluebooks* and other export or tax records in the West Indies and Bermuda probably can add appreciably to our reconstruction of catches. Caribbean scholars need to be made aware of the potential contribution represented by these sources. It is also possible that the Danish records of the whaling stations or 'factories' at West Greenland during the nineteenth century, mentioned by Eschricht and Reinhardt (1866; and see Mitchell and Reeves, 1981), would add to what is known about Davis Strait catches.

6. Regional and quantitative studies of changes in fishery technology and intensity around Newfoundland over the last two decades are needed if the causes of the recent high rate of collision between mysticetes and fishing equipment are to be understood. It is, in our view, facile to assume that the higher incidence of reported collisions is due only to dramatic biological population growth or to a change in the feeding behavior and local distribution of the whales. As a feeding generalist, the humpback in particular is probably capable of exploiting various alternative food sources to offset whatever nutritional stress may have been caused by overfishing of Grand Banks capelin.

7. The Newfoundland incidental, accidental net-entanglement mortality should be recognized as a major source of removals from the population, and steps should be taken not only to monitor and sample the catch as proposed in (2) above but to reduce the frequency and seriousness of collisions by humpbacks and other mysticetes. Future experiments to develop devices for deterring whales from colliding with fishing gear should include adequate controls and rigorous statistical data collection procedures.

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Notes added in proof

[1] We arranged for the St Vincent *Bluebooks* to be examined on our behalf at the Public Record Office, Kew, Surrey, U.K.

Elizabeth Cooke (in litt., 25 November 1981) undertook this work, and our Table 15 is based on data provided in her report to us.

The year 1864 appears to be the first in which St Vincent assessed a tonnage duty on vessels 'Whale Fishing off the Coasts of this Government'. In that year it was stated in the *Bluebook* that, although no domestic whale fishery had yet been established, 'The American Whaling Vessels visit the Grenadines where they fish and obtain huge quantities of whale oil.' This same section of the *Bluebook* ('Return of the Manufactures, Mines and Fisheries') for 1868 indicates that the American whalers 'take a large quantity of oil from the Hunchback Whale, and Blackfish'. Thus, 'whale oil' totals given in the *Bluebooks* probably include the produce of both humpbacks and pilot whales. The data are further confounded by the fact that returns are given in 'casks', 'packages' or 'barrels'.

It appears that by the mid 1870s the pelagic whalers were spending less time humpbacking in the Grenadines. In 1876 the *Bluebook* stated: 'American Whalers used to fish in the waters of this Government but none have been here in the last year or two'. The following year: '...in the last year or two there were not as many of these vessels as formerly'. The last year in which whale oil was exported to the United States was 1878 (Table 15).

In the section 'Return of the Manufactures, Mines and Fisheries' for 1876, reference is made to 'three or four Whaling Boats now owned in the Smaller Islands of the Government which, in the season, go out whale fishing in the channels between the Islets'. It is probably fair to assume that after 1878, all the reported production of oil, meat, and other whale products came from the domestic fishery. Adams's (1970, 1971) statement that 25,000 gallons of whale oil were exported annually between 1893 and 1903 is thus a fair approximation. Our calculated average for these 11 years is 23,816 gallons, assuming 1 barrel = 31·5 (American) gallons. Bulkeley's (1889) estimate of only 5,000 gallons being exported from the Grenadines, apparently during the 1880s, is apparently much too low. Regarding the statement by Adams (1975) that close to a half-million gallons were exported between 1890 and 1925, we calculate slightly more than 400,000 gallons (assuming 1 barrel = 31·5 gallons) for 1890–1920.

We checked our estimates of the Grenadines kill (Table 1) in the years 1876–79 (7 per year), 1880–1913 (44 per year), and 1914–20 (9 per year) against the production statistics in Table 15. Assuming an average yield of 25 barrels or 1,000 gallons, according to the units used in the lists, using only non-U.S. exports for 1876–78, and applying a loss rate factor of 1·85, we calculate a kill of 19 per year in 1876–79, 37 per year in 1880–1913, and 9 per year in 1914–20. (Hogsheads were converted to U.S gallons by using: Hogshead × 52·5 × (277/231); 'casks' were assumed to be equivalent to barrels.) Particularly considering the proviso that our estimates come only from Grenadines landings and that non-Barbados, non-Grenadines catches have been ignored, we believe the data in Table 15 substantiate our assertion that estimates listed in Table 1 are conservative.

[2] We use this net recruitment arbitrarily. Chittleborough assumed that what are called two 'Growth Layer Groups' (ie. 4 laminae = 2 pairs of light and dark laminae) represent one year and that the calving interval is three years. The calving interval is unknown precisely, and current usage infers that about one Growth Layer Group represents one year. In the present context of back-calculating to earlier population levels, use of the possibly high net recruitment rate estimate of 0.046 will cause our estimate of 'initial' population size to be low – thus, conservative.

[3] J. Sigurjónsson (in litt., 31 July 1981) suggested to us that the catches attributed to Iceland during 1883–1915 (Table 1) are 'too low'. In his view, we could have calculated, *pro rata*, the unspecified catches for 1890–97 and 1903–15 as we did those for 1898–1902, notwithstanding Risting's (1931) remarks about catch composition. Sigurjónsson drew our attention to the statement by Saemundsson (1939. Mammalia. *The Zoology of Iceland*, IV (76): 1–38) that 'a great number [of humpbacks] (30–33 whales per boat) was caught in the years 1902–09.'

[4] Additional information has come to our attention concerning the nineteenth-century Gaspé sailing vessel fishery in the Gulf of St Lawrence. During his visit to the North Shore in the summer of 1858, Abbé Ferland (in Chambers, E.T.D. 1912. *The Fisheries of the Province*

of Quebec, Part I. Historical Introduction. Published by the Department of Colonization, Mines and Fisheries of the Province of Quebec, pp. 1–206) observed the capture of a large 'sulphurbottom whale' near Tabatière (p. 157). It was 'killed with a single blow of the lance' and towed to shore, where it was expected to produce 80 barrels of oil, worth $12–16 per barrel. Abbé Ferland claimed that five or six Gaspé whaling schooners 'frequented' the Labrador coast at this time. He noted that the whalers sometimes sent killed whales adrift when seas were rough. In spite of their efforts to facilitate recovery of the carcass by attaching a buoy to it, 'it often happened that the whale was lost through the breaking of the cable in storms, or through drifting away beyond recovery'. These observations substantiate our comments about this fishery and support our decision to use a loss rate factor of 1·20 to account for whales killed but not secured by the Gaspé whalers.

In 1823 reference was made to the whale fishery prosecuted in the Gulf of St Lawrence and St Lawrence River as far up as Green Island (J. T. Taschereau, *in* Chambers, 1912, p. 126).

There was considerable interest in the establishment of a whale fishery in New France – at Matane on the Gaspé coast – during the late seventeenth and early eighteenth centuries (Chambers, 1912, pp. 50–3). Spanish Basque harpooners were enlisted to instruct local fishermen in whaling techniques. We have not found detailed enough information to comment on the nature or magnitude of this fishery, but we believe that such information is available.

[5] An apparently contemporary description of the West Indies island of Trinidad (Anonymous. 1869. Reminiscences of Trinidad. – From a Visit to Port Spain as it was. *The Nautical Magazine and Naval Chronicle for 1869. A Journal of Papers on subjects connected with Maritime Affairs*, London, pp. 362–72) indicates that the whaling season was January–March and the species involved was 'the common hump-backed whale'. The whaling establishment at this time was located at Gasparee. In the absence of detailed information about the activities at this shore whaling station, we did not include an estimate for the Trinidad kill in Table 1. This decision clearly adds to the conservatism of our estimates of total fishing mortality and, therefore, of our estimate of initial population size (*if* Trinidad winter [?] humpbacks are North Atlantic whales).

[6] Guldberg, G. 1981. On the migrations of various whalebone whales. Canadian translation of Fisheries and Aquatic Sciences No. 4740. Translated by the Translation Bureau, Multilingual Sciences Division, Department of the Secretary of State of Canada, Ottawa, pp. 1–24 typescript [translation of Guldberg, G. 1904].

Table 15

Exports of whale oil, 'whale bone', 'whale fins and gills', and whale meat from St Vincent, West Indies, 1860–1920. Data compiled from *Bluebooks*, read and extracted by E. Cooke (*in litt.*, 25 November 1981). BWI = British West Indies; GB = Great Britain; US = United States; DWI = Dutch West Indies; FWI = French West Indies; DaWI = 'Danish West Indies'; SWI = 'Swedish West Indies'; UK = United Kingdom; BG = British Guiana

		Quantity (barrels, except as noted)				
Article	Country to which exported	In British vessels	In foreign vessels	Total	Total value in sterling	Year
—	—	—	—	—	—	1860
—	—	—	—	—	—	1861
—	—	—	—	—	—	1862
Oil, whale	BWI	—	—	—	12	1863
Whale oil	BWI	30 casks	—	30 casks	150	1864
Whale oil	BWI	—	—	15 pkgs	86.0.0	1865
Whale oil	US	—	—	76 or 96 pkgs	464.2.0	1865
—	—	—	—	—	—	1866
Whale oil	BWI	102	12	114	456.0.0	1867
Whale oil	US	—	1296	1,296	5,184.0.0	1867
Whale oil	GB	10 casks	—	10 casks	40.0.0	1868
Whale oil	BWI	257 casks	200 casks	457 casks	1,828.0.0	1868
Whale oil	FWI	2 casks	—	2 casks	8.0.0	1868
Whale oil	DWI	—	216 casks	216 casks	864.0.0	1868
Whale oil	US	—	1160 casks	1,160 casks	4,640.0.0	1868
Whale oil	BWI	203	664	867	3,468.0.0	1869
Whale oil	DWI	—	185	185	740.0.0	1869
Whale oil	US	—	745	745	2,980.0.0	1869
Whale oil	BWI	166	1210	1376	5,504.0.0	1870
Whale oil	US	—	235	235	940.0.0	1870
Whale oil	BWI	28	—	28	70.0.0	1871
Whale oil	US	—	465	465	1,162.10.0	1871
Whale oil	BWI	113	—	113	282.10.0	1872
Whale oil	US	171	—	171	427.10.0	1872
Whale oil	BWI	284	—	284	} 960.0.0	1873
Whale oil	US	—	100	100		1873
Whale oil	BWI	140	—	140	420.0.0	1874
Whale oil	BWI	125	—	125	375.0.0	1875
Whale oil	BWI	190	—	190	570.0.0	1876
Whale oil	US	—	420	420	1,260.0.0	1876
Whale oil	BWI	320	—	320	960.0.0	1877
Whale oil	US	—	430	430	1,290.0.0	1877
Whale oil	BWI	96 bbls, 5 casks	—	96 bbls, 5 casks	161.15.0	1878
Whale oil	US	440	—	440	1,020.0.0	1878
Whale oil	DaWI	35	—	35	52.10.0	1878
Whale oil	BWI	50	—	50	75.0.0	1879
Whale oil	FWI	160	—	160	160.0.0	1879
Whale oil	DWI	160	—	160	80.0.0	1879
Whale oil	BWI	322	—	322	} 586.5.0	1880
Whale oil	SWI	140	—	140		1880
Whale oil	BWI	99 casks	—	99 casks	} 377.0.0	1881
Whale oil	GB	40 bbls	—	40 bbls		1881
Whale oil	GB	9 casks	—	9 casks	} 360.0.0	1882
Whale oil	BWI	151 casks	—	151 casks		1882
Whale oil	GB	32 casks	—	32 casks	}	1883
Whale oil	BWI	161 bbls	—	161 bbls	832.10.0	1883
Whale oil	DWI	140 bbls	—	140 bbls		1883
Oil, whale	GB	116 casks	—	116 casks	}	1884
Oil, whale	BWI	195 casks	—	195 casks	1,077.10.0	1884
Oil, whale	FWI	120 casks	—	120 casks		1884
Oil, whale	GB	159 casks	—	159 casks		1885
Oil, whale	BWI	29 hogsheads 124 bbls 10 casks 39 bbls		29 hogsheads 124 bbls 10 casks 39 bbls	} 534.0.0	1885
Oil, whale	FWI	45 bbls	—	45 bbls		1885
Bone, whale	BWI	30 tons	—	30 tons	17.0.0	1886
Oil, whale	GB	418 casks	—	418 casks		
Oil whale	BWI	121 bbls 15 casks 255 bbls	—	121 bbls 15 casks 255 bbls	} 1,230.10.0	1886
Oil, whale	US	205 bbls	—	205 bbls		1886
Bones, whale	BWI	2 tons	—	2 tons	1.0.0	1887
Oil, whale	GB	163 casks 78 bbls	—	163 casks 78 bbls	}	
Oil, whale	FWI	100 bbls	—	100 bbls		1887
Oil, whale	BWI	39 casks 34 bbls	—	39 casks 34 bbls	693.0.0	1887
Oil, whale	DaWI	175 bbls	—	175 bbls		1887
Oil, whale	DWI	3 bbls	—	3 bbls		1887

Table 15 (*continued*)

Article	Country to which exported	Quantity (barrels, except as noted) In British vessels	In foreign vessels	Total	Total value in sterling	Year
Oil, whale	GB	294	—	294	336.0.0	1888
Oil, whale	BWI	42	—	42		1888
Oil, whale	FWI	1	—	1	400.16.8	1889
Oil, whale	GB	396	—	396		1889
Oil, whale	BWI	84	—	84		1889
Oil, whale	GB	499	—	499	587.0.0	1890
Oil, whale	BWI	88	—	88		1890
Whale fins and gills	GB	11 cases	—	11 cases	32.0.0	1890
Oil, whale	GB	385	—	385	575.0.0	1891
Oil, whale	BWI	190	—	190		1891
Whale fins and gills	GB	20 cases	—	20 cases	60.0.0	1891
Whale oil	GB	240	—	240	340.0.0	1892
Whale oil	BWI	100	—	100		1892
Whale fins and gills	GB	9 cases	—	9 cases	27.0.0	1892
Oil, whale	GB	544	—	544	676.0.0	1893
Oil, whale	BWI	132	—	132		1893
Whale fins and gills	GB	22 cases	—	22 cases	66.0.0	1893
Whale bone	GB	12 tons	—	12 tons	240.0.0	1893
Whale meat	BWI	15 bags	—	15 bags	7.10.0	1893
Whale oil	GB	405	—	405	473.0.0	1894
Whale oil	BWI	68	—	68		1894
Whale fins and gills	GB	27 cases	—	27 cases	71.0.0	1894
Whale bone	GB	33 tons	—	33 tons	660.0.0	1894
Oil, whale	GB	284	—	284	475.0.0	1895
Oil, whale	BWI	286	—	286		1895
Whale fins and gills	GB	8 cases	—	8 cases	24.0.0	1895
Whale bone	GB	19 tons	—	19 tons	38.0.0	1895
Whale oil	UK	13,800 gals	—	13,800 gals	658.2.6	1896
Whale oil	BWI	1,604 gals	—	1,604 gals	67.15.0	1896
Whale oil	UK	23,760 gals	—	23,760 gals	742.10.0	1897
Whale oil	BWI	2,711 gals	—	2,711 gals	85.7.6	1897
Whale oil	UK	24,840 gals	—	24,840 gals	956.0.0	1898
Whale oil	BWI	2,438 gals	—	2,438 gals	60.0.0	1898
Oils, whale	UK	16,784 gals	—	16,784 gals	452.0.0	1899
Oils, whale	BWI	1,152½ gals	—	1,152½ gals	30.6.3	1899
Oils, whale	UK	21,195 gals	—	21,195 gals	2,222.4.3[1]	1900
Oils, whale	BWI	403 gals	—	403 gals	57.10.0	1900
Whale meat	St Lucia	23 bags	—	23 bags	4.3.0	1901
	Trinidad	1 bag	—	1 bag	3.0	1901
Whale bone	UK	?	—	?	7.10.0	1901
	Barbados	?	—	?	23.0.0	1901
Whale oil	UK	41,038 gals	—	41,038 gals	1,220.15.0	1901
Whale oil	St Lucia	162 gals	—	162 gals	8.12.0	1901
Whale oil	Trinidad	44 gals	—	44 gals	1.2.0	1901
Whale oil	Barbados	40 gals	—	40 gals	1.0.0	1901
Whale meat	St Lucia	290 lbs	—	290 lbs	3.10.0	1902
Whale bone	UK	?	—	—	7.4.1	1902
Whale oil	UK	27,280 gals	—	27,280 gals	1,090.11.8	1902
Whale oil	Trinidad	333 gals	—	333 gals	9.0.0	1902
Whale oil	Barbados	126 gals	—	126 gals	3.3.0	1902
Whale oil	St Lucia	92 gals	—	92 gals	3.12.0	1902
Whale oil	BG	30 gals	—	30 gals	1.5.0	1902
Whale meat	St Lucia	780 lbs	—	780 lbs	2.8.0	1903/4
Whale bone	UK	?	—	?	2.0.0	1903/4
Whale bone	Trinidad	?	—	?	5.0	1903/4
Whale oil	UK	28,691 gals	—	28,691 gals	1,099.6.6	1903/4
Whale oil	Trinidad	1,209 gals	—	1,209 gals	46.10.6	1903/4
Whale oil	Carriacou	8 gals	—	8 gals	4.0	1903/4
Whale oil	Demerara	40 gals	—	40 gals	2.10.0	1903/4
Whale oil	Barbados	40 gals	—	40 gals	1.0.0	1903/4
Whale oil	St Kitts	6 gals	—	6 gals	12.0	1903/4
Whale meat	St Lucia	?	—	?	2.4.0	1904/5
Whale bone	Barbados	29,120 lbs	—	29,120 lbs	26.10.0	1904/5
Oils, whale	UK	4,258 gals	—	4,258 gals	187.10.0	1904/5
	Demerara	184 gals	—	184 gals	4.15.0	1904/5
	Trinidad	5,712 gals	—	5,712 gals	237.17.0	1904/5
	St Lucia	126 gals	—	126 gals	4.12.0	1904/5
	Grenada	46 gals	—	46 gals	2.0.0	1904/5
Whale meat	St Lucia	90 lbs	—	90 lbs	1.10.0	1905/6
Whale bone	Barbados	123,200 lbs	—	123,200 lbs	35.1.8	1905/6
Oil, whale	UK	5,920 gals	—	5,920 gals	228.0.0	1905/6
Oil, whale	Trinidad	420 gals	—	420 gals	18.15.0	1905/6

Table 15 (*continued*)

Article	Country to which exported	Quantity (barrels, except as noted): In British vessels	In foreign vessels	Total	Total value in sterling	Year
Oil, whale	Grenada	40 gals	—	40 gals	2.0.0	1905/6
Oil, whale	St Lucia	94 gals	—	94 gals	4.14.0	1905/6
Oil, whale	Demerara	8 gals	—	8 gals	12.6	1905/6
Whale bone	Barbados	11,240 lbs	—	11,240 lbs	2.15.0	1906/7
Whale bone	US	60 lbs	—	60 lbs	6.3	1906/7
Oil, whale	UK	5,440 gals	—	5,440 gals	233.0.0	1906/7
Oil, whale	Trinidad	200 gals	—	200 gals	10.0.0	1906/7
Oil, whale	Demerara	160 gals	—	160 gals	5.0.0	1906/7
Oil, whale	Grenada	24 gals	—	24 gals	2.8.0	1906/7
Whale meat	St Lucia	?	—	?	3.5.0	1907/8
Whale bone	Trinidad	13 tons	—	13 tons	6.9.0	1907/8
Oil, whale	UK	8,716 gals	—	8,716 gals	404.16.0	1907/8
Oil, whale	Trinidad	365 gals	—	365 gals	16.5.0	1907/8
Oil, whale	Demerara	202 gals	—	202 gals	6.2.0	1907/8
Oil, whale	Grenada	202 gals	—	202 gals	10.15.3	1907/8
Oil, whale	St Lucia	147 gals	—	147 gals	8.9.0	1907/8
Whale meat	St Lucia	320 lbs	—	320 lbs	18.0	1908/9
Whale oil	UK	12,332 gals	—	12,332 gals	577.4.0	1908/9
Whale oil	Trinidad	640 gals	—	640 gals	30.10.0	1908/9
Whale oil	Demerara	247 gals	—	247 gals	10.6.9	1908/9
Whale oil	Grenada	114 gals	—	114 gals	5.14.0	1908/9
Whale oil	St Lucia	85 gals	—	85 gals	5.6.3	1908/9
Whale oil	Carriacou	16 gals	—	16 gals	16.0.0	1908/9
Whalebone	Barbados	4 tons 1,000 lbs	—	4 tons 1,000 lbs	4.1.8	1909/10
Whale oil	UK	4,748 gals	—	4,748 gals	225.8.0	1909/10
Whale oil	Trinidad	664 gals	—	664 gals	28.12.0	1909/10
Whale oil	Demerara	159 gals	—	159 gals	7.19.0	1909/10
Whale oil	Grenada	216 gals	—	216 gals	9.16.0	1909/10
Whale meat	BWI	200 lbs	—	200 lbs	1.13.4	1910/11
Whale oil	UK	2,127 gals	—	2,127 gals	106.7.0	1910/11
Whale oil	BWI	1,192 gals	—	1,192 gals	57.5.0	1910/11
Whalemeat	BWI	240 lbs	—	240 lbs	1.18.0	1911/12
Whale oil	UK	3,918 gals	—	3,918 gals	195.18.0	1911/12
Whale oil	BWI	642 gals	—	642 gals	31.14.2	1911/12
Whalemeat	BWI	940 lbs	—	940 lbs	5.10.0	1912/13
Whalemeat	BWI	3,200 lbs	—	3,200 lbs	11.0.0	1913/14
Whale oil	UK	3,026 gals	—	3,026 gals	151.6.0	1913/14
Whale oil	BWI	1,290 gals	—	1,290 gals	65.10.0	1913/14
Whalemeat	BWI	750 lbs	—	750 lbs	4.3.4	1914/15
Whale oil	UK	1,072 gals	—	1,072 gals	53.12.0	1914/15
Whale oil	BWI	547 gals	—	547 gals	29.76.0	1914/15
Whale oil	BWI	3,624 gals	—	3,624 gals	188.10.0	1915/16
Whale oil	UK	926 gals	—	926 gals	44.6.0	1915/16
Whale oil	BG	121 gals	—	121 gals	3.0.0	1915/16
Oil [apart from cotton seed = whale]	BWI	2,351½ gals	—	2,351½ gals	147.14.11	1916/17
	BG	452 gals	—	452 gals	24.9.8	1916/17
	UK	3,910 gals	—	3,910 gals	202.7.11	1916/17
Whale oil	UK	1,952 gals	—	1,952 gals	127.18.0	1917/18
Whale oil	BWI	900 gals	—	990 gals	53.14.0	1917/18
Whale oil	BG	158 gals	—	158 gals	16.9.2	1917/18
Whalemeat	Grenada	2,000 lbs	—	2,000 lbs	13.0.0	1918/19
Whale oil	BG	400 gals	—	400 gals	60.0.0	1918/19
Whale oil	Barbados	680 gals	—	680 gals	90.0.0	1918/19
Whale oil	Grenada	1,079 gals	—	1,079 gals	135.0.0	1918/19
Whale oil	Trinidad	790 gals	—	790 gals	104.0.0	1918/19
Whalemeat	Martinique	100 lbs	—	100 lbs	1	1919
Whale oil	Barbados	720 gals	—	720 gals	62	1919
Whale oil	UK	5,080 gals	—	5,080 gals	292	1919
Whale oil	Grenada	60 gals	—	60 gals	6	1919
Whale oil	Demerera	3,664 gals	—	3,664 gals	425	1919
Whale oil	St Lucia	12 gals	—	12 gals	2	1919
Whale oil	Trinidad	304 gals	—	304 gals	35	1919
Whale oil	Martinique	36 gals	—	36 gals	5	1919
Whale bone	UK	537 lbs	—	537 lbs	7	1919
Whale meat	St Lucia	170 lbs	—	170 lbs	£4	1920
Whale oil	BG	200 gals	—	200 gals	7	1920
Whale oil	Grenada	12 gals	—	12 gals	4	1920
Whale oil	St Lucia	120 gals	—	120 gals	21	1920
Whale oil	Trinidad	879 gals	—	879 gals	172	1920
Whale oil	Barbados	592 gals	—	592 gals	63	1920
Whale oil	UK	680 gals	—	680 gals	102	1920
Whale bone	UK	700 lbs	—	700 lbs	10	1920

[1] 'Return of the Manufactures, Mines and Fisheries' for this year gives value of 21,598 gals as £611.18.0, which seems more reasonable.

SC/32/O 8

Historical Whaling Records from the Western Indian Ocean

PHOEBE WRAY[1] and KENNETH R. MARTIN[2]

ABSTRACT

Preliminary data from 19th century whaling in the western Indian Ocean is presented, including summary of effort by whaling grounds and by species. The influence of this whaling, especially by American vessels, on the resources of the region, as well as its effects on human institutions and attitudes, is assessed. Catch data from 27 voyages (1800–88) is summarized, with comments on the possibility of overfishing on sperm and right whales in the western Indian Ocean. Also included is an extensive bibliography which assembles, for the first time, an assortment of imprints and primary sources.

SCOPE OF THIS STUDY

About 14,000 voyages were made by American whaling vessels, and of these, at least 25% are documented by logbooks, journals, and other original materials in the possession of museums and libraries (Sherman, 1965). Additional records (hundreds, if not thousands, of logbook journals) are in the hands of private collectors and are, unfortunately, not readily available to researchers (Martin, 1981). These materials are only now beginning to be systematically examined, and the data they contain quantified. This study contributes to that effort.

The focus of this paper is on the western Indian Ocean, from 20° E to Amsterdam Island, from the Arabian Coast and the Gulf of Manar to the Crozets (*ca.* 48° S). Logbook journals plus a variety of charts and published accounts were examined. The earliest manuscript is that of the ship *Kingston* of London from 1800–01. The latest is that of the Bark *Mermaid*, 1888–89. From 1835 onwards, each decade is represented by two or more manuscripts. Except for the *Kingston*'s, all are from American vessels. The manuscripts are in the collection of the Kendall Whaling Museum, Sharon, Massachusetts, USA.

This study presents preliminary data on the species, numbers and movements of whales in the western Indian Ocean, as well as remarks on the fishery.

ACCURACY OF THE DATA

Whaling voyages were long and tedious. Boredom and frustration are often reflected in the logbook and journal entries. Small incidents ('lost the dog overboard', 'killed a terrapin for dinner') were reported as well as, in general, sightings of most if not all cetaceans which came in view. Martin (1981) has pointed out that the logs were, in fact, records kept for ship owners at home, and were part of the economic documentation of a voyage, a fact encouraging careful notation. Further, an officer wanting to someday have a ship of his own found it prudent to keep personal records which might serve him in his advancement. For these reasons, logbooks and reference journals (as opposed to seamen's diaries) may be assumed to be accurate impressions by the best-trained observers of the time. Manuscript sources have been substantially augmented by period imprints (see bibliography), which, though often esoteric, contain a surprising amount of whaling lore.

Species of great whales were recognized with accuracy by the whalemen. It would not serve them to waste time and effort lowering on whales with no economic value. Although occasional mistakes were made ('saw breaches, lowered but they were killers'), these are noted and the pursuit was aborted as soon as the species was recognized.

Baleen whales are always noted as right, humpback and 'sulphur-bottom' (blue) whales; but rorquals are all called 'finbacks'. Sperm and blackfish (pilot whales) were easily recognized. Small cetaceans are noted as 'porpoise', which covered all but 'cowfish' (*Tursiops* spp.), killer whales and grampus. Experienced whalemen apparently could recognize some whales by their behavior. The logbook of the *South Carolina* (Taylor, 1835–37) notes, for instance: '...saw a whale that acted like a right whale with irons in her going to the N very quick.'

Dates, vessels and the reported catch of voyages of this study follow as Table 1.

Whaling covered by this study shows good agreement with Townsend (1935). A total of 727 cetaceans were reported killed by vessels under examination.

GENERAL EFFORT

It might be possible to calculate CPUE (catch per unit effort) from logbook entries showing the number of boats lowered, whales struck, lost and saved, time spent in pursuit of whales. We did not attempt these calculations, and this may be an area of further research. Most vessels carried four, sometimes five, whaleboats. Generally all were lowered when a school was encountered. Success depended on the skill of the captain and the harpooner, and the strength of the iron. Until the toggle-head harpoon came into use after 1848, irons often drew.

The fishery clung to traditional methods, and in general eschewed the use of explosives. Here is one professional comment on the newly-developed bomb lance (S. Braley, 1854–57, 4 February 1856):

> I have not a very exalted opinion of those...bomb lances for I find that one must be as near to the whale in order for them to go in as he would be to kill a whale in the usual way besides the gun kicks worse than a rhode-island horse with all four shoes on one foot...*I would not give a straw for a thousand of them.* [Italics in original.]

Klinowska (1980) sets forth preliminary evidence of diurnal rhythms in Cetacea, but is hampered by lack of data. Logbooks promise to add to the needed information. Entries frequently mention the time of day whales

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Table 1
Dates, vessels and reported catch of voyages of this study

Date	Vessel	Sperm	Right	Hump.	Pilot	Porp.	Other
1800–01	Ship *Kingston* of London	13	—	—	—	—	—
1835	Ship *Averick* of New Bedford	10	2	2	1	—	—
1836	Ship *Ceres 2nd* of New Bedford	17	29	—	9	—	—
1836–37	Ship *South Carolina* of New Bedford	8	31	2	—	—	—
1842	Ship *Good Return* of New Bedford	11	3	—	11	—	—
1844–46	Bark *Maria* of New Bedford	39	—	—	2	17	—
1845–46	Bark *Marcella* of New Bedford	35	—	—	1	1	—
1846–49	Ship *Arab* of Fairhaven	62	—	—	—	—	—
1847–48	Bark *Montezuma* of New Bedford	10	—	—	3	1	—
1848–50	Ship *Stephania* of New Bedford	—	9	—	15	3	—
1849–53	Ship *Arab* of Fairhaven	28	—	—	—	1	—
1854–57	Ship *Harrison* of New Bedford	31	—	—	—	—	—
1859–62	Bark *Thomas Pope* of New Bedford	7	—	—	—	—	—
1861 (2 mos)	Bark *Messenger* (log is a fragment)	1	—	—	—	—	—
1867 (2 mos)	Bark *Benjamin Franklin* of New Bedford	—	—	—	—	—	—
1867–69	Bark *Sea Fox* of Westport	17	—	—	2	—	—
1868–69	Ship *Herald* of New Bedford	46	—	—	—	—	1*
1869–70	Ship *Hecla* of New Bedford	22	—	—	—	—	—
1870	Bark *Sea Fox* of Westport	2	—	—	—	—	—
1870–72	Bark *Lancer* of New Bedford	4	—	2	—	—	—
1872–74	Bark *Petrel* of New Bedford	43	—	—	3	1	1†
1873 (2 mos)	Bark *Avola* of New Bedford	1	—	—	—	—	—
1873–76	Bark *Marcella* of New Bedford	50	—	—	1	28	1†
1875 (1 mo)	Bark *Avola* of New Bedford	—	—	—	—	—	—
1877 (2 mos)	Bark *Avola* of New Bedford	—	—	—	—	—	—
1886–87	Bark *Mermaid* of Westport	35	—	—	—	—	—
1888–89	Bark *Mermaid* of Westport	23	—	—	1	27	1†
Totals		520	74	6	48	75	4

* Blue whale. † Cowfish.

are seen, generally expressed as AM (or First Part), middle, and PM (or Last Part). We have not yet quantified these data, but our general impression is that whales were most frequently seen in the morning and late afternoon.

ADVANTAGES AND DISADVANTAGES OF WHALING THE INDIAN OCEAN

To the growing 19th century whaling industry, the Indian Ocean offered unique advantages. Unlike the Pacific, its waters had been systematically charted. Mariners were further assisted by James Horsburgh's *India Directory*, a detailed navigational guide prepared for the East India Company, which enjoyed reverential respect (B. Morrell, 1832; A. Morrell, 1833). After the Napoleonic Wars, many Indian Ocean outposts were governed by Britain, a circumstance congenial to whaling's virtual Anglo-American monopoly, and which implied political stability unknown in most of the Pacific. Finally, there were abundant whales to be found along the East African and Arabian coasts, among the Comoro, Seychelles and Mascarene Islands, and their connecting banks. Indeed, the Indian Ocean might have undergone a whaling boom about 1800, were it not for the world military situation and British mercantilism, which restricted venturesome whaling and development of an Australian fishery (Hainsworth, 1972).

By the beginning of the 19th century a few armed British vessels, travelling in company, had begun to take sperm whales at Delagoa Bay, in the Mozambique Channel and off east Madagascar (*Kingston* logbook, 1800–01, June 1800 ff). Following the Congress of Vienna, Indian Ocean whaling grew dramatically. By 1830, Yankee ships were clearing home ports not for Delagoa Bay but for the Indian Ocean in general: at least 4 in 1830, 14 in 1835, 49 in 1840, 90 in 1845 (Starbuck, 1878). By 1845, perhaps three dozen British vessels also whaled the Indian Ocean (Villiers, 1931). The peak of this traffic occurred in the latter 1840s, following which came a steady reduction in the number of whalers. The Americans abandoned the Indian Ocean in the late 1880s, although after the turn of the century a few whaling/sealing voyages were made to Kerguelen (see Table 2).

The abundance of Indian Ocean whales was a mixed blessing, however. Strong currents and changing monsoons made seasonal movement between some of the best grounds extremely difficult, and increased catch effort accordingly (S. Braley, 1849–53; 19 November 1850). Such factors were believed to affect the seasonal whereabouts of whales (Maury, 1855) to an extent that whalemen were perpetually confounded by fortune. Hunters relied heavily upon the grapevine for whaling information, because year-to-year experience proved unreliable (Anon, 1835–37; E. Barnard, 1844; Whitecar, 1861), and published directories of Indian Ocean grounds tended to simplify deceptively the movements of whales (Beale, 1839; Wilkes, 1845; Clark, 1887).

Take for example Captain Samuel Braley of Massachusetts, whose years of experience netted him small reward:

> I dont know what has become of the whales: tis time they were on again... This whaling business, is much like the Nantucket girls rolling down a sand hill and singing at every turn
> Now you see it; now you dont
> Perhaps you will; perhaps you wont.
> (Braley, 1849–53; 15 June 1851.)

> Ah! me! how long is this to last. Day after day passes and we see nothing it seems to me that it is quite useless for me to go places where I have seen whales with the expectation of finding them again for I am almost sure to meet with disappointment: what little oil I get

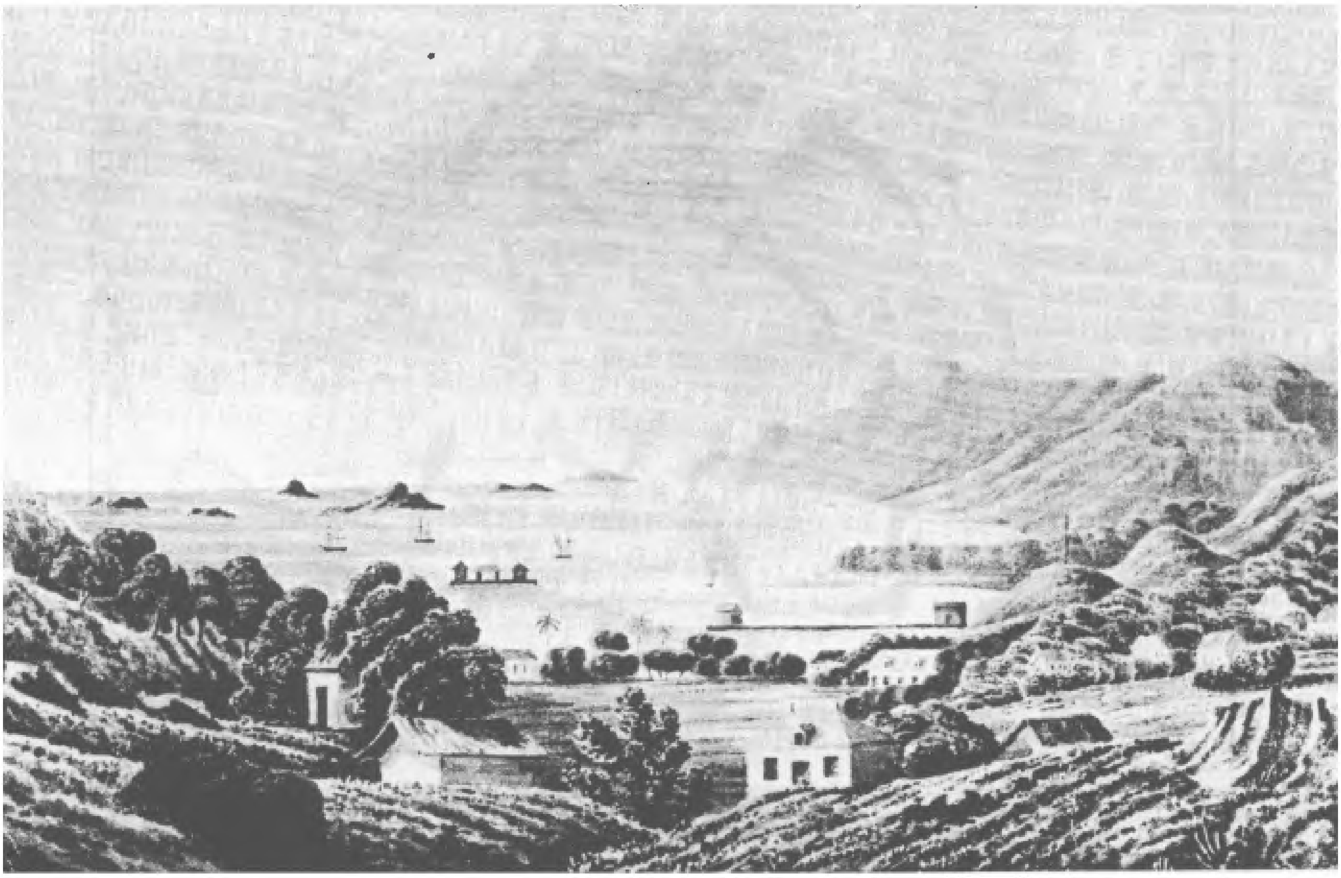

Fig. 1. A 19th century watercolor of Mahe, the Seychelles, a favorite stopover for whaleships. (Courtesy of the Kendall Whaling Museum.)

Table 2

Number of ships cleared for Indian Ocean, 1801–1900

Year	Number	Year	Number	Year	Number
1801	1	1845	90	1866	14
1802	3	1846	47	1867	16
1803	3	1847	60	1868	14
1804	1	1848	35	1869	12
1805	0	1849	35	1870	11
1806	2	1850	23	1871	12
1817	1	1851	33	1872	6
1830	4	1852	24	1873	6
1832	3	1853	27	1874	2
1833	19	1854	31	1875	14
1834	9	1855	40	1876	7
1835	14	1856	55	1877	3
1836	13	1857	44	1880	5
1837	30	1858	33	1883	3
1838	48	1859	38	1884	3
1839	33	1860	24	1886	1
1840	49	1861	4	1887	5
1841	72	1862	9	1888	0
1842	63	1863	8	1889	0
1843	72	1864	10	1890	0
1844	86	1865	14	1900	0

Above table based on Starbuck, 1878; Hegarty, 1959.

comes when least expected henceforth I will endeavor not to care a straw either way but just plod along easyly and abide the results. (Braley, 1854–57; 14 April 1856.)

Discouraged by contrary winds and currents, and baffled by elusive quarry, whalemen also faced higher operating costs than in the Pacific. Trade was advantageous, though risky, in less developed ports of call; but provisioning and repair fees at such centers as Colombo, Victoria or Port Louis could and did send vessels elsewhere (Braley, 1845–53; 10 July 1850 ff). After slavery was abolished, conversion of agriculture in the Mascarenes from food plantation crops and increased home consumption of locally grown produce reduced the attractiveness of these ports of call to the parsimonious whaling industry (Lionnet, 1972). Bureaucratic red tape, high prices, and port duties persuaded many skippers to abandon Mauritius and Victoria for cheaper, less officious stopovers (Braley, 1854–57, 25 May 1857; Wright, 1974). The dynamics of the Indian Ocean fishery were therefore dependent upon a variety of subtle historical factors.

Generally speaking, the exploitation of western Indian Ocean whaling grounds began about 1800 with those nearest the Cape of Good Hope, and extended east and north in later years. By 1850, vessels were numerous as far east as the Gulf of Manar; by the 1870s, the Arabian coast, the last major whaling ground, was popular. Below are brief ground-by-ground descriptions (see also Fig. 5), arranged in chronological order. Comments about the whaling seasons are based upon the authors' primary research and upon Charles Haskins Townsend's charts (1935).

WHALING BY GROUNDS

Delagoa Bay

The closest ground to the Cape of Good Hope, Delagoa Bay sustained a sperm and right whale fishery for almost half a century after 1800. The peak season for both sperm and right whaling was June and July. Nantucket ships (or foreign vessels skippered by Nantucketers) began

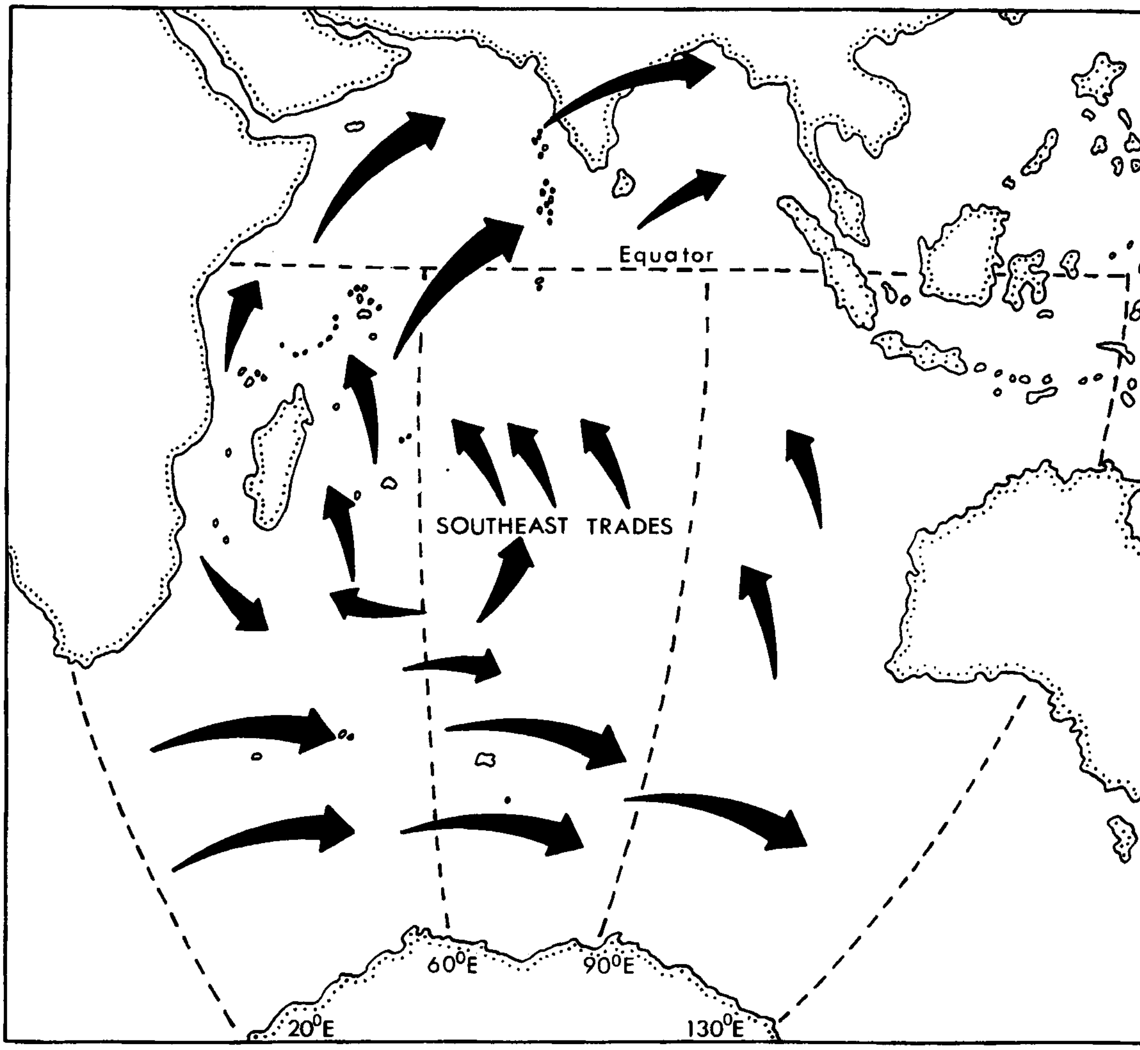

Fig. 2. Southwest monsoon season: May–September. Arrows indicate wind direction. Currents in the Indian Ocean are also strong.

clearing for Delagoa as early as 1791. At least eight sorties to Delagoa were made before 1800 (Starbuck, 1878). Sofala Bay, north of Delagoa, was a later alternative site (Taber, 1841–43, February–June 1842).

Despite an apparent gradual decline in the numbers of whales, Delagoa was frequented well into the 1840s, perhaps because of the advantageous trade thereabouts. (The importance of cheap provisions and sideline trading to the whaling industry has been underestimated.) Interaction between visiting vessels and local inhabitants was reminiscent of such contacts in the South Seas: it was in the short run symbiotic, though not always amicable. As elsewhere, whalemen feared tribal warfare, inevitable rumors of onshore cannibalism, and 'Delagoa Fever', so they did not acquaint themselves much with local politics (T. W. Smith, 1844). Nonetheless, their impact on the region was considerable. Gunpowder and hoop iron for weapon manufacture could be bartered at very favorable terms (Williams, 1894):

> We ran into Dillago Bay [in 1842], where we found other whaling ships. We found plenty of fresh meat. We could buy a whole ox, weighing eight or nine hundred pounds, for a common coffee mug of powder...
>
> ...The natives were arrant thieves and adepts at their profession. They had a particular fancy for old hoop iron. We learned after we left that a blacksmith had a few months before escaped from a whaling ship, and to please the natives he made spearheads or points from hoop iron. When ships came into the harbor the natives would take the blacksmith into the forest and hide him until the vessel had left. They were afraid he would leave the island, and they wanted him for their own use.

Other creatures than cetaceans were in demand at Delagoa Bay: terrapin were a favored food source, since as livestock they could survive on board ships for months without care; and hippopotami were hunted to supply a lively trade in ivory (T. W. Smith, 1844; Williams, 1894).

By 1850, whales were scarce at Delagoa. Opinions varied as to whether this condition was due to overfishing (Clark, 1887) or increased wariness of the quarry. Here is one occupational view (Nordhoff, 1856):

> Whalemen assert that the sperm whale mother also approaches the land to give birth to her young, but her haunts have, I believe, never been discovered, and this is, therefore, more a probability gathered from analogy, than an ascertained fact. The right whale mother is very careful to choose a retired and unfrequented roadstead for the scene of her maternal labors, and bays on the eastern coast of Africa which were formerly noted as the annual resort of great numbers of these animals, have been altogether deserted by them shortly after the whalemen got among them.

By mid-century, Indian Ocean whalers were exploiting more lucrative grounds.

Madagascar

Both the east and west coasts of Madagascar offer interesting early parallels to whaling at Delagoa Bay.

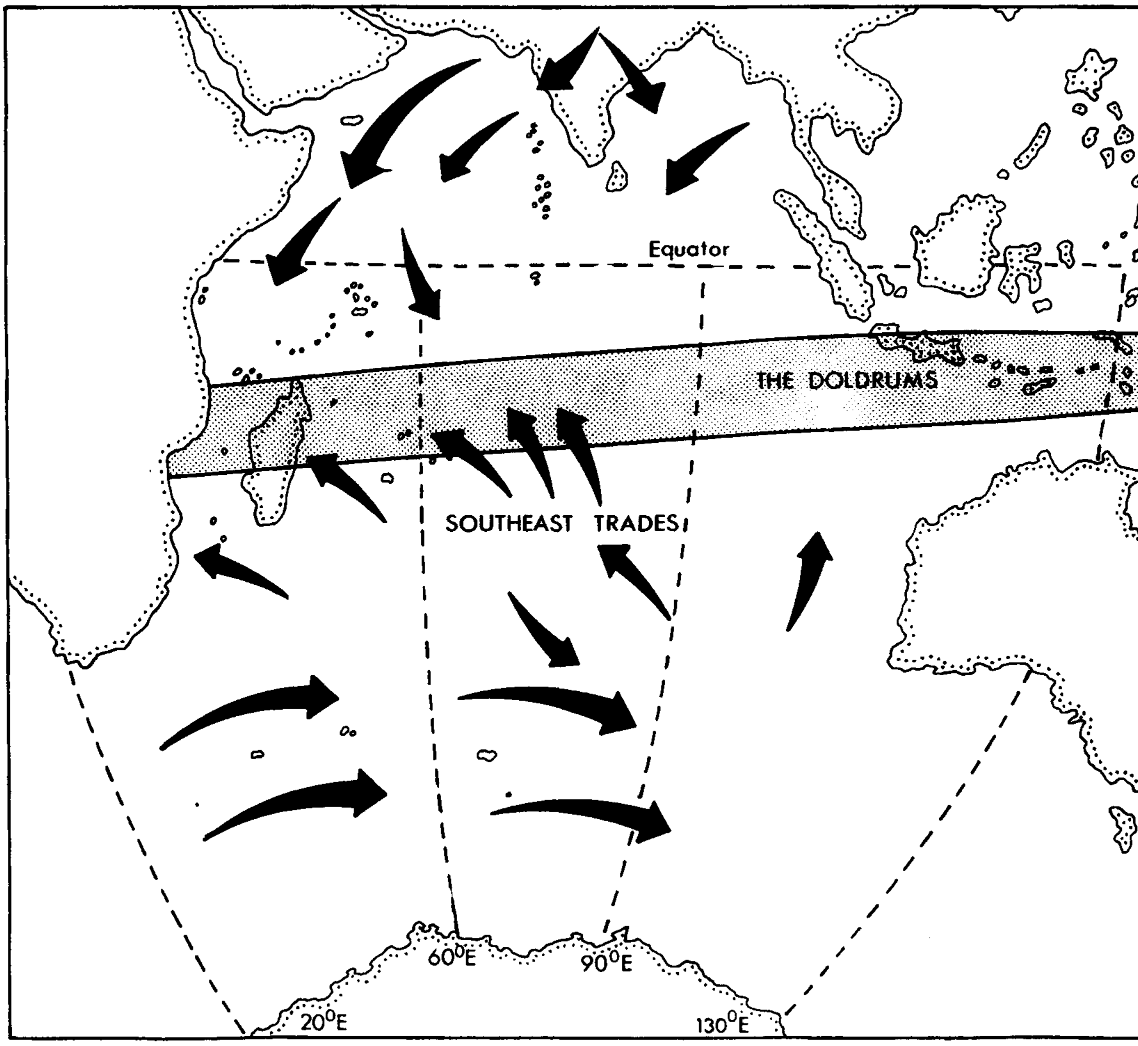

Fig. 3. Northeast monsoon season: October–April.

Vessels moving north in the Mozambique Channel found sperm whales there throughout the year, although as at Delagoa, the peak season was mid-winter. Some whalemen assumed that sperm stocks encountered off the south and west coasts of Madagascar were the same as those of the East African bays (Browne, 1846). East of Madagascar, sperm whales were plentiful in the region from Ft. Dauphin east to the Mascarenes from December to March, and off the northeast coast in April and May. East Madagascar was whaled as early as 1800 by British vessels returning from Australia (Anon, 1800–01, January 1801). Chilly and rainy, it remained famous throughout the 19th century as a reliable ground of last resort on which a homeward bound whaler might 'chock off' its cargo (Nordhoff, 1856; Beane, 1905).

At Antongil Bay, in northeast Madagascar, seasonal visits by humpbacks attracted substantial interest by 1850. Humpbacking was a difficult enterprise requiring special techniques; but at Antongil as elsewhere, Yankees quickly mastered these (Nordhoff, 1856):

> As in the bays of tropical countries the strong sea breeze generally alternates with a mild and genial land breeze, the humpback in running to windward does not so often get beyond the reach of his pursuers, and although hard to kill, generally falls prey to a good whaleman, when struck during the prevalence of a land wind.
>
> Orders were given not to fasten to a bull...This restriction was rendered necessary by the fact the male humpback invariably runs on being struck, and moreover turns out for his size a much smaller quantity of oil than the female.
>
> Care was taken...not to kill the young calves 'as it was a useless waste of life,' so said the mate of the Rodgers, 'and besides had a tendency to excite the cow whale.'
>
> I thought it would have been the part of mercy to kill the calves after dispatching the mother, inasmuch as they were not yet old enough to get their own living, and would most likely starve to death.
>
> The humpback...the most stupid of whales, clings obstinately to the [calving] place it has once chosen, and thus numbers of this fish are annually taken in the great bays of New Holland, Madagascar and Africa.

The east and west coasts of Madagascar afforded vessels the opportunity to combine seasonal whaling with trade so advantageous as to reduce the increasing overhead of the whaling industry. The Mozambique Channel bays of St Augustine, Bombetaka and Passandava saw heavy traffic. In July 1836, for example, at least 18 whalers anchored at St Augustine (Anon, 1835–37, 30 July–1 August 1836). The east coast towns of Ft. Dauphin and Tamatave were likewise popular with vessels working west from the Mascarenes. Thus did Madagascar become crucial to whaling strategy.

As trade centers, Malagasy towns offered visitors the same pros and cons as East African stopovers. The climate was disagreeable to Americans and Europeans, who had good reason to fear 'Madagascar Fever' (Nordhoff, 1856; Graham, 1972). Captain Sam Braley spoke for many when he summed up the weather east of Antongil: 'Hot, hotter, hotest, hottentot, hottotest, hottotisimus, hottotisime: hot as an oven; hot as two

Fig. 4. 'This is the house that Jack built July 16th trying to get to Johanna and cannot make it out.' Whaleman Frederick Smith's wry doodle is a comment on the perfidious weather and current conditions besetting Indian Ocean whalemen. (Courtesy of the Kendall Whaling Museum.)

ovens; hot as seven ovens; HOT!!!' (S. Braley, 1854–57, 23 November 1856). The Malagasy regarded outsiders with suspicion because of the controversial inroads of European influence. Nonetheless, substantial trade developed between coastal Malagasy and visiting whaleships, which were faced with virtually no competition (Graham, 1967).

The whaling trade helped underwrite and sustain Madagascar's ongoing regional hostilities by providing a continual source of firearms. For generations the staple Yankee trade item was the musket, obsolete versions of which whalemen swapped even for bullocks on the hoof (Anon, 1800–01, 2 February 1801; Robbins, 1899; Beane, 1905). In early times, three cups of gunpowder netted two sheep or goats (Anon, 1800–01, 18 February 1801). In 1856 a whaleman at St Augustine Bay noted (Anon, 1837):

> ...[most] of these people have in their possession muskets, the stockes of which are driven full of brass nails... Brass nails are articles of great demand...cotton cloth, powder and tobacco, are the principal articles that ships bring to this island...for which they get bullocks, pumpkins, shell &c.

In 1842, a British visitor found the townspeople clad in the cast-off garb of whalemen, speaking a vulgar English corrupted by whalemen's profanities (F. Barnard, 1843).

Whaling annals are replete with accounts of trade at Madagascar. In general, writers found the Malagasy handsome, imperious, mercurial, and perfidious (Anon, 1837; Browne, 1846; Nordhoff, 1856; Densmore, 1876). Unwary bargaining or failure to respect the courtly pomp of regional rulers could be dangerous, even fatal (Anon, 1835–37, 17–18 August 1836; Anon, 1837; Browne, 1846). Except for Nosy Be (Passandava), with its wholesome climate and French veneer, whalemen found the ramshackle trade towns of Madagascar dangerous and unattractive. Incipient deserters usually planned to jump ship elsewhere (Nordhoff, 1856; Ely, 1971).

Mozambique

> Stick out line till we get clear of the school, and then we'll pull up on the other side of this fellow, and soon settle him with a lance.
>
> This was done, and as we again hauled upon the still furious beast, the mate poised his bright lance for a moment, then sent it deep into his heart. With a tremendous roar, and a desperate final struggle...our prize gave up the ghost, and after sinking for a moment, rose again to the surface, lying on his side.

Thus did a Yankee whaleboat crew (Nordhoff, 1856) turn a hippo 'fin out' at Bazaruto Island, Mozambique. The low-lying coast of Mozambique alternated with Malagasy landfalls as provisioning stops for whalers. Sightings of sperm, humpbacks, finbacks and blackfish were frequent in the Mozambique Channel, especially during June and July; and the importance of Delagoa and Sofala Bays has been mentioned above. Calving humpbacks were also taken in numbers on the Mozambique shore. Otherwise, Mozambique provided a convenient wooding site for many vessels bound for the Comoros or Zanzibar.

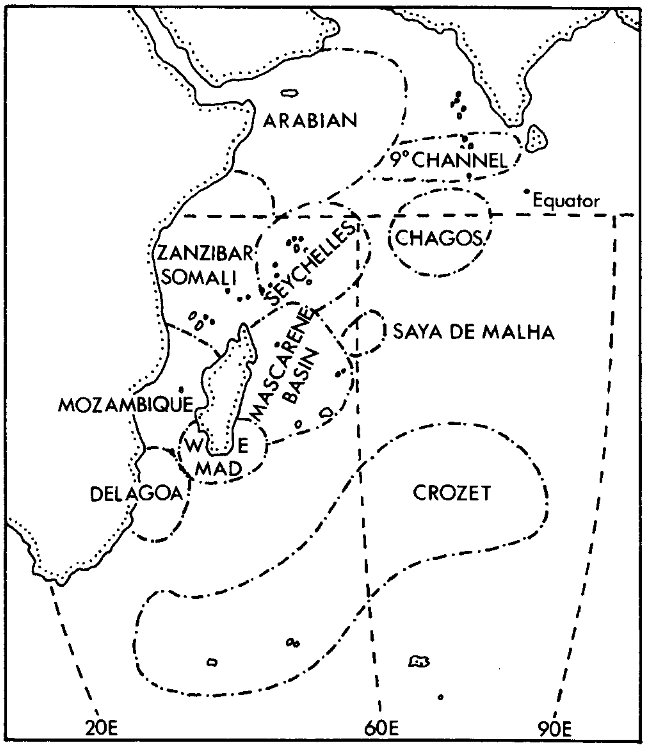

Fig. 5. Whaling grounds in Western Indian Ocean.

Townsend's charts A and B (1935) show intermittent sperm whaling in the Mozambique Channel, notably during May through July. Manuscripts consulted for that study suggest a northward movement of sperm whales in the Mozambique Channel during autumn, as does more recent evidence (Gambell, 1972). In any case, the Mozambique coast may be regarded as an ancillary 19th century ground, given its location between Delagoa and the Comoros and its seasonally abundant humpback stocks. But the general impression gained from reviewing historical sources is that the waters of the Channel offered unreliable whaling (Anon, 1835–37, 23 February 1836; Bullen, 1899). Boredom and despondency often followed (Nordhoff, 1856):

> Land was plainly in view for days at a time. Either the blue mountains of Madagascar, or the flat, desert-like beach of the opposite African coast, were ever in sight. And thus we drifted along, day after day, with naught but the semi-occasional trick at the helm or masthead to excite the sluggish blood, and relieve the constant dullness of our monotonous lives.
>
> ...I...took to whittling as a last resort, and...got through some weary days, and many feet of cedar plank. One resource the others had, of which I was deprived – they chewed tobacco; and a quid engaged not only their jaws, but by sympathy their minds.

Zanzibar Grounds: Comoros, Zanzibar, East African coast

North of the Mozambique Channel lay a large sperm whaling ground often called the Zanzibar Grounds, but which encompassed that island, Pemba, the nearby East African coast, the Somali Basin, and the Comoro Islands.

Most whaling in these areas took place in May through September, the period of the southwest monsoon. (Vessels could and did move from more easterly grounds before the monsoon, and could move east again at the season's close.) As elsewhere sperm whales were abundant but unpredictable; early and late accounts alike acknowledge the former circumstance and bemoan the latter (E. Barnard, 1844; Bullen, 1899). Occasionally, whaling could be very good indeed: consider the *Ceres 2nd* of New Bedford, which in five weeks in March and April 1836, with at least three other vessels in sight off east Zanzibar, bagged 16 whales (Anon, 1835–37, 20 March–25 April 1836).

The Somali Basin was an extension of the Zanzibar grounds and appears to have gained popularity after mid-century, as did the coast of Arabia.

It is important to note the significance of climatic and economic factors on whaling in this area. The Comoro Islands were able to supply livestock and fresh provisions very cheaply, and were physically attractive, underdeveloped liberty ports (Graham, 1967). Unstable relations with inhabitants of Mayotta, Mohilla and Grand Comoro, and the port charges levied at those islands, caused bargain-hunting whalers to resort to Johanna [Anjouan] (Graham, 1967; Bullen, 1899). But Johanna's harbor is protected only during the seasonal monsoon. Consequently, the harbor traffic at Johanna was not predicated solely upon the seasonal presence of sperm whales (see Fig. 4). Such traffic could be heavy: in July 1846 during the industry's peak period, at least 11 Yankee whalers called at Johanna (S. Braley, 1845–49, 1–3 July 1846). Nine years later, there were at least four (S. Braley, 1854–57, 5 July 1855).

Johanna's rulers controlled the flow of trade by a time-honored system of squeeze: gifts payable by visiting skippers. Some Yankees found this an attractive, even amusing system, others did not (Anon, 1837; Browne, 1846). In any case, it brought whalemen and local royalty into personal contact, and for years lavish entertainments afloat and ashore graced many a visit to Johanna (Anon, 1837):

> His majesty came on board dressed in a purple velvet jacket, with a Turkish gown, a crown of crimson velvet ornamented with gold, and carried a splended sword. We set the colors, and all the signals, and fired a salute with our only cannon. The king was delighted with the appearance of things in his welcome reception, but said it was a pity to waste so much powder; he thought it would be much better to give it to him to carry on his wars.

And (H. Allen, 1871, 19 May 1871):

> Abdallah's boy and six attendants came on board. His father is one of the richest men there you would never see him without one of his attendants. He is eleven years old [the writer is ten] and his name is Abdhu. His chief attendant Abbass said to me 'friendly the me want makee friendly the you.' I said 'yes' and Abdhu...put out his hand and we shook hands as a sign of friendship. I treated him and his attendants to hard bread water and sugar and went ashore with them and father in the afternoon.

Gunpowder and calico were favored trade items at Johanna.

Vessels seeking major repairs, consular assistance or excitement could call at Zanzibar's capital, N'Googa, an important East African commercial center and (until 1873) slave market (Browne, 1846; H. Allen, u.d.):

> From the bay it has quite a flourishing appearance. Many of the buildings along the beach are large stone edifices, which are whitewashed, and present a very pleasing appearance to the eye. The imaum's harem, or town residence, occupies a prominent position near the water's edge, and is a regular, though not handsome building, of a larger size than any other fronting the bay. Before the door is a tall staff, bearing the blood-red flag of Arabia.
>
> I have a very pleasant memory of our stay at Zanzibar [in 1871]...We stayed on shore at the American consulate..., and everyone...showed us the sights of Zanzibar. I have a memory of walking through the narrow streets, passing all kinds of foreign

Fig. 6. Johanna (Anjouan) in whaling times. (Courtesy of the Kendall Whaling Museum.)

people and animals, and being terrified upon turning around to find a camel walking very, very close to me.

We visited the Sultan's palace... we had crossed an open court with a fountain in the center and many lovely flowers. I looked at all the shuttered windows expecting to see faces, for some one had told me that women and slaves were probably watching us.

Despite its *Arabian Nights* allure, port duties and the propensity of whalers to call at remoter spots reduced N'Googa's importance as a whaling stopover. But the United States and Zanzibar enjoyed regular trade relations, which made the Sultanate a predictable labor exchange for the whaling industry. Many who shipped were of course Yankees or Europeans between voyages; but others were not, as is indicated by a bizarre incident on the Ship *Arab*. In June 1847, Captain Sam Braley shipped three Arabs at Zanzibar. In October, off Ceylon, they quietly disappeared over the side (S. Braley, 1845–49, 26 October 1847):

What induced them to take this step, I am at a loss to determine; I had done everything in my power to make them comfortable...in a place separate from the Americans for fear that they might misuse them; had their victuals cooked separately...and they have given good satisfaction, always appeared cheerful and happy;... Last night we lay becalmed within 6 or 7 miles of the land, they might have reached the shore but... the chances are about 99 for them to perish to one for them to survive... the place abounds in sharks of the most ravinous kind.

This mysterious incident exemplifies the mixing of cultures that was inherent in Indian Ocean whaling. It also suggests the rude awakenings and despair that became the lot of so many foremast hands in the trade.

The Seychelles: Mahe Banks, Aldabra, Fortune Banks

Several of our boatsteerers and officers, had visited the Seychelles, and described most beautifully situated, fertile, and inhabited by a very innocent and quiet-lived people... In fact, every circumstance in our lives was henceforth viewed merely as it would affect... liberty at the Seychelles... Our entire lives hinged upon that delightful name. (Norhoff, 1856)

Mahe was the nerve center of an important whaling ground which encompassed the Seychelles group, including the Amirantes and Aldabra, and extended to the northern edge of the Seychelles–Mauritius Plateau. Here the southeast monsoon (May through September) alternates with the northwest monsoon (October through April); sperm whales could be found on the Mahe bank throughout both seasons.

Because of dangerous shoals, these waters had acquired a bad reputation prior to whaling times (Delano, 1817; Graham, 1967). Merchantmen and naval vessels avoided the area, reducing the commercial importance of the Seychelles (Bullen, 1899; Graham, 1967). Nonetheless, by the 1820s several vessels were whaling the bank (Lionnet, 1972). This traffic increased toward mid-century, and the ground remained important until about 1880 (Clark, 1887; Lionnet, 1972).

The best whaling occurred on the north edge of Mahe Bank, around Bird and Denis Islands, especially from June through August (Lionnet, 1972). The grounds were visited yearly by vessels on long voyages; these kept in close touch and exchanged trade gossip in a constant attempt to outwit whales, weather and climate (S. Braley, 1845–49, 28 July 1846; H. Allen, 1868–72, 18 June 1869 ff). There were at least thirteen of these regulars on Mahe bank in 1869 (H. Allen, 1868–72).

Mahe, and to a lesser extent Praslin, might be visited two or more times by a whaler in a single year. Victoria's harbor was safe during both monsoons, and there was usually mail awaiting arriving whalers (Nordhoff, 1856):

We came to anchor at night, and at early dawn were boarded by the harbor master (whose principal business seemed to be to receive and dispence news) and shortly after by a host of natives, who brought alongside all manner of fruits and vegetables, and – wonder of wonders – some copies of a newspaper, published on the island.

...I purchased a copy for a plug of tobac. and read the news while discussing my breakfast, a compound luxury I had not enjoyed for a long time.

Seamen were seldom disappointed by liberty on Mahe. Officers, however, found stopovers a mixed blessing. Major ship repairs were expensive and slow (S. Braley, 1849–53, 10–19 July 1850). In addition, rowdyism and desertion were a real problem in so delightful a spot (S. Braley, 1854–57, 16 May 1855):

While laying there [at Victoria] I have had some difficulty with the things that alias sailors – getting drunk, getting in prison, deserting and so on. One by the name of Walker is now in prison; sentenced to one years hard labor for stabbing a police-man one named Alfred Strous got away from the ship by swimming...

Whaling skippers and their wives might enjoy brief times ashore in pleasant hotels or cottages. They were soon

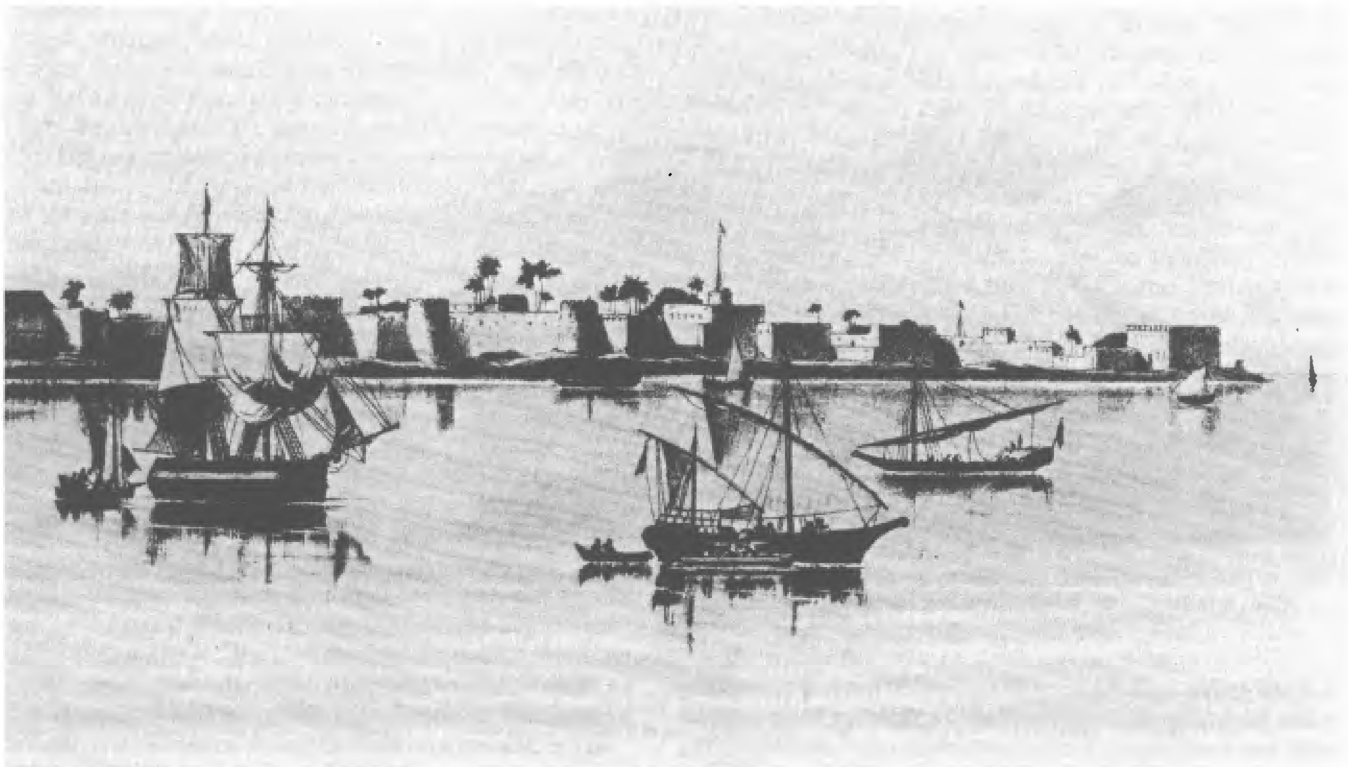

Fig. 7. N'Googa, Zanzibar. (Courtesy of the Kendall Whaling Museum.)

adopted by a genteel group of Seychellois bent on emulating European society and treated to a pleasant succession of sightseeing trips, concerts and dinners (H. Allen, 1868–72, February 1871 and *passim*; H. Allen, 1871, 19 February 1871). Surely many friendships were made during these stopovers.

By the 1880s with almost no American whalers active in the Indian Ocean, the Seychellois operated at least one whaleship out of Mahe, the *Diamantina* (Anon, 1887–90, 26 June 1888). To date little is known of that enterprise.

Mahe had one other important whaling function: it was a center for the trans-shipment of whale oil (Lionnet, 1972). Although after 1880 American and Australian vessels became scarce, there was still an occasional whaleship seen on the bank in the early 20th century (Anon, 1979).

The lonely Aldabra group, a world away from bustling Zanzibar and pleasant Mahe, was a frequent stopover for whalers. Here crews could relax and replenish food supplies gratis, for the Aldabras abounded in turtles, birds' eggs, coconuts, wood and fresh water. The Aldabras were all but uninhabited, so skippers could give their men a turn ashore without worrying much about desertions. Reprovisioning afforded restorative, quiet moments (H. Allen, 1868–72, 19 March 1869):

> ...the lagoon is a lovely place, especially in the misty light of early evening. I enjoyed it. The still water, the many islands, the little bays, capes & by ways, the deep-dark shadows – the only sounds the plashing of our oars & the voices of the sea-birds disturbed in their quiet settlements.

Revived by a few days ashore at the Aldabras, whalers might proceed west to the Zanzibar Grounds, or, depending on the monsoon, east to the Mahe Banks.

Fortune Banks provided catches of sperm whales, but were not as reliable as the Mahe Banks. Vessels usually hunted on Fortune either coming from or going to the Saya de Malha Banks.

Saya de Malha

This sperm whaling ground ran along the easternmost bend of the Seychelles–Mauritius Plateau, and was defined as 11° 30′ S to 8° 18′ S, 52° 20′ E to 59° 58′ E (Lawton, 1846–49). Most whales were taken here between February and July. Saya de Malha was apparently not much whaled until after mid-century, but it proved to be a reliable source of oil for skippers who could manage to be on hand in the proper months. For example, the *Herald* of New Bedford struck 12 and killed nine sperm during May and June of 1868 (F. Smith, 1868–69, 13 May–20 June 1868). One of the *Herald*'s officers, Frederick Smith, returned to the bank as skipper of the *Hecla*. In March and April 1870, his crew struck 13 and killed seven sperm (F. Smith, 1869–70, 3 March–23

Fig. 8. Port Louis, Mauritius, adjacent to the Mascarene whaling grounds, and a center for whaleship repair, recruitment and the trans-shipment of oil. (Courtesy of the Kendall Whaling Museum.)

April 1870). In March of 1872, Smith, now commanding the *Petrel* struck five and killed four sperm; one year later he was back again, striking and killing 18 and salvaging one found dead (F. Smith, 1861–74, 20 March 1872, 3 March–6 April 1873). Smith took 38 sperm whales in four seasons at Saya de Malha.

Mascarene Basin: Mauritius, Reunion, Rodrigues

Sperm whales could be found year round among the Mascarene Islands. Influenced by the westward flow of the South Equatorial Current, and the deeper northward flow of the Aghuelas Counter Current, the waters around the Mascarenes are abundant with sea life (Maury, 1864; Wright, 1974). Whalers working the Saya de Malha Bank or the Chagos Archipelago might conveniently extend their cruise on this ground, putting in at Mauritius, Reunion or Rodrigues. The best whaling occurred between August and December, a season which immediately preceded that on the adjacent East Madagascar Grounds, although working westward was no easy task during the northwest monsoon (October–April).

As elsewhere, whaling on this ground was at times extravagantly good (Whitecar, 1861; Beane, 1905), although whale movements remained a constant source of uncertain speculation, and the Port Louis grapevine hummed with rumors and tips (Whitecar, 1905):

> The Martha reports that the portion of the whaling fleet which went to the northward humpbacking [off Western Australia], were as unsuccessful as ourselves.... This goes to strengthen our theory of the absence of whale feed on the coast during the preceding season. The Martha made as short a stay as the Bell – both vessels having, like us, seen sperm whales near the Island of Rodrigue, and both intending to return there. Hence their haste to leave port.
>
> The next whaler that made her appearance...had accomplished nothing humpbacking, but on her passage from New Holland to this port, had captured three hundred and fifty barrels of sperm oil, in the vicinity of the Island of Rodrigue.

Port Louis, Mauritius, was the only large city of European culture in the Western Indian Ocean, so its attractiveness as a recreational stop was great. American mercantile ties with Port Louis predated whaling, and the city provided substantial ship repair, consular, recruiting and trans-shipping services (Clark, 1887; Albion, 1972). Whalers in need of such amenities were a common sight at Port Louis; yet many vessels stayed away. High prices, excessive port dues, zealous medical inspections and an eight o'clock curfew tended to discourage visits (Whitecar, 1861; Wright, 1974). So did the local bureaucracy, which combined inefficiency with officiousness (S. Braley, 1854–57, 25 May 1857):

> At 2 P.M. took a fresh breeze from S.S.E. which enabled us to reach the Road of Port Louis at 4 P.M. Got no visit from the health officer it being the Queens berth-day and I suppose that all the Public functionaries are tight or intend to be by mid-night.

Seasonal inconvenience to other grounds and the above port conditions retarded regular whaling around the Mascarenes by many vessels of the Indian Ocean fleet. This, in turn, may partly explain why Mauritius developed no fleet of her own, although in one veteran's opinion she was 'on the very best sperm whaling ground in the Indian Ocean, and the prevalence of the trade-winds and generally good weather for nine months of the year render it an eligible cruising ground' (Whitecar, 1861). Another possibility is that local oil needs were provided by home-grown coconuts (Whitecar, 1861).

Whalers sometimes called at Reunion (which lacked a sheltered harbor) or Rodrigues, where provisions were less dear; although these lonely, quiet landfalls were as seductive to deserters as the bright lights of Port Louis (Delano, 1817; Nordhoff, 1856; Whitecar, 1861; Beane, 1905; Ely, 1971). Liberty for whalemen was given warily and sparingly in the Mascarenes.

Ceylon

In the 1840s, the Gulf of Manar afforded examples of the best and worst of Indian Ocean whaling. Here sperm whales were abundant from August to December, but monsoon changes and local currents made it difficult for vessels to integrate that season with established itineraries.

Most whaling took place off the Ceylonese coast between Colombo and Galle. The grounds' importance may have lasted less than a decade.

Sam Braley spent six seasons on this ground before 1855. His journals are the most informative single source located during the research for this preliminary study; in fact they are a handbook on Ceylon whaling during its brief heyday. Arriving in November 1846, Braley's crew struck 11 and killed 10 sperm whales in one month. Working toward the equator by February, Braley killed 13 more (saving eight) east of the Maldives. This last group averaged almost 44 barrels each (S. Braley, 1845–49, 26 November 1846–24 February 1847). This was good whaling, and there were apparently few other partakers at the time.

Braley returned in September 1847 to find the Gulf full of sperm, humpbacks and finbacks, and at least five other whalers. In 14 weeks Braley killed 15 and saved 10. One of these was a lone sperm. All averaged 54 barrels each, belying the common complaint that Indian Ocean whales were on the small side (S. Braley, 1845–49, 15 September–29 November 1847). With the change of the monsoon, the whales disappeared, leaving the speculative Braley to ponder a possible connection between these phenomena (S. Braley, 1845–49, 7 January 1848):

> There has been nothing seen for six weeks past which convinces me that the whal do not visit this coast much in the NE monsoon; last year when we left we had seen nothing for a long time, and the two ships that stayed till the first of April got nothing while we in the time took 350 bbs [to the south].

Another possible factor in the whales' disappearance was the increasing number of vessels on the grounds (S. Braley, 1845–49, 14 December 1847).

Braley's return in mid-July 1848, before many other ships had arrived, netted him the small reward of two whales, averaging 15 barrels, in a month (S. Braley, 1845–49, 16 July–16 August 1848). Nothing was seen for more than a month afterward; but by late September, the whales were predictably abundant. In about six weeks Braley killed nine (S. Braley, 1845–49, 22 September–2 November 1848). Braley believed that whalemen might be overfishing this newly-popular area, remarking 'there is four ships on this little spot of groun. and if a poor whale showes his noodle he will stand a grate chance of loosing it; and is many more ships to come...' (S. Braley, 1845–49, 7 October 1848). 'Seven whalers worked off Colombo that season' (S. Braley, 1845–49, 11 October 1848).

More whalers would probably have worked Ceylon were it not for adverse currents and winds which made a westward passage all but impossible after the end of the season (S. Braley, 1849–53, 19 November 1850). Assuming, as Braley did, that the whales moved toward the equator, following them could likewise be a tactical mistake (S. Braley, 1845–49, 3 December 1848):

> The current [at the equator] is so strong to the Eastward and the wind so far to the westward that I consider it impossible to make any western without going as far south as 15° South lat and the chance for whales very small therefore I have resolved [to] run back to the North till I get the NE. monsoon and then run to the westward hoping that in passing the Ceylon ground to get a whale of which we are sadly in want.

Braley's next chance on Ceylon came in October 1850. He was in the right place at the right time, yet in a month his crew did not so much as see a sperm whale. Other vessels had similar experiences (S. Braley, 1849–53, 7 October 1850 ff). The same thing occurred in 1851, and Braley concluded that 'no whales visit that ground this season' (S. Braley, 1849–53, 20 September 1851). In 1852, the story was the same, although Braley sighted whales and killed one in the Laccadive Sea (S. Braley, 1849–53, 25–26 November 1852).

Old habits die hard; and Braley made another unsuccessful out-of-season scan in February 1855. Following an unpleasant visit at Colombo, during which he was almost overpowered by heat and humidity, Braley prenounced that port 'one of the most miserable ones in the world' and vowed never to whale Ceylon again (S. Braley, 1854–57, 11 February 1855).

Were Ceylon's sperm whale stocks in fact in decline? Whatever the case, the ground's inconvenience and the abundance of whales elsewhere probably reduced its early popularity. But a few diehards continued to whale Ceylon until 1870 or later (Anon, 1867–69, 18 April 1868; Clark, 1887).

Chagos Archipelago

Whalers leaving Ceylon at the end of the whaling season could work south and west to Diego Garcia and the other Chagos Islands, where sperm whaling was lucrative from January through May. The popularity of the Chagos grounds developed at the same time as that of Ceylon. Vessels whaling western Indian Ocean grounds below the line could conveniently sail eastward to Chagos during the southwest monsoon. Braley favored Chagos by 1850. That ground's remoteness was compensated for by abundant whales and the adjacent islands' provisions, many of which could be had for next to nothing, far from those developed ports which proved so alluring to deserters.

At Chagos as elsewhere, whalemen found their quarry abundant in general but unpredictably so in particular (S. Braley, 1845–49):

> Saturday evening 1st April 1848
> My dear Mary Ann
> Your husband Old Sam
> Is in a bad fix to night
> He cant find a whale
> Which makes [him] so ill
> He could bit off a nail or a spike
> Sunday evening 2nd April 1848
> Again Mary Ann
> Your husband Old Sam
> Has been blest by the sight of a whale.
> We chased him all day
> But I am sorry to say
> All we got was a sight of his tail.

> Worked hard all day: the whales are toughf and poor one was a little bull and never was fat: the other two were cows that had just weaned their calfs..., with udders dry and blubber any thing but fat. (19 June 1850)
> Hard luck to day – never had so hard in my life – ...and one small whale is all;...I think I never saw so many whales together as to day, and I never saw them more... (4 December 1850)

It is from this ground that a whale is described repeatedly attacking a boat even though it had not been struck.

[The first mate's boat] was [g]owing on to a whale, and when within a short distance of her she settled, and he layed his boat for another whale, but had gon but a little way, when he perceived the first whale coming under water for the boat, and too near and coming to quick to allow him a chance to avoid her: the whale took the boat amid ships with her head and broke her in nearly in two, and left her a compleat wreck...It appears that the third mate was going on to strike a whale, and when close to it another whale at a little distance ahead of the boat turned round, made for the boat on a clear rush, took her amid ships with her head, and knocked every thing flying, and started of[f] from here a little way but soon shied and came for hier in the same way again...which left her a compleet wrek, and again went of[f] as before, and again returned and as a third and last call, smashed her with her tail then left the boat and went away to the shoal...; how a boat could be smashed so and no one hurt, I cannot see but thank God such is the case... I never herd of the like, nor do I believe that a parelell to it can be found in the anals of whaling. only to think! two boats smashed, and neither of them darted a pice of craft, and both by the same whale, and she a very small cow! (20 May 1851)

A[t] 11 AM saw sperm whales lowered and got fast about noon struck 4 saved 3 and drew the Iron from the 4th...saw more whales; went for them struck one...a 100 bbler he stove a boat but with the assistance of the Bomb lance we killed him and got them all to the ship. (S. Braley, 1854–57, 10 April 1857).

Captain Braley whaled Chagos for five season with productive though not spectacular results. So did several other regulars after mid-century, although the ground suffered from drawbacks reminiscent of Ceylon. In March 1857, for example, the current took the ship *Harrison* 200 miles eastward while she was cutting in (S. Braley, 1854–57, 7 March 1857).

Accounts suggest that a social bond existed between the whaling fleet at Chagos and the local planters, whose ephemeral society was congenial to visiting vessels (S. Braley, 1854–57 9 February 1856):

To repair our disabled mast we went to Diego Garcia, an island of coral formation encircling a lagoon, There were many cocoa-nut trees on the island, and the inhabitants were occupied in making cocoa-nut oil. There were three establishments, Minnie Minnie, Point East, and Point Marrianne, each run by a few white men with their families, and several hundred blacks.

...Crowded together at the end of the pier, the ladies and children dressed in white, to my childish eyes it looked like a multitude awaiting us (H. Allen, n.d.).

Like other Indian Ocean grounds, the complex pros and cons of Chagos were based on much more than its abundant seasonal whale stocks.

Coast of Arabia

Whaling

One morning we were off the coast of Arabia near a place called Cape Morebat. It was a dead calm and not a fish to be seen, By and by the man at the mast head called out 'there goes flukes...' My father came on deck and looked with his spy glass and said it was a school of sperm whales. We got the line in the boat and bent the irons and lowered down... By and by father said that a boat was fast, then another, then another, and another, and they were all fast. In about half an hour we saw a white flag, then a blue one, and by and by we saw two more then we knew that the four whales were dead. Then another boat got fast and soon that whale was dead also... The five that we got made us eighty barrels of oil.

H. M. Allen [age eleven]

Henry Allen, born on Mauritius during one of his parents' whaling voyages, wrote the above account as a composition assignment while on board the New Bedford bark *Merlin* (H. M. Allen, 1870). The Allen family's ship was one of several which regularly whaled the coast of Arabia, the last popular whaling ground in the western Indian Ocean. This Northern Hemisphere ground evolved as an extension of activities along the Somali coast, and was apparently unfrequented by whalers until after 1850. The best whaling occurred between September and January. Capes Fartak and Mirbat, and the Khuriya Muriya Islands were the favored spots. The ground seasonally supported several vessels from about 1850 until the late 18th century. Ships characteristically moved from grounds to the east by means of the northeast monsoon. Vessels using the ground provisioned before or after their cruise in the shadow of this sere coast, of which Sam Braley, never at a loss for words, has left at memorable description (S. Braley, 1849–53, 6 January 1853):

...such a Coast! Barren and desolate: not a tree or shrub or blede of grass to be seen for miles and miles; nothing but black and brown rock piled up layer upon layer for two thousand feet; now and then the dark masses are divided by a vene of white marble which glitters in the sun light and forms a beautiful contrast with sombre neighbor like gems in the dark hair of the fair...

Whaling off Arabia was good. For example, Frederick Smith recorded the taking of 23 sperm and one blue whale by three vessels during two months of whaling in 1868 (F. Smith, 1868–69, 24 September–23 November 1868). Smith himself took eight in a month during 1870 (F. Smith, 1868–70, 15 October–11 November 1870). This study uncovered no account suggesting a reduction in whales' sizes or numbers over the years in this area, but whales taken were small.

The fleet kept in close proximity, gamming and exchanging information frequently (H. Allen, 1868–72, 18 October 1869):

Gave Captain W. nearly all the late American papers, 'Spaniards & their Country' three of Dickens' books – Some 'London Illustrated News' & some bird seed. D[avid Allen] gave him a bottle of wine & he gave *D* a box of cigars & five novels.

By 1870 the number of Yankee vessels whaling the Indian Ocean had dwindled to about 30 (Starbuck, 1878). These had perfected the knack of cooperation and sharing of secrets, a practice that seemed mutually beneficial in that region of exotic cultures, language barriers, and the perfidy of whales, winds and currents.

Right whaling grounds: Crozets, Kerguelen, Amsterdam and Saint-Paul

Right whales were abundant at sea and among islands in season. The whaling was accordingly good – at least in early times. For example, in 1836 the *Ceres 2nd* of New Bedford commenced operations at about 34° S, 60° E, and whaled due eastward to about 78° E, the vicinity of Amsterdam Island. In less than 11 weeks she killed 29 rights, noting also the abundance of blackfish, finbacks and humpbacks on the ground (Anon, 1835–37, 21 September ff). The right whaling hereabouts was strictly seasonal, but after 1840, many vessels clearing for the Crozets, Desolation (Kerguelen) or even Heard Island could supplement their cargo with seal skins and/or elephant seal oil (Starbuck, 1878). Sealing activities enhanced the attraction of these grounds, as did the fact that their northern range overlapped with sperm whaling grounds, the latter circumstance caused by the Indian Ocean's unusually southward current of warm water (Maury, 1855). (A surface sighting of giant squid occurred about 1840, northwest of Saint-Paul at about 35° S, 73° 30′ E [Samuels, 1887]).

By the 1870s, right whales were scarce, though, as with Delagoa Bay, it was unclear whether they had been

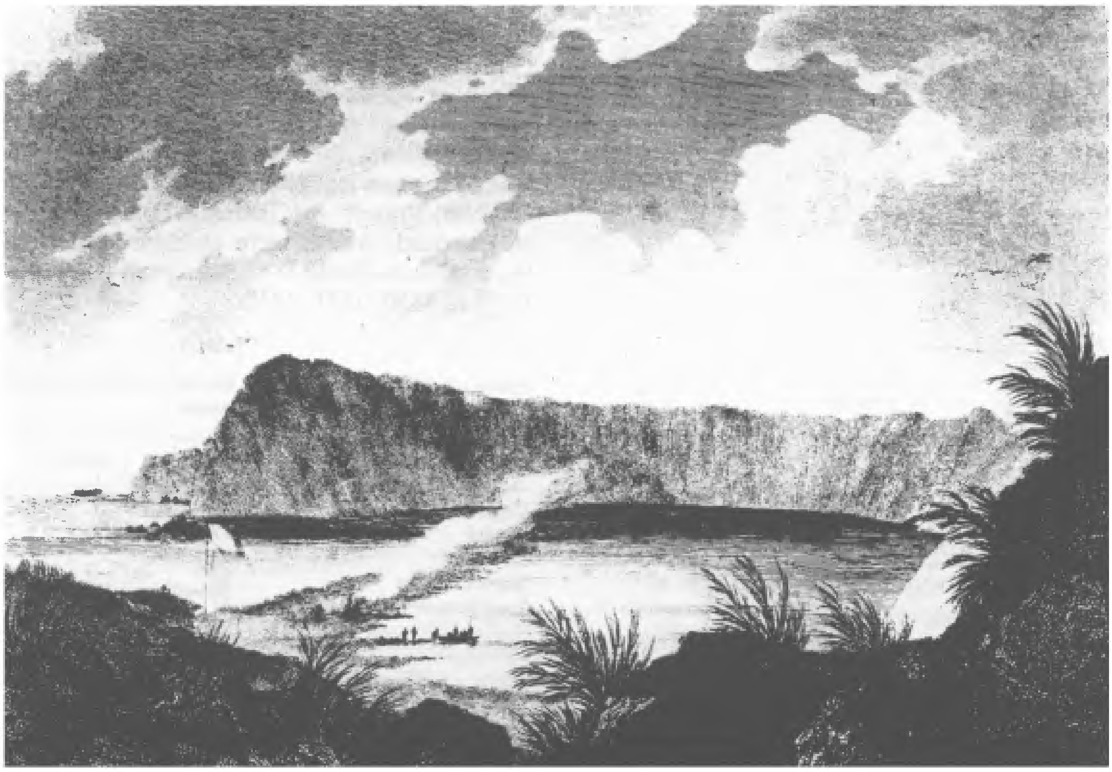

Fig. 9. A camp on Saint-Paul Island, often visited by sperm and right whalers. (Courtesy of the Kendall Whaling Museum.)

overfished or had been 'driven from the ground' (Clark, 1887). Nonetheless, vessels continued to work the area, the last Yankee whaler/sealer being the bark *Charles W. Morgan*, 1916–17 (Hegarty, 1959).

WHALING BY SPECIES

Sperm whales

Perhaps the most significant element of open-boat whaling is the concentrated effort on local populations of whales. Where whales congregated in breeding or nursery schools, vessels also came together. Whaling was not random. Whalers went directly to grounds where they expected whales to be, as the previous section relates. Besides general information shared amongst the fleets, whalers followed signs of whaling activity encountered at sea – ships boiling, cutting or lowered, carcasses and offal floating in the water – to join in fishing on a particular school. It was not uncommon for two or more ships to accompany each other on the grounds, at least for a time. A list of ships spoken and seen (Appendix A) indicates the scope of whaling activity evident even from the small sample of logbooks examined for this study. Three, four or five ships frequently whaled on the same grounds at the same time, often within sight of each other. The *Stephania*, whaling the Crozet grounds, reported six sails in sight, two ships boiling, on the morning of 4 February 1844, and ten ships in sight by that evening (J. Braley, 1847–50). The *Lancer*, cruising the Seychelles between Bird and Denis Islands, saw seven other ships on 16 June 1870 (Anon, 1869–70).

As discussed in the previous section, whalers went from ground to ground. They were following monsoon and current patterns as often as whales. Fig. 10 (below) presents sperm whaling by season and grounds. It is based on catch statistics of voyages of this report.

The effort was opportunistic: whales of all sizes were taken, including calves. It may be that large whales were selected for if possible, but the whaleboats took what they could harpoon and hang on to. A significant number were 20 barrels (bbls) or under.

Catch figures for the 19th century have been generated based on the volume of oil documented in shipping accounts and other sources, using two average yield sizes for whales: 25 bbls and 40 bbls (Kugler, 1981). Fig. 11 shows sizes, in bbls, of whales taken by ships of this study. Sizes were noted for only about one-third of the whales taken. Most whales were smaller than 25 bbls and larger than 40 bbls.

It may be that the generally-accepted 25 and 40 bbl averages are incorrect for all grounds, and further study

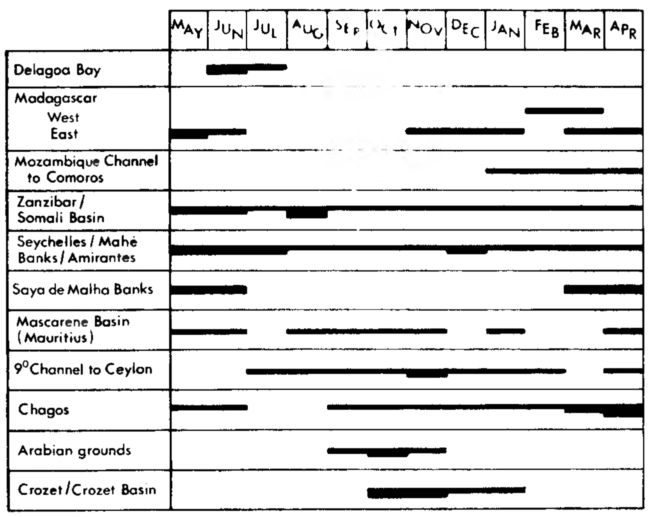

Fig. 10. Western Indian Ocean sperm whaling by season and grounds. Note: wider bar indicates increased activity.

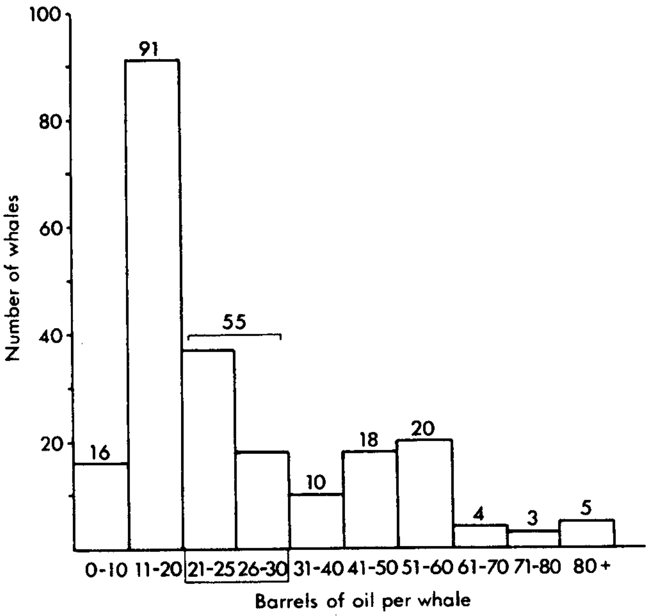

Fig. 11. Size (in bbls) of sperm whales taken in the 27 voyages of this study.

may alter them, and, subsequently, the estimates of numbers of whales taken by the open-boat fishery.

The comment that Indian Ocean sperm and right whales were undersized was widespread from earliest times. If that were indeed the case, each whaler would have required more whales than elsewhere in order to fill the hold. The prevalence of small sperm whales taken noted in Fig. 11 suggests that the bulk of the catch was females and immature animals. This is not surprising, of course, since they are the most abundant individuals in any sperm whale population. But the effect of the concentrated fishery on breeding stocks may have been significant.

Further investigations of primary sources may give clews to the sex composition of some schools. Calves are often mentioned, of course, but there may be other indicators which could assist in learning about the composition of local stocks. Since like-age (therefore like-sized) sperm whales are known to aggregate (Mitchell, 1978) and, further, segregation of sexes occurs, some speculations may be possible based on the size of whales killed, season and location. These await further inquiry.

Estimates of whales taken (derived from oil volumes) customarily include 10–15% for mortally wounded whales (Kugler, 1981). Take from the 27 voyages of this study was 520 sperm whales out of 668 struck, the success thus being 77% (Table 3). The fate of the 23% struck but lost is unknown. Besides losing whales to broken lines, drawn irons and stoven boats, lines were cut when the whale proved too strong or too dangerous, and dead whales were lost when rough weather swept their carcasses from the ship or chains parted. The *Averick* lost four whales spouting blood in Delagoa Bay when the irons broke, and whales bit through the lines (Shearman, 1834–36). The *South Carolina* took a stinker with two irons and a spade attached to it (Taylor, 1835–37). The *Arab* struck one whale 'over and over and still lost it' (S. Braley, 1849–53). Death times are not available, but the fishery is generally believed to have been inhumane. There are numerous notations of whales pulling boats for hours.

Did sperm whales decline?

Our sample does not permit speculation about the general health of sperm whales in the western Indian Ocean. There are, however, comments in the manuscripts which would indicate the whalemen themselves believed the whales became less plentiful in some areas. The voyages of Sam Braley, for instance, off Colombo may be summarized: whales were abundant and large in 1846; less so and smaller in 1847; scarcer still in 1848; none were there in 1850, 1851, 1852.

Table 3

Sperm whales struck, lost, saved, and times whaleboats lowered without success

Vessel	Struck	Saved	Lowered
Kingston	14	13	0
Averick	17	10	12
Ceres 2nd	29	17	2
South Carolina	14	5+3 stinkers	2
Good Return	19	11	24
Maria	53	39+2 stinkers	19
Marcella	47	35	14
Arab	89	61+1 stinker	
Montezuma	13	10	15
Stephania	3	0	7
Arab	40	28	
Harrison	40	31	
Thomas Pope	21	7	6
Messenger (2 mos)	0	1 stinker	0
Benjamin Franklin (2 mos)	0	0	0
Sea Fox	17	17	11
Herald	52	45+1 stinker	6
Hecla	25	19+3 stinkers	2
Sea Fox	3	2	
Lancer	5	4	12
Petrel	45	42+1 stinker	6
Avola (2 mos)	1	1*	0
Marcella	51	50+1 stinker	5
Avola (1 mo)	0	0	0
Avola (2 mos)	0	0	1
Mermaid	39	33+2 stinkers	7
Mermaid	31	24	2
Totals	668	520	153

* Took whale with a bomb-lance, using three bombs. Note: stinkers retrieved do not necessarily belong to the boat that finds them.

The effort on Indian Ocean sperm whales peaked about 1846 (Starbuck, 1878). Logbooks of the *Maria* (1844–46) and the *Marcella* (1845–46) both contain many entries about the whales being 'shy,' and long days spent 'chasing whales' without success ('lowered but couldn't get near them' is a typical entry) (Holley, 1843–46; Hinkley, 1844–46). The *Montezuma* (1847–48) records whales being 'gallied' (frightened) by the whaleboats, and the *Stephania* reported from the Crozet Basin 27 January 1850: '... saw plenty of whales as wild as devils' (Lawton, 1846–49; J. Braley, 1847–50). Later logbooks (the *Avola*, 1875–77, and the *Mermaid*, 1886–88) also note whales being 'gallied,' one time by fin whales (Morrison, 1870–74, 1874–77; Anon, 1886–87, 1887–90). Logbooks from the 1850s and 1860s reveal long periods of inactivity without sighting whales. From the reports, it is clear that sperm whales became more difficult to approach over time, and more effort was required once they were sighted. Ships speaking each other also reported fewer whales seen.

It is difficult to draw a correlation between the number of whaleships operating and the abundance of Indian

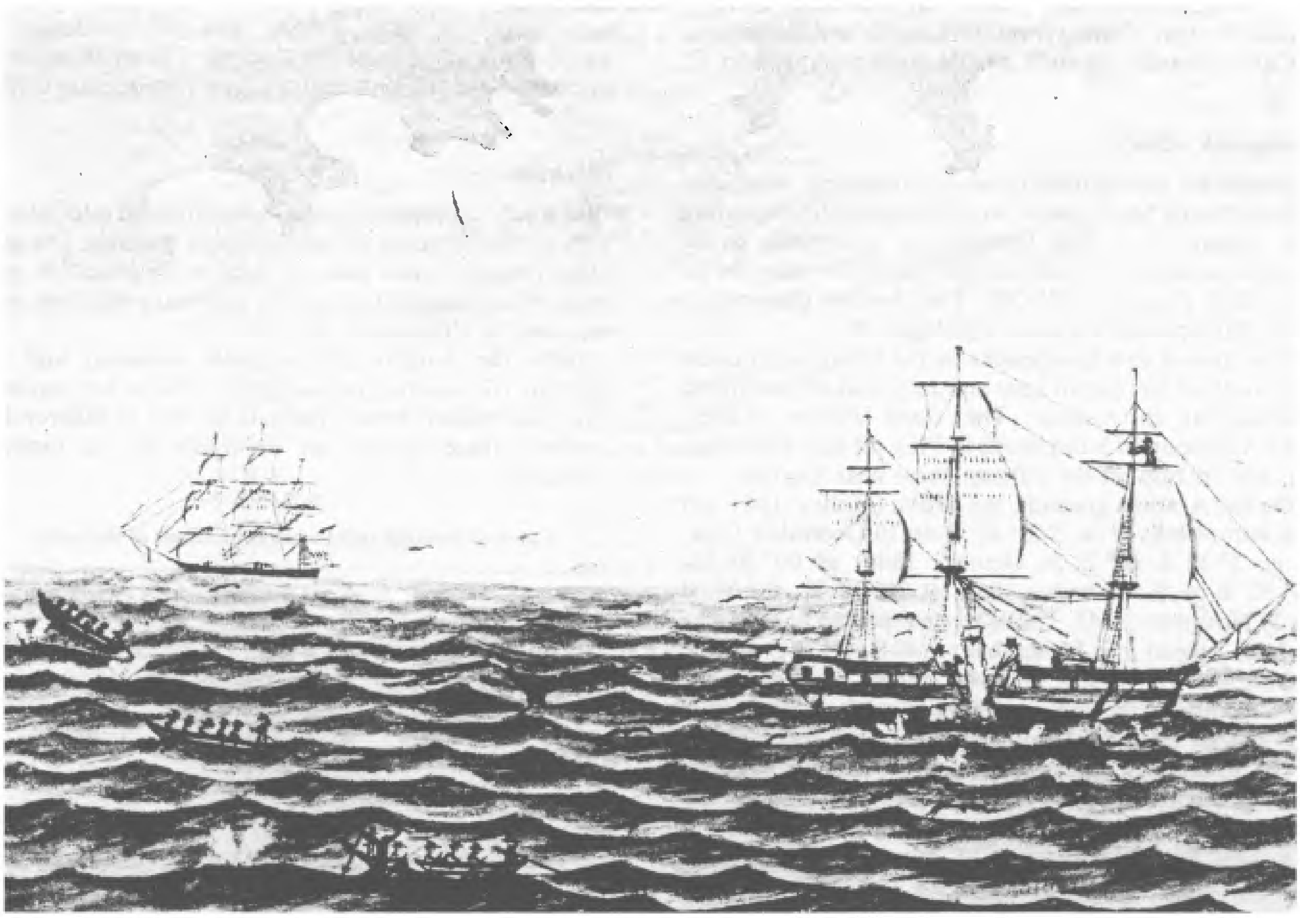

Fig. 12. 'Ship South Carolina Right Whaling', a watercolor from the Indian Ocean journal of whaleman William W. Taylor, 1835–37. (Courtesy of the Kendall Whaling Museum.)

Ocean sperm whales, because political factors had an important influence on the fishery. The industry was unnaturally restricted during the Napoleonic period, for instance. Likewise, although the number of Yankee vessels whaling the Indian Ocean had dropped sharply after 1846, it plummeted during the uncertainties of the American Civil War (see Fig. 2), and did not much revive in peacetime. There were thereafter perhaps no more than a dozen Yankee whalers working the western Indian Ocean in any year, although British colonial whalers may have at least equaled that number.

If it is so that the number of whales correlates with catch effort, the diminished effort in the western Indian Ocean by and after mid-century may well indicate serious overfishing. While the general decline of 19th century sperm whaling has been attributed to a number of economic and other factors, there are persuasive indicators that overfishing played an important part (Starbuck, 1878; Holman, 1928; Shuster, 1972).

The catch of sperm whales by vessels of this study, with coordinates (where known) is set forth as Appendix B.

Right whales

Almost all of the 74 right whales noted killed by vessels under examination were taken in the Crozet grounds (including Crozet Basin), and off Amsterdam Island. However, the *Good Return* took one right whale in Sofala Bay (20° 24′ S – 34° 31′ E), and two others at 25° 45′ S – 35° 24′ E. This latter kill was a female and calf. The female was killed and brought to the ship, but because of rough weather, cutting in was left for the morning. At dawn the calf was still accompanying its dead mother, and it was killed.

Size (in number of bbls) is given for only 11 of the whales taken, with an average yield of 59 bbls. The largest noted was 80 bbls. However, the *Averick*'s chronicler observed the *Zephyr* boiling a 200 bbl cow whale in the Crozet grounds 6 March 1835 (Shearman, 1834–36). a number which seems questionable. None of the ships under study took right whales after 1850 (some were still taken at Tristan de Cunha coming to or leaving the Indian Ocean).

Almost all right whales reported from the manuscripts examined were in small groups of two to four whales. The *Good Return* logbooks notes 'they have calfs' when right whaling in Sofala Bay on 3 July 1842 (Taber, 1841–43). This entry further reports three right whales 'going south' were seen.

It is interesting to note that although the price of whalebone rose dramatically – from 21¢ per pound in 1835 to $1.72 per pound in 1865 – right whaling did not increase in the western Indian Ocean grounds. Quite the contrary. The whalemen knew the grounds and seasons well, so the absence of effort at a time of high prices may well mean that the grounds were seriously overfished.

There is a further point which will require additional examination of sources. While sealers took elephant seals on Desolation (Kerguelen), whalers did not do so until after the peak whaling years of the 40s. Thereafter, 'whale oil' was frequently a mix of right whale and elephant seal oil. The figures from this period may thus mask an early decline in right whaling from the Crozets and Kerguelen.

Catch statistics on right whales given as Appendix C.

Humpback whales

Humpbacks were pursued around southwest, southeast and northeast Madagascar, and Mozambique, including one report of a ship fastening a humpback in St Augustine Bay itself, seen by the *South Carolina* on 20 July 1836 (Taylor, 1835–37). The *Averick* (Shearman, 1834–36) reported the most sightings: 30.

The *Averick* saw humpbacks on the Delagoa grounds, and south of Durban in June and July, and off southwest Madagascar in August. The *Good Return* (Taber, 1841–43) reported humpbacks in May off east Madagascar, and in July off the African coast near Durban.

On the Arabian grounds, the *Maria* (Holley, 1843–46) saw humpbacks at *ca.* 3° S–42° E on 30 December 1844; at *ca.* 2° 30′ S 48° E 26 October 1845; at 00° 20′ N–46° 50′ E on 8 November 1845; at 00° 08′ S – 48° 07′ E on 21 November 1845. The *Marcela* reported humpbacks in July, August and September *ca.* 4° S–41° E.

The *Arab* (S. Braley, 1845–49) sighted one humpback off Colombo in the winter of 1846. No other sightings of this species from the Ceylon grounds were reported.

No humpback sightings appeared in the logbooks under examination after Braley's 1846 sighting until the *Lancer* killed three (lost one, took a female and calf) in Antongil Bay, Madagascar, in July and August 1872 (Anon, 1869–73). Humpbacks are not reported from northeast Madagascar in these months by Slijper *et al.* (1964), but Antongil Bay was an active humpbacking area in the 19th century.

The *Avola* saw one humpback off Madagascar in 1873 (Morrison, 1870–74). The *Mermaid* (Anon, 1887–90) reported 'jumpers' off east Madagascar in May 1888. She also reported humpbacks in October at 5° 52′ N–50° 16′ E (Seychelles). These reports from the *Mermaid* are from areas and times not noted on the charts of Slijper *et al.* (1964) from recent years.

Because of the small number of humpbacks noted killed by vessels of this study, catch statistics are given as Table 4.

Table 4

Catch of humpback whales reported from this study

Date	Vessel	Location	Number/size
7/17/35	*Averick*	27° 19′ S–33° 50′ E	1
9/5/35	*Averick*	in Augustine Bay	1
9/28/36	*Ceres 2nd*	Madagascar	2 (?)
7/29/72	*Lancer*	Antongil Bay	1 (lost)
8/8/72	*Lancer*	Antongil Bay	2 (♀+calf = 35 bbls)

Although few humpbacks were killed by vessels studied here, world-wide effort increased on these animals after 1850. Humpbacks yielded a high-grade oil, but were more difficult to take than sperm whales. Yankee whalers became adept at fishing on humpbacks, which required skills different from sperm whaling.

The number of humpbacks taken in the 19th century may be underestimated. It is puzzling why more attention has not been paid to open-boat humpback whaling, in view of the abundance of published accounts of the fishery. This species was taken in breeding grounds (see the accounts from Madagascar in the previous section). Breeding grounds probably couldn't support a large fishery, but a large fishery was not necessary to significantly affect local populations. The whole effort on humpbacks in the 19th century is an area begging further study.

Blackfish

'Blackfish', as 19th century whalemen called pilot whales, were encountered on all Indian Ocean grounds, and were often pursued when seen. A total of 29 blackfish were taken by voyages of this report, and many sightings were recorded at all times of the year.

Both the longfin (*Globicephala melaena*) and the shortfin (*G. macrorhynchus*) pilot whales are reported from the Indian Ocean. There is no way to differentiate between these species on the basis of the logbook accounts.

Table 5

Catch of blackfish (pilot whales) by vessels of this study

Date	Vessel	Location	Number/size
6/14/35	*Averick*	26° 07′ S–34° E	1
9/3/36	*Ceres 2nd*	36° S–37° E	9
10/11/36	*South Carolina*	34° 52′ S–69° 18′ E	2 (?)
1/9/37	*South Carolina*	37° 40′ S–59° E	1 (1 bbl)
1/10/42	*Good Return*	40° 33′ S–26° 50′ E	9
8/3/42	*Good Return*	24° 56′ S 33° E	2
9/9/44	*Maria*	9° 45′ S–48° 40′ E	1
4/8/44	*Maria*	*ca.* 8° S–48° E	1
4/17/45	*Marcella*	*ca.* 9° S–41 °E	1
2/3/48	*Montezuma*	standing off Colombo	2
3/1/48	*Stephania*	33° S–65° 12′ E	4
3/4/48	*Stephania*	37° 48′ S–68° 36′ E	4
4/1/48	*Montezuma*	Saya de Malha	1
2/11/50	*Stephania*	*ca.* 44° S–48° E	3
3/17/50	*Stephania*	40° 16′ S–45° 00′ E	1
3/29/68	*Sea Fox*	4° 55′ S–72° 55′ E (Chagos)	2
10/31/72	*Petrel*	South Somali coast	1
11/4/72	*Petrel*	South Somali coast	1
4/17/73	*Petrel*	off Mahe	1
9/15/74	*Marcella*	NE of Pemba	1 (60 gals)

Porpoise

Many species of dolphins and porpoises are recorded from the Indian Ocean. The 19th century whalemen did separate out some species, e.g., 'cowfish', which were probably *Tursiops truncatus* (Melville, 1962), grampus and killer whales. The latter two species were not caught, but porpoises were generally taken as they rode the bow-wave of whaleships. There is one record of lowering for porpoises, but that was not normal practice. Porpoises were sometimes struck and lost. The meat was sometimes eaten, and the blubber was rendered.

There are abundant sightings of porpoise in all the manuscripts, at all times of the year, on all grounds. Mixed schools of small cetaceans are often reported: cowfish in company with blackfish and other porpoises.

Catch statistics on porpoise are attached as Appendix D.

Blue whales

Blue whales ('sulphur-bottoms') are often reported, and one was taken by the *Herald* 12 December 1868 off Khuyira Muyira, which made 75 bbls (F. Smith, 1868–69). In logbooks consulted here, blue whales were seen on the Crozet grounds in February, and the Arabian grounds

Table 6

Blue whale sightings reported in manuscripts of this study

Date	Vessel	Location	Remarks
5/28/36	*South Carolina*	21° 18′ S–41° 15′ E	
10/3/36	„	32° 20′ S–68° 32′ E	
10/12/44	*Maria*	Mozambique Channel	
2/3/49	*Stephania*	*ca.* 44° S–48° E	
2/13/49	„	44° 02′ S–49° E	
2/24/49	„	44° 55′ S–48° 39′ E	'plenty of sulphur-bottoms'
2/9/50	„	off Crozets	
12/12/61	*Messenger*	*ca.* 7° S–57° E	
0/7/74	*Marcella*	Arabian grounds	
11/9/74	„	near Socotra	
11/29/74	„	past Cape Guadofi	
11/30/74	„	past Cape Guadofi	
3/17/75	„	Fortune Banks	
5/20/74	„	Saya de Malha	
9/17/74	„	near Socotra	
9/28/74	„	near Socotra	
10/14/74	„	Fartak	
1/17/75	*Avola*	37° 55′ S–51° 03′ E	
1/24/75	„	39° 26′ S–73° 42′ E	
1/31/75	„	37° 20′ S–95° 41′ E	'plenty...'
8/26/77	„	W of Rodrigues	'plenty...'
3/14/86	*Mermaid*	17° 28′ S–42° 23′ E	
5/13/86	„	31° 28′ S–42° 25′ E	
5/17/86	„	30° 56′ S–42° 29′ E	
5/29/88	„	29° 50′ S–48° E	
10/6/88	„	00° 55′ S–42° 45′ E	
10/14/88	„	7° N–50° 49′ E	'lots...'

from September through November. One was seen in the Mozambique Channel in October, and others were sighted on the Saya de Malha Banks in May.

Rorquals

All rorqual whales are called 'finbacks' in the manuscripts. Minke, sei and Bryde's whales are known from the Indian Ocean, and presumably some of the whales noted as finbacks were these other species. Sightings of finbacks were frequent at all seasons. Breaching finbacks are also reported. Whalers occasionally lowered on finbacks, especially in times of boredom. One finback was struck and lost by the *Maria*, the logbook of which also contains a reference to shooting at a finback with a musket, apparently from the deck of the ship, so the whale must have been close to the vessel (Holley, 1843–46). The *Marcella* also struck and lost a finback, and lowered once without success (Hinkley, 1844–46).

Sam Braley of the *Arab* reported 'abundant' finbacks in the Gulf of Manar in 1847 (S. Braley, 1845–49). Finbacks were reported around Madagascar, on Saya de Malha, the Mascarene Basin, the Crozets, the Arabian grounds, Somali Basin, and the Seychelles.

The *Montezuma* reported fin whales 'gallied' a larger sperm whale so that they missed him (Lawton, 1846–49).

Data have not yet been quantified on all the finback sightings reported in the manuscripts examined, but our impression is that they were seen more frequently at all seasons than data reported by Slijper *et al.* (1964), e.g., off Seychelles in February and August. The vessels did not sail lower than the Crozets (*ca.* 47° S), so it is not known if minkes were also sighted and called finbacks.

Other cetaceans

Killer whales were always differentiated from 'grampus' in the manuscripts examined. Killers were reported from Saya de Malha, and especially from the Arabian grounds and Delagoa. Grampus were frequently noted, often in company with blackfish.

The logbooks further note puzzling sightings of 'white grampus' (possibly *Grampus griseus*?), 'square-nose grampus' (this seen breaching), and 'peaked-nose whale' (also breaching).

CONCLUSION

American whalers made more than 1,350 voyages to the Indian Ocean in the 19th century. This most conservative estimate is based upon Starbuck's and Hegarty's admittedly incomplete tallies of vessels cleared specifically for the Indian Ocean (Starbuck, 1878; Hegarty, 1959). Our list of vessels spoke and seen includes dozens of ships not listed on these tallies.

The impact of this onrush to Indian Ocean whale stocks is more than implicated in this preliminary study. The importance of whaling on other resources – turtles and forests, for instance – was considerable. Also important was the commercial and cultural influence: interaction with non-technological people, plantation economics, and the sprinkling of deserters and others who remained throughout the region. The introduction of trade goods such as iron and weapons impelled political and social changes in some areas.

The men who brought back tales of wonder of exotic places to home ports were the same men who complained bitterly of the boredom and harsh shipboard conditions, but continued to chase the whale. Whaleman Prince Lawton on the *Montezuma* (1846–49) doubtless spoke for thousands of men who had little else but whaling on their minds when he wrote (24 April 1847):

> ...5 PM we saw a Large Sperm whale rising and then he went down and the Sun with him and may Joy go with him all to make him fat.

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Appendix A

SHIPS SPOKE AND SEEN

Date	Vessel	Number/barrels	Location
By *Averick*			
3/6/35	*Zephyr* of New Bedford	boiling 200 bbl cow	23° 50′ S–43° 10′ E
3/18	*Thomas Milridge**		25° 07′ S–43° E
3/20	*Zephyr* of New Bedford		25° 31′ S–43° 45′ E
	London Packet of Fairhaven		
3/21	*Louisa* of Lynn	600	36° 30′ S–42° 48′ E
	George & Martha of New Bedford	800	
	George of Nantucket	400	
3/29	*John* of New Bedford	850 whale/70 sperm	
4/4	*Mozambique* (not US, home port unknown)	1,500	
4/5	*Zephyr, Mozambique*, 2 other ships in sight		24° 10′ S–43° 00′ E
4/7	*Thomas Milridge**		St Augustine Bay
	Albion of Fairhaven	800	
	London Packet	1,200	
	George of Nantucket	500 whale/70 sperm	
	*Tristan Bailey**		

Appendix A *(continued)*

Date	Vessel	Number/barrels	Location
	Mozambique (see above)	1,500	
	Zephyr of New Bedford	1,200	
	Herald 2nd of New Bedford	500	
	Famous of Bristol		
	*Mary Howes**		
4/9	*Good Return* of New Bedford	19?	St Augustine Bay
	Washington of Sag Harbor	1,500	,,
4/14	*Janeton Bayly**		,,
4/18	*Eastham**	4 whales	,,
4/22	Saw five ships		*ca.* 24° S–42° E
4/30	*Good Return* of New Bedford		22° 36′ S–39° 48′ E
5/5	*Herald 2nd* of New Bedford		23° 55′ S–36° 14′ E
5/9	*Hope* of New Bedford	750 whale/40 sperm	27° 22′ S–36° 36′ E
5/27	*James Monroe* of Hudson	200	26° 27′ S–36 °E
	Zephyr of New Bedford		
6/13	*Chile* of New Bedford	1,000 whale/25 sperm	*ca.* 26° 18′ S–33° E
	(Name blank)	1,100 whale/50 sperm	
6/18	*Neptune*	took 1 whale	26° 43′ S–33° 54′ E
6/20	*Neptune* of New London? Sag Harbor?	800/40 sperm	26° 36′ S–33° 38′ E
7/9–10	*Good Return* of New Bedford	took 1 sperm, 1 humpback	27° 18′ S–34° E
7/14	*Neptune* of New London? Sag Harbor?		28° 33′ S–34° 15′ E
7/16	*Hope* of New Bedford	150 sperm	27° 38′ S–34° E
7/21	*Good Return* of New Bedford	had one 50 bbl whale spouting blood	27° 06′ S–33° 25′ E
8/14	18 ships, 2 barks in port		St Augustine Bay
9/5	*Hercules 2nd* of New Bedford	humpback whaling	,,
By *South Carolina*			
4/3/36	*Cicero* of New Bedford	1,100 whale/100 sperm	*ca.* 23° S–40° E
4/4	*Marcia* of Fairhaven		St Augustine Bay
	White Oak of New York		
	Reaper of Salem		
	*Trust**		
	Bengal of Salem		
	Shylock of Rochester		
	Portland of New York		
	Brandt of New Bedford		
	Falcon of New Bedford		
	Palladium of New London		
4/13	*Janus* of New Bedford	1,100	St Augustine Bay
4/25	*Galconda* of Bristol		22° 40′ S–39° 35′ E
5/23	*Portland* of New York	75	22° 44′ S–45° 25′ E
	Heard from		
	Xenophon of Sag Harbor	140	
	Cicero of New Bedford	300	
	General Pike of New Bedford	400	
6/28	*Emile**		22° 57′ S–41° E
7/2	*Java* of New Bedford	8 right/360 sperm	St Augustine Bay
	North America of Warren	50 bbls in Channel	
	Portland of New York	125 bbls in Channel	
	Palladium of New London	125 bbls in Channel	
7/4	*Atlantic* of Bridgeport	130 bbls in Channel	,,
7/6	*James* of New Bedford	60	,,
7/7	*Janus* of New Bedford	60 bbls in Channel	,,
7/8	*Lord Sidney**		,,
7/11	*Reliance* of Nantucket (?)		,,
7/13	*Rajah* of New Bedford	40	,,
7/20	*Galconda* of Bristol	fastened a humpback in St Augustine harbor, had to cut line	
	Phocian of New Bedford	240	
7/22	*Xenophon* of Sag Harbor	200	
	Bayard of Greenport	20	
7/23	*Atlas* of Lynn	1 right	
7/26	*Ceres 2nd* of New Bedford	360 sperm	
8/26	*Two Brothers* of New Bedford	13 whales off Amsterdam since 1 May	off Amsterdam Island
	Heard from: *Mary Ann* of New Bedford	18 whales	
8/30	*Hibernia* of New Bedford	5 whales off Amsterdam	,,
9/7	*Connecticut* of New York	2 sperm	,,
9/9/36	*India* of New Bedford	90 days out – clean	off Amsterdam
	Philetes of Stonington	350	
9/11	*Falcon* of New Bedford	3 months – clean	,,
9/14	*Hibernia* of New Bedford	8 whales	,,
	Georgia of New London	2 whales today	
	Emerald of New Bedford	11 whales	
	Tuscarara of New London	15 whales	

Appendix A (*continued*)

Date	Vessel	Number/barrels	Location
9/19	*Two Brothers* of New Bedford		*ca.* 36° S–76° E
10/1	*Courier* of New Bedford	4 months – clean	32° 54′ S–70° E
10/9	*Lucy Ann* of Wilmington	took 2 whales	34° 28′ S–69° 22′ E
	Lucas of New Bedford	4 months – 2 whales	
10/13	*Stephania* of New Bedford	900/350 sperm	34° 11′ S–70° 30′ E
10/14	*Atlantic* of Bridgeport	2 whales this season	”
10/16	*Tuscarara* of New London	1,200	34° 14′ S–69° 42′ E
10/13	*Messenger* of New Bedford	900	34° 20′ S–69° 31′ E
10/28	*Triton* of Plymouth	900/150 sperm	32° 39′ S–71° 21′ E
11/7	*Hunter* (Bristol? Warren?)		33° 01′ S–73° 33′ E
11/9	*America* of Bristol? Warren?	200 bbls since 2 July	33° 27′ S–73° 20′ E
	two ships in sight boiling		
11/18	*Triton* of Plymouth	took a whale	*ca.* 34° S–72° E
11/20	*Hunter* (Bristol? Warren?)	1,100	”
11/22	*Triton* of Plymouth	1,400	”
11/26	*Triton* of Plymouth	cutting 2	”
12/9	*Sally Anne* of New Bedford	1,500	35° 26′ S–72° 40′ E
12/10	*Java* of New Bedford	1,950	35° 34′ S–71° 23′ E
	Heard from: *Hibernia* of New Bedford	1,750	
12/23	*George* of New London		39° 09′ S–68° 02′ E
12/29	*Neptune* of New London? Sag Harbor?	1,400	40° 35′ S–61° 05′ E
	Margaret of St Johns	1,400	
	Falcon of New Bedford	1,300	
By *Good Return*			
1/31/42	*Portland* of New York	1,700	*ca.* 45° S–50° E
	Phocian of New Bedford	600	
2/10	*Florida* of New Bedford	900	*ca.* 45° S–49° E
8/12	*Fosdick* of New Bedford	500	St Augustine Bay
	Elizabeth of Mattapoisett	300 sperm/300 whale	
10/29	*Octavia* of New Bedford		34° 38′ S–63° 45′ E
11/29	[Undecipherable] of Fairhaven		*ca.* 34° S–66° E
12/5	[Undecipherable] of New Bedford	1,900	*ca.* 35° S–84° E
By *Maria*			
3/13/44	*Minerva* (?) of New Bedford	900 sperm	9° 18′ S–47° 30′ E
3/14	*Lafayette* of Warren	1,200 sperm	”
4/29	*Peri* of New Bedford	50 sperm	near Johanna
5/5	*Vesta* of Edgartown	250	Johanna
	Maine of Boston	250	
	Penobscot of Nantucket	220	
7/12	*Leander* of Mystic	750	near Comoros
9/27	*Emerald* of New Bedford	passed boiling	Coast N of Zanzibar
11/28	*Peri* of New Bedford	200	*ca.* 2° S–51° E
12/7	*Japan* of London	1,500	”
12/7	*Peri* of New Bedford		*ca.* 3° S–45° E
5/12/45	*Morrison* of New Bedford	650	off Denis Island
6/15	*Martha* of Plymouth	300	near Comoros
6/26	*Penrod**	850	”
7/1	*Maine* of Boston	400	”
7/6	*Martha* of Plymouth		Comoros
	Charleston of New London		”
7/25	*Lucinda**	1,500	Johanna
	Martha of Plymouth	300	
	Emma of New Bedford	450	
	Dove of New London	400	
9/19	*Marcella* of New Bedford	200	5° 30′ S–42° 14′ E
10/2	*Emma* of New Bedford	700	2° 30′ N–52° 50′ E
2/3/46	*Marcella* of New Bedford	350	off Aldabra
By *Marcella*			
3/15/44	*Cornelia* of New Bedford	500/140 sperm	25° 30′ S–38° E
4/26	*United States* of Stonington	700	9° 07′ S–46° 20′ E
5/5	*Cornelia* of New Bedford	500/150 sperm	9° 20′ S–45° 46′ E
5/6	*Peri* of New Bedford	500	10° 03′ S–45° 08′ E
6/1	*Arab* of Fairhaven	1,650 sperm (2,300 bbls)	Johanna
	Maine of Boston	450 sperm	
	Maria of New Bedford	700 sperm	
	Harbinger of Westport	6 months – clean	
	*Finback**	1,600	
6/13	*Charleston* of New London	400/300 sperm	*ca.* 11° S–45° E
6/21	*Martha* of Plymouth	600	*ca.* 8° S–46° E
8/28	*Triton* of Plymouth	1,600	*ca.* 4° S–41° E
9/5	*Triton* of Plymouth		5° 41′ S–42° 23′ E
2/3/46	*Maria* of New Bedford	850	*ca.* 9° S–45° E
2/18	*Emma* of New Bedford	940 sperm	near Aldabra
3/22	*Heliner* (home port unknown)*	cruising for slaves	*ca.* 8° S–42° E

Appendix A *(continued)*

Date	Vessel	Number/barrels	Location
5/25	*Hector* of New Bedford	250 sperm	5° 30′ S–42° E
6/18	*Lafayette* of Warren	400 sperm	Comoros
7/19	*George Washington* of New Bedford	350	off Aldabra
8/2	*George Washington* of New Bedford	350	11° 40′ S–40° 47′ E
By *Montezuma*			
4/13/47	*George Washington* of New Bedford	850	off Johanna
4/27	*Peri* of New Bedford		Comoros
5/18	*Diamond* of New Bedford		off Johanna
5/24	*Arab* of Fairhaven	600	Comoros
5/28	*United States* of Westport		near Aldabra
6/14	*United States* of Westport	whaling	,,
6/17	*Cornelia* of New Bedford	350	,,
7/4	*United States* of Westport		near Assumption
	Cornelia of New Bedford		
	Phocian of New Bedford		
7/28	*Leander* of Mystic	700	Fernandelos Bay
7/29	*Peri* of New Bedford		,,
	Delta of Greenport		
8/23	*Hector* of New Bedford	1,000	Johanna
9/5	*United States* of Westport	480	Comoros
11/1	*Diamond* of New Bedford	700	Arabian grounds
12/13	*Hecla* of New Bedford	350	off Colombo
	Arab of Fairhaven	1,300	
	Clarice of New Bedford	300	
1/20/48	*Bartholomew Gosnard* of New Bedford	104	,,
1/27	*Griffin* of London*	70	,,
3/28	*Bright Planet* of London*		Saya de Malha
4/18	*Leonides* of Westport	66	Fortune Banks
5/4	*Phocian* of New Bedford	a-whaling	near Aldabra
5/11	*Emma* of New Bedford	230	Johanna
5/16	*United States* of Westport	800	Comoros
5/21	*Phocian* of New Bedford		near Aldabra
6/1	*Phocian* of New Bedford		,,
6/10	2 ships, 2 barks, 1 brig in sight		,,
6/13	*Emma* of New Bedford		,,
6/17	*Phocian* of New Bedford		,,
	Maria of New Bedford		
6/23	*Daphne* (home port unknown)*	got a 50 bbl whale	,,
By *Stephania*			
9/3/48	Unidentified French bark*		off Madagascar
1/1/49	*Oronoke* of Greenport	230 sperm/150 whale	44° 03′ S–49° 01′ E
1/5	*Oronoke* of Greenport	took 1 whale	42° 22′ S–48° 40′ E
	Julius Caesar of New London	took 1 whale	
1/12	*Canton* of New Bedford		44° 00′ S–48° 50′ E
	Nile of Greenport	took 1 whale	
1/21	*Henry* of Sag Harbor		*ca.* 44° S–49° E
	Philip the First of Greenport		
1/26	*Carolinus* of Mystic	4 whales this season	*ca.* 44° S–48° E
1/27	*Canton* of New Bedford	3 whales this season	45° 00′ S–48° 40′ E
2/4	6 sails in sight, 2 ships boiling		44° 27′ S–48° E
	PM 10 ships in sight		
2/10	*Canton* of New Bedford	4 whales this season	44° 50′ S–49° 40′ E
2/21	*Julius Caesar* of New London	8 whales this season	*ca.* 44° S–50° E
2/27	*Julius Caesar* of New London	took a whale	,,
3/4	*Julius Caesar* of New London	took 2 whales since 2/27	*ca.* 44° S–48° E
3/15	*Julius Caesar* of New London		,,
1/9/50	*United States* of Westport	700 bbls elephant oil	*ca.* 44° S–49° E
1/11	*Hibernia* of New London	3 months – clean	,,
2/7	*South Carolina* of New Bedford	1,300/300 humpback	45° 00′ S–49° 40′ E
2/28	*Henry* of Sag Harbor		44° 30′ S–50° 42′ E
3/8	*Nimrod* of Sag Harbor	1,100	44° 50′ S–50° E
By *Thomas Pope*			
1/20/60	*Endeavor* of New Bedford		
3/19	*Pioneer* of New Bedford	350	
	Hope of New Bedford	clean	
3/28	*Sea Fox* of Westport	500	
4/7	*Janet* of Westport (?)	150	
1/19/61	*President* (2nd?) of New Bedford	200	
1/25	*Joseph Maxwell* of Fairhaven	400	
6/1	*Zephyr* of New Bedford	500	
4/16/62	*Brewster* of Mattapoisett	500	
4/29	*Young Phoenix* of New Bedford	100 bbls in last 5 days	off Rodrigues
5/10	*Young Phoenix* of New Bedford	took a whale	,,

Appendix A (*continued*)

Date	Vessel	Number/barrels	Location
By *Messenger*			
10/30/61	*Pamelia* of New Bedford		off Mauritius
11/2	*Pamelia* of New Bedford		"
	Kathleen of New Bedford		"
By *Sea Fox*			
6/19/68	*John Dawson* of New Bedford		off Bird Island
7/4	*Mary Frazier* (?)		" " "
7/8	*Elizabeth* of Westport		" " "
7/31	*Thomas Winslow* of New Bedford		Johanna
8/7	*Herald* of New Bedford		"
10/18	*Elizabeth*		off Fartak/Morbat
	Thomas Winslow		" " "
	Herald		" " "
11/14	*Lawrence* (?)		near Fartak
12/23	*Para* of Salem		" "
By *Herald*			
4/24/68	*Elizabeth* of Westport	100	Saya de Malha
5/23	*Young Phoenix* of New Bedford		"
7/68	*Sea Fox* of Westport		Seychelles
	John Dawson of New Bedford		"
10/22	*Para* of Salem		Cape Fartak
10/24	*Thomas Winslow* of New Bedford		"
By *Hecla*			
10/70	*Merlin* of New Bedford		off Arabia
10/16	*Herald* of New Bedford	took 7 whales today, 3 a few days previous	"
12/70	*Orray Taft* of New Bedford		Mahe Bank
By *Lancer*			
3/1/70	*Mercury* of New Bedford	250 sperm/180 whale	East Madagascar
3/15	*John P. West* of New Bedford	2,000 sperm	"
4/10	*Annie Ann* of New Bedford	220 sperm	"
4/19	*Atlantic* of New Bedford		"
6/16	*Robert Morrison* of New Bedford	330 sperm	Bird/Denis Islands
	Greyhound of Westport		
	Orray Taft of New Bedford	170 sperm	
	Laconia of New Bedford		
	Falcon of New Bedford		
	Annie Ann of New Bedford		
	Para of Salem		
10/2	*Atlantic* of New Bedford	1,150 sperm	off Bourbon
7/23/72	*Charles W. Morgan* of New Bedford		Antongil Bay
7/25	*John P. West* of New Bedford		"
9/19	*Pacific* of New Bedford		off Reunion
9/22	*Charles W. Morgan* of New Bedford		"
By *Petrel*			
1873	*Sea Queen* of Westport	650	
	Islander of New Bedford	200 bbl this season	
	Osceola of New Bedford	no rudder – took in tow	
6/73	*John Dawson* of New Bedford		off Seychelles
	Charles W. Morgan of New Bedford		"
	Laetitia of New Bedford	185	"
	Gazelle of New Bedford	600	"
By *Avola*			
10/31/73	*Charles W. Morgan* of New Bedford	1,100 sperm/195 whale	Mauritius
9/2/77	*John Dawson* of New Bedford	200	Rodrigues
	Atlantic of New Bedford	700	"
10/4	*Laconia* of New Bedford	500 (had not seen a whale for 5 months)	4° 30′ S–53° 33′ E
10/13	*Platina* of Westport		en route to Mahe
	John Dawson of New Bedford		
	Laconia of New Bedford		
By *Marcella*			
4/28/74	*John Dawson* of New Bedford	520 sperm	*ca.* 15° S–54° E
4/8	*Laetitia* of New Bedford	700 sperm	*ca.* 10° S–58° E
5/10	*Laetitia* of New Bedford		"
5/31	*Laetitia* of New Bedford		"
7/24	*John Dawson* of New Bedford		off Bird Island
8/11	*Greyhound* of Westport		Comoros
8/12	*Laetitia* of New Bedford		Johanna
8/15	*Sea Queen* of Westport		"
9/27	*Mermaid* of Westport	620 sperm	near Socotra
10/3	*Mermaid* of Westport		"

Appendix A *(continued)*

Date	Vessel	Location	Number/size
10/10	*Mermaid* of Westport	cutting in	Arabian grounds
	Sea Queen of Westport	nothing since Johanna	,,
10/12	*Mermaid* of Westport	got 5 whales = 75 bbls	,,
10/22	*Laetitia* of New Bedford	130 oil, 100 lbs ambergris	,,
10/27	*Sea Queen* of Westport		,,
11/17	*Sea Queen* of Westport	seen nothing; Mermaid has taken 130 bbls since 10/12	,,
11/20	*John Dawson* of New Bedford		,,
11/23	*John Dawson* of New Bedford		,,
11/25	*John Dawson* of New Bedford		near Socotra
12/6	*John Dawson* of New Bedford		down Somali coast
12/16	*John Dawson* of New Bedford	each took a whale	SSW Yuba Island
4/3/75	*Sunbeam* of New Bedford	400	Saya de Malha
4/16	*Sunbeam* of New Bedford	boats blackfishing	,,
6/3	*Mercury* of New Bedford	550 sperm/450 whale	,,
6/18	*Sunbeam* of New Bedford		Victoria
	Mermaid of Westport		
	Petrel of New Bedford		
	Undaunted (British warship)		
7/7/75	*Petrel* of New Bedford	nothing since Mahe	off Denis Island
7/17	*Mermaid* of Westport	,,	off Bird Island
8/26	*Mermaid* of Westport	took 4 whales	NNW of Johanna
10/1	*Petrel* of New Bedford	170 bbls since Mahe	N of Fartak
10/3	*Mermaid* of Westport	took 75 bbls whale	,,
11/3	*Mermaid* of Westport	300 bbls in 4 weeks	off Morbat
11/14	*Petrel* of New Bedford	nothing on Arabia	off Fartak
11/16	*Petrel* of New Bedford	took 5 whales	,,
By *Mermaid*			
7/12/86	*Kathleen* of New Bedford		*ca.* 10° S–40° E
9/6	*Diamantina* of Mahe*		near Denis Island
12/7	*Kathleen* of New Bedford	whaling and boiling	Seychelles
12/24	*Kathleen* of New Bedford		*ca.* 4° S–41° E
	Melinda (home port unknown)*		
12/30	*Kathleen* of New Bedford	whaling 10 miles off	,,
1/1/87	*Kathleen* of New Bedford		,,
6/20/88	*Diamantina* of Mahe*	no oil for a month	Seychelles
6/23	*Kathleen* of New Bedford		near Bird Island
6/26	*Kathleen* of New Bedford		off Denis Island
	Diamantina of Mahe*		
	Sea Queen of Westport		
11/12	*Kathleen* of New Bedford		3° 23′ S–40° 52′ E
2/16/89	*Kathleen* of New Bedford	transferring oil to Boston bark	Zanzibar

* Not a US whaleship.

Appendix B

CATCH OF SPERM WHALES

Date	Vessel	Location	Number/size
6/17/00	*Kingston*	Delagoa Bay	2
6/22	,,	,,	1
6/23	,,	,,	1
1/15/01	,,	East Madagascar	2
3/6	,,	West Madagascar	6
6/20/35	*Averick*	26° 45′ S–33° 54′ E	4 (2 = 40 bbls)
7/17	,,	27° 19′ S–33° 50′ E	1
7/21	,,	27° 06′ S–33° 50′ E	2
7/25	,,	27° 36′ S–33° 51′ E	1
3/20/36	*Ceres 2nd*	Pemba	2
3/21	,,	,,	4
3/22	,,	,,	2
3/27	,,	,,	2 (lost 4)
4/8	,,	,,	2 (lost 1)
4/22	*South Carolina*	22° 19′ S–40° 28′ E	1 (lost)
4/25	*Ceres 2nd*	Pemba	4
5/29	,,	Comoros	1

Appendix B (*continued*)

Date	Vessel	Location	Number/size
9/7	*South Carolina*	Crozet grounds	1
10/5	„	35° S–69° 11′ E	3 (2 small)
10/13	„	39° 11′ S–70° 30′ E	1 stinker
11/2	„	33° 26′ S–72° 35′ E	1 ('dry skin')
1/7/37	„	33° 50′ S–62° 33′ E	1
4/24/42	*Good Return*	Mascarene Basin	1 (45 bbls)
5/2	„	23° 17′ S–49° E	1 (45)
5/18	„	23° 27′ S–48° 16′ E	1 (45)
10/21	„	34° 25′ S–65° E	1 (40)
10/23	„	34° 26′ S–64° 02′ E	1 (40)
11/4	„	35° 30′ S–62° 25′ E	1 (60)
11/6	„	35° 05′ S–61° 47′ E	1 (60)
11/11	„	35° 32′ S–60° 53′ E	1
11/23	„	34° 49′ S–65° E	1
11/24	„	34° 40′ S–66° 30′ E	1
12/1	„	35° 30′ S–70° E	1 (60)
6/14/44	*Maria*	near Comoros	1 (35)
6/19	„	„	1 (calf)
7/11	„	„	2 (45, 80)
9/5	„	5° 25′ S–41° 02′ E	1 stinker (80)
9/22	„	offshore Africa	1 (small calf)
9/23	„	„	2 (25@)
10/4	„	off Zanzibar	3 (6, 14, 24)
10/6	„	„	1 (30)
10/9	„	„	?
10/28	„	4° 00′ S–41° E	2 (12, 18)
11/12	„	5° 00′ S–47° 82′ E	1 (82)
11/30	„	2° 30′ S–30° 51′ E	1 (15)
12/1	„	2° 00′ S–51° E	1 stinker (20)
1/27/45	„	off Aldabra	1 (30)
3/10	„	*ca.* 6° S–50° E	1 (30)
3/20	„	*ca.* 3° S–55° E	2 (3, 6)
3/25	*Marcella*	14° 14′ S–41° 50′ E	1 (30)
4/19	*Maria*	5° S–58° 12′ E	2 (20, 30)
5/16	„	near La Digue	1 (25)
5/23	„	*ca.* 6° S–50° E	2 (18, 20)
7/6/45	*Marcella*	3° S–42° 58′ E	1 (lost)
8/2	„	5° S–42° 22′ E	1 (15)
8/9	„	4° 44′ S–41° 45′ E	1 (3)
8/25	*Maria*	*ca.* 5° S–44° E	1 (60)
8/28	*Marcella*	4° 41′ S–41° 38′ E	3 (8, 15, 25)
9/3	*Maria*	5° 30′ S–44° E	1 (15)
9/6	„	*ca.* 5° S–45° E	3 (12, 2@20)
9/22	*Marcella*	5° 30′ S–42° E	1
10/23	„	4° 55′ S–42° 52′ E	3
12/3	*Maria*	3° 20′ S–51° 01′ E	3 (12, 15, 20)
12/5	„	3° 20′ S–50° 50′ E	1 (25)
12/5	*Marcella*	5° 50′ S–51° 50′ E	2
12/19	*Maria*	3° 20′ S–50° 50′ E	1 (25)
2/18/46	„	17° 49′ S–40° 25′ E	?
2/18	*Marcella*	off Aldabra	1
3/10	„	11° 40′ S–53° 00′ E	2 (15,30)
5/9	„	6° 06′ S–41° 35′ E	2 } 150 bbls total
5/14	„	6° 07′ S–41° 30′ E	2 } 150 bbls total
5/15	„	6° 07′ S–41° 40′ E	1 } 150 bbls total
5/29	„	5° 03′ S–42° E	4
5/31	„	3° 30′ S–42° 40′ E	1
6/3	*Arab*	north of Johanna	1
7/14	*Marcella*	9° 40′ S–45° 08′ E	1
11/26	*Arab*	off Colombo	2
12/3	„	„	3
12/4	„	„	5
12/27	„	„	1
2/8/47	„	3° N–75° 30′ E	8 (av 44 bbls @)
2/24	„	5° S–77° 45′ E	5
5/17	„	south of Farquhars	1
5/30	*Montezuma*	12 mi E Aldabra	1
6/15	„	Aldabra	1
6/19	„	„	1
6/19	*Arab*	east of Pemba (*ca.* 43° E)	1
7/4	*Montezuma*	in sight Assumption	1
9/15	*Arab*	off Colombo	2 (av 54 bbls @)
9/28	*Montezuma*	above equator	1
10/7	*Arab*	off Colombo	1 stinker
10/18	„	„	9 (av 54 bbls @)

Appendix B (*continued*)

Date	Vessel	Location	Number/size
11/10	,,	,,	1 (54)
11/29	,,	,,	2 (54@)
12/19	*Montezuma*	9° E near Ceylon	1
12/31	,,	,,	1
1/1/48	,,	,,	3 (av 15 bbls @)
4/11	*Arab*	West Chagos	3
4/16	*Montezuma*	WSW Coetivy	2
4/17	,,	,,	3
5/16	,,	off Aldabra	1 (30)
7/24	*Arab*	off Colombo	1 (15)
8/16	,,	,,	1 (15)
9/22	,,	,,	5 (av 15 bbls @)
10/1	,,	,,	1
10/2	,,	,,	4
10/31	,,	,,	2
11/2	,,	,,	3
3/21/50	*Arab*	West Chagos	1 (60)
4/13	,,	Chagos	2
5/17	,,	,,	1 (100)
6/18	,,	,,	3 (small bull, 2 ♀)
11/30	,,	,,	3
12/4	,,	,,	1
4/8/51	,,	,,	1 (25)
5/20	,,	,,	1 (70)
5/24	,,	,,	2
5/28	,,	,,	2 (lost cow, got calf)
3/11/52	,,	,,	2
8/13	,,	Comoros	2
8/20	,,	Aldabra	1
8/26	,,	,,	2
11/25	,,	Maldives	1
12/25	,,	Cape Morbat	3
6/18/55	*Harrison*	north of Comoros	1
9/21	,,	West Chagos	3
10/2	,,	,,	1 (in nursery school)
11/2	,,	,,	2
12/10	,,	,,	3
1/17/56	,,	,,	5
2/4	,,	Chagos	1 ('rogue')
12/17	,,	11° 30′ S–55° E	1
3/3/57	,,	Chagos (Diego)	5
3/5	,,	,,	3
4/5	,,	,,	1
4/10	,,	,,	4 (100 bbl ♂, cows)
6/20	,,	East Madagascar	1 (96 bbl ♂)
4/24/60	*Thomas Pope*	Seychelles	1
8/24	,,	Rodrigues	2
9/28	,,	,,	1
3/19/61	,,	Seychelles	1
9/17	,,	Mauritius	1
11/2	*Messenger*	Mascarene Basin	1 stinker (12)
6/4/62	*Thomas Pope*	Seychelles	1
4/18/68	*Sea Fox*	4° 30′ M–78° 34′ E	2 (20@)
5/13	*Herald*	Saya de Malha	1 (22)
5/17	,,	,,	2 (25@)
6/2	,,	,,	1 (25)
6/17	,,	,,	1 (18)
6/20	,,	,,	4 (8, 2@19, 25)
6/22	*Sea Fox*	off Denis Island	1
7/25	*Herald*	Fortune Banks	4 (5, 2@25, 20)
8/15	,,	Aldabra	2 (10, 25)
8/23	*Sea Fox*	1° 46′ S–4° 46′ E	6 (87 bbls total)
9/24	*Herald*	Cape Fartak	5 (25, 4@15)
10/1	,,	,,	7 (15@)
10/6	,,	,,	2 (12@)
10/17	*Sea Fox*	off Cape Morbat	3 (103 bbls total)
10/24	,,	Cape Fartak	5
	Herald	,,	2 (15, 18)
11/14	,,	Khuyira Muyira	1 stinker (17)
11/18	,,	,,	3 (5, 15, 20)
11/23	,,	,,	4 (10, 12, 16, ?)
1/3/69	*Herald*	2° 14′ S–47° 12′ E	4 (21@)
1/8	,,	,,	2 (25, 50)
3/3/70	*Lancer*	24° 19′ S–48° 90′ E	1
3/13	*Hecla*	Saya de Malha	2

Appendix B *(continued)*

Date	Vessel	Location	Number/size
4/12	*Lancer*	25° 11′ S–48° 40′ E	1
4/14	*Hecla*	Saya de Malha	2
4/23	,,	,,	3
6/10	*Sea Fox*	Chagos	2
7/1	*Hecla*	Mahe Banks	1
8/14	,,	Amirantes	2 (72, 90)
10/15	,,	Cape Morbat	4
10/19	,,	,,	1 stinker (12)
10/20	,,	,,	1 stinker (10)
11/6	,,	,,	5
11/11	,,	,,	1 stinker
1/25/72	*Petrel*	38° 32′ S–29° 01′ E	1 (45)
3/20	,,	Saya de Malha	4 (2@25, 30, 40)
6/18	,,	Bird Island	2 (35, 45)
7/27	,,	Comoros	1 (36)
9/30	,,	Seychelles	4 (3@25, 10)
11/2	*Lancer*	24° 55′ S–47° 54′ E	1
11/5	*Petrel*	2° 20′ N–50° E	3 (25@)
12/31	*Lancer*	25° 15′ S–43° 38′ E	1
3/3/73	*Petrel*	Saya de Malha	4 (165 bbls total)
3/12	,,	,,	2 (13, 22)
3/14	,,	,,	5 (3@26, 24, 25)
3/21	,,	,,	1 stinker (4)
4/6	,,	,,	6 (20@)
8/11	,,	Comoros	2 (20@)
9/20	,,	Amirantes (D'Arros)	4 (2@20, 2@25)
10/24	,,	16° 36′ S–52° 42′ E	3 (2@25, 35)
10/28	*Avola*	Mauritius	1 (50)
11/2	*Petrel*	24° 40′ S–48° 20′ E	1 (40)
3/12/74	*Marcella*	37° 05′ S–32° 43′ E	4 (115 bbls total)
5/25	,,	Mascarene Basin	1 (43)
6/20	,,	,,	1 (30)
7/24	,,	off Bird Island	1 (54)
9/29	,,	Arabian grounds	2
9/30	,,	,,	1
10/2	,,	,,	2 (46 bbls total)
12/16	,,	,,	1 (65)
1/21/75	,,	off Praslin	1 (46)
2/25	,,	Seychelles	1 (30)
4/19	,,	Saya de Malha	1 (80)
5/9	,,	,,	5 (135 bbls total)
8/26	,,	Somali Basin	1 (16)
10/6	,,	Arabian grounds	4 (156 bbls total)
10/8	,,	,,	4
10/25	,,	,,	5 (91 bbls total)
10/26	,,	,,	1 stinker
11/16	,,	,,	6 } 123 bbls total
11/17	,,	,,	2 } 123 bbls total
11/23	,,	,,	7 } 123 bbls total
5/3/86	*Mermaid*	*ca.* 37° S–31° E	1
5/12	,,	32° 12′ S–42° E	3
7/25	,,	Seychelles	1
8/4/86	*Mermaid*	Seychelles	1
8/5	,,	8 mi off Denis	1
8/10	,,	near Denis Island	1
8/15	,,	8 mi N Denis	1
9/2	,,	near Denis Island	1
9/10	,,	,,	4
9/21	,,	8 mi off Denis	2
10/29	,,	Seychelles	1 stinker
12/7	,,	,,	1
1/1/87	,,	*ca.* 4° S–41° 50′ E	2
1/6	,,	4° 40′ S–41° 50′ E	4
1/8	,,	4° 32′ S–41° 10′ E	3
1/9	,,	,,	3
1/10	,,	,,	1 stinker
1/21	,,	4° 17′ S–41° 59′ E	1 large ♂
1/25	,,	,,	2

Appendix C

CATCH OF RIGHT WHALES

Date	Vessel	Location	Number/size
3/25/35	*Averick*	25° 31′ S–43° 45′ E	1 (lost)
9/21/36	*Ceres 2nd*	*ca.* 37° S–60° E, and a line	1
9/29	”	to 70° E	1
10/2	”	”	1
10/3	”	”	1 (sunk)
10/9	”	”	3
10/14	”	”	2
10/16	”	”	2
10/19	”	”	1
10/20	”	”	1
	South Carolina	34° 57′ S–69° 35′ E	1
10/21	”	34° 12′ S–69° 53′ E	2 (lost)
10/24	”	33° 55′ S–70° 01′ E	1 stinker
10/24	*Ceres 2nd*	(see above)	1
10/25	*South Carolina*	*ca.* 33° S–70° E	1
10/26	*Ceres 2nd*	(see above)	1 (sunk)
11/1	”	”	1
11/6	*South Carolina*	32° 50′ S–73° 30′ E	1
11/10	”	off Amsterdam Island	1
11/13	”	34° 80′ S–72° 35′ E	3
11/13	*Ceres 2nd*	(see above)	1
11/14	”	”	1
	South Carolina	34° 13′ S–72° 31′ E	1
11/15	*Ceres 2nd*	(see above)	3 (1 sunk)
11/17	*South Carolina*	34° 10′ S–72° 15′ E	1
11/18	*Ceres 2nd*	(see above)	1
11/20	”	”	2 (1 sunk)
11/21	”	”	1
11/22	*South Carolina*	off Amsterdam Island	1
11/23	*Ceres 2nd*	(see above)	1
11/25	*South Carolina*	34° 45′ S–72° 41′ E	1
11/26	”	”	1 (20 bbl)
11/28	”	35° 10′ S–72° 20′ E	3
11/28	*Ceres 2nd*	(see above)	1
11/29	”	”	1
12/1	”	”	1
12/7	*South Carolina*	35° 30′ S–73° 06′ E	1
12/8	”	35° 30′ S–73° 06′ E	1
2/2/42	*Good Return*	*ca.* 45° S–49° E	1
6/30	”	Sofala Bay	1
7/21	”	25° 45′ S–35° 24′ E	1
7/22	”	”	1 calf
1/13/49	*Stephania*	44° 16′ S–48° 40′ E	1 (75)
1/15	”	44° 18′ S–48° E	1 (80)
1/20	”	43° 40′ S–49° 00′ E	1 stinker (40)
2/11	”	*ca.* 44° S–49° E	1 (70)
2/27	”	*ca.* 44° S–48° E	1 (70)
3/3	”	”	1 (30)
3/10	”	”	1 (69)
3/18	”	”	1 (70)
1/15/50	”	44° 20′ S–49° E	1 (40)
1/16	”	”	1 (80)

Appendix D

CATCH OF PORPOISE

Date	Vessel	Location	Number/size
4/20/36	*South Carolina*	23° 14′ S–40° 46′ E	1
6/25	„	22° 57′ S–41° 50′ E	1
6/27/44	*Maria*	Mozambique Channel	2
6/29	„	„	1
8/27	„	near Comoros	1
4/9/45	„	*ca.* 50° S–57° E	2
7/20	„	off Johanna	1
8/3	„	„	1
8/4	„	11° 10′ S–43° 55′ E	1
8/10	„	6° 54′ S–40° 57′ E	1
9/27	„	0° 00′–48° E	1
10/5	„	2° 42′ N–43° 43′ E	1
10/22	„	2° 80′ N–48° 36′ E	1
10/23	„	2° 40′ N–48° 30′ E	1
10/26	*Marcella*	4° 28′ S–42° 09′ E	1
11/18	*Maria*	00° 2′ N–46° 50′ E	2
1/25/46	„	9° 50′ S–44° 18′ E	1
1/17/48	*Montezuma*	9° Channel near Ceylon	1
1/31/49	*Stephania*	*ca.* 44° S–48° E	2
1/5/50	„	44° 29' S–48° 29' E	1
4/11/53	*Arab*	6° 16' S–70° 59' E	1
4/12/72	*Petrel*	Saya de Malha	1 (cowfish)
4/12/73	„	„	1
6/13/74	*Marcella*	Mascarene Basin	2
·6/23	„	„	2 (8 gals)
6/27	„	near Coetivy	1
8/4	„	near Aldabra	2
9/13	„	NE of Pemba	2
11/27	„	Socotra in sight	1
11/28	„	between Socotra & coast	1
11/30	„	past Cape Guadofi	1
12/1	„	„	1
12/15	„	SSW Yuba Island	1
3/14/75	„	SE Fortune Banks	1
3/15	„	„	1
3/21	„	near Saya de Malha	1
4/2	„	Saya de Malha	1
4/3	„	„	2
4/8	„	„	2
4/27	„	„	1 (cowfish)
6/10	„	Mahe Banks	1
7/6	„	off Denis Island	1
7/23	„	near La Digue	1
7/26	„	Seychelles	1
9/8	„	near 0° coast	1 } 2.5 gals
9/9	„	„	1 }
10/2/88	*Mermaid*	4° 10′ S–40° 50′ E	1 (cowfish)
12/6	„	4° 26′ S–41° 26′ E	2

SC/Jn80/SpW18

Logbook Records of 19th Century American Sperm Whaling: A Report on the 12 month project, 1978–79

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ABSTRACT

From around 800 American Whaling logbooks available on microfilm for voyages to the northwest Pacific from the 1820s to 1860s, 100 were found to provide comprehensive enough sperm whaling data to give information on shifts in location of whaling effort (from west to east) changes in abundance (a decrease, particularly over the earlier years) and in catch composition (from emphasis probably on breeding schools to 'bachelor bulls') as well as minimum estimates of total removals (24,500–34,000 animals over the period). Of nearly 150 logbooks available from the eastern Indian Ocean, again about 100 should provide comprehensive data for similar analysis. The pilot project results suggest that useful information may be obtained from such studies.

INTRODUCTION

The work reported here represents the results of a 12-month 'pilot study' undertaken in response to the proposal agreed to at the Sharon, Massachusetts meeting on historical logbook records (Anon, 1977) held in September 1977.

Log extractions and basic analyses were undertaken under Bannister's supervision, by Taylor, employed as a graduate assistant under funds provided by the Peoples Trust for Endangered Species. Assistance in data analysis was given by Sutherland, employed at the time by Bannister on modern sperm whaling data analyses.

In the submission for funds to the People's Trust, it was proposed that in addition to concentrating on data for the American whalemen's 'Japan' and 'Coast of Japan' whaling grounds, data for the 'Coast of New Holland' ground off Western Australia should also be examined. In the event, extractions and preliminary analyses for the latter were undertaken, but further work is required; a summary of the results so far is given in Appendix A. Results in the main body of this report refer only to data from the 'Japan' and 'Coast of Japan' grounds and nearby areas in the Northwest Pacific.

WHALING AREAS STUDIED

Data from the two whaling areas favoured by 19th century North American whalemen in the Northwest Pacific—the 'Japan' and 'Coast of Japan' whaling grounds—were chosen at the Sharon meeting as appropriate for a pilot study since it was believed that the number of logbooks available (coupled with their availability on microfilm) and the high number of whales thought to have been taken over a probably well-defined time span in the second quarter of the 19th century, would provide sufficient information to indicate not only the course of that fishery but the general usefulness of a study of logbooks in providing information on the pelagic open-boat fishery's effect on whale stocks.

The area of study was initially defined on the basis of Townsend's Charts (Townsend, 1935) which show the two main areas of concentration in the latitudes between 20° and 40°N already referred to—the 'Japan' ground (approximately 140°E–150°E) and the 'Coast of Japan' ground (approximately 150°E–180°) in plottings of the positions of whaling vessels on days when sperm whales were taken. Early in the study, however, it seemed that the number of logbooks from either area that could be readily selected for examination was likely to be small, and the area of study was enlarged to embrace the major spread of the 'Western Stock Division' of the North Pacific adopted for assessment purposes at the Cambridge meeting of the Scientific Committee of the International Whaling Commission in 1978 (IWC, 1979). The area from which logbook records used in this study originate thus extends from 140°E to 160°W, i.e. from approximately the Bonin Islands in the west to the Hawaiian Islands in the east, in the band between 20°N and 40°N (Fig. 1).

LOGBOOKS EXAMINED

Microfilm copies of logbooks available under the New England Microfilming Project of the Pacific Manuscripts Bureau, as listed in Langdon 1978, and obtained through that project by the Battye Library of the Library Board of Western Australia, were examined as a routine by Taylor. As shown in Table 1, of 827 logbooks indexed by Langdon for likely areas (i.e. from vessels passing through Hawaii and/or the Bonin Islands), and examined, about 13% proved to be of voyages through the area of study (as defined above); of those, most (100 out of 111) proved to contain 'good' data for extraction, i.e. a wide range of useful data. The number of 'good' logs available thus just meets the limit set at the Sharon meeting of the total desirable of 100 'good' logs from the area examined.

DATA EXTRACTED

'Good' logbooks used in the extractions all included basic information on date, latitude and longitude, weather, 'single' and 'plural' sightings, species, number of whales struck, and number tried out. Many 'good' logs also included information on the number of barrels of oil obtained from whales tried out. Logs not providing the basic information were excluded from further study. A list

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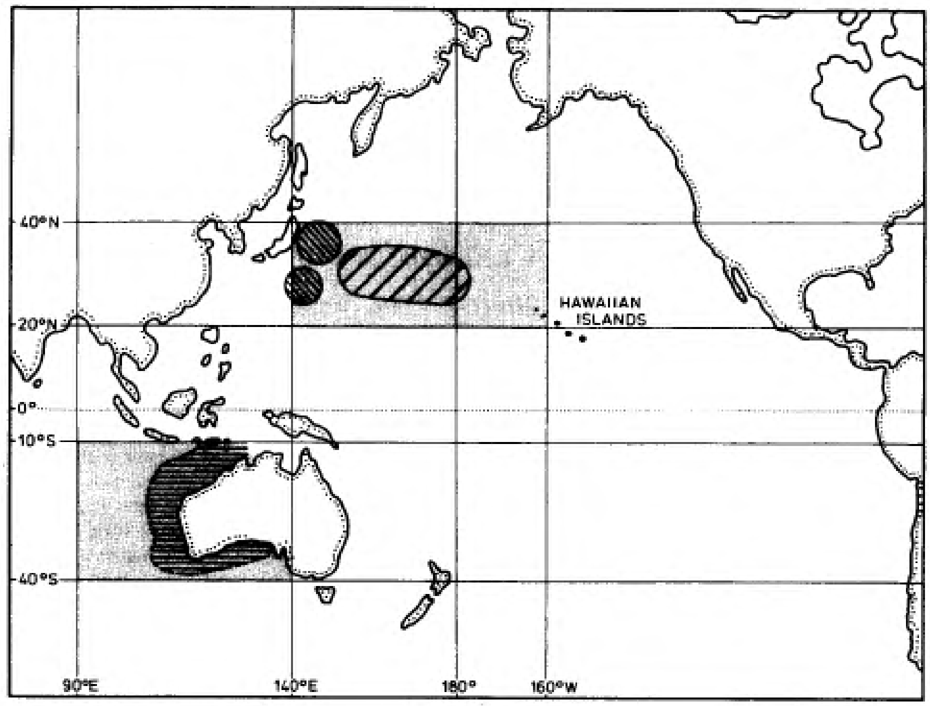


Fig. 1. North West Pacific and East Indian Ocean Areas used in the Study.
Townsends Ground: ▨ Japan; Coast of Japan; ▤ Coast of New Holland.

of vessels for which 'good' logbooks exist, and have been used in this study, is given in Appendix B.

A standard format for extraction of data was devised, as illustrated in Fig. 2. From such primary sheets, data were transferred to two further analysis sheets, as in Fig. 3 (for general analysis) and Fig. 4 (for derivation of a 'mortality factor').

RESULTS

As shown in Table 1, the 100 logbooks providing comprehensively 'good' data gave 159 annual data points between the years 1822 to 1868, the majority being from 1830 to 1859, the highest number in any one 5-year period (40) being from 1840–44. For most analyses, the data have been grouped by 5 year periods, except for the 1820s and 1860s, where the data are relatively more sparse.

Distribution of effort

The whaling season in the area studied extended from April to September. A logbook with 'good' data was used if the vessel was recorded as being in the area for a reasonable time (most of the season) and not judged simply to be passing through en route to another ground. Most relevant logbooks, particularly in the earlier years, record voyages to and from Hawaii just before or after the season; from the 1840s, voyages are often recorded from Guam and the Bonin Islands.

Plots of the distribution of vessel positions, obtained from the 'good' logbooks, on days when whales were tried out (Fig. 5) show a shift in location of whaling over the period. From the 1820s to the mid-1840s, most voyages passed through Hawaii and westwards towards Japan, mainly through Townsend's 'Japan' ground, and then

Table 1

Number of logbooks examined for the area of study, North West Pacific, 1822–68

Voyages	Number of logs indexed for Hawaiian and Bonin Islands*	Number of logs checked	Number of voyages to the area of study	Number of voyages, begun during the period listed for which 'good' logbooks were found	Number of vessel-years for which 'good' logbooks were found
1820–24	19	19	7	4	2
1825–29	31	31	14	13	12
1830–34	46	46	24	17	27
1835–39	38	38	16	18	25
1840–44	141	141	28	26	40
1845–49	132	132	9	9	24
1850–59	313	313	11	11	23
1860–69	107	107	2	2	6
Totals	827	827	111	100	159

* In Langdon, 1978.

EXTRACTION SHEET — PLOUGHBOY JAPAN 1828

DATE	LAT/LONG	WEATHER	ENCOUNTERS: single	plural	boats lowered	SPECIES	NO. OF WHALES: STRUCK	ESC.	SUNK	TRIED OUT	BARREL YIELD	COMMENTS
4/4/28	161·38 W 19·4 N	light	None → 10/4									HAWAII MARCH
11/4/28	174·19 W 19·24 N	fine		P	1	Sp	–					
12/4			None → 4/5									SW/G 11
5/5	175·3 E 30·43 N	fresh		P	1	Sp	2			2	30 30 F	20/4 177 E 27·3 N
6/5			None →									
7/5	177·5 E 30·2 N	brisk		P	1	Sp	2			2	30 30	
8/5			None →									
9/5	178·28 E 31·09 N	mod.		P	1	Sp	1			1	20	
10/5			None → 20/5									SW/9 11
21/5	174·14 E 32 N	strong breezes		P	1	Sp	1					"struck, lost a line..."
22/5			None → 24/5									
25/5	173·4 E 32 N		single		1	Sp	–					
26/5			None → 3/6									SW/9 1111
4/6	170·3 E 32·3 N	brisk		P	1	Sp	1			–		"struck, lost a line, iron drew".
5/6	171·58 E 32·11 N	light		P	1	Sp	1			1	20 M	
6/6			None → 11/6									
12/6	167·3 E 32 N		single		1	Sp	1			1	not recorded	in company with 'Dauphin' 1800 bbls
13/6			None → 20/6									SW/9 1

Fig. 2. Sample Primary Data Extraction Sheet.

SHIP PLOUGHBOY (NANTUCKET)
CAPTAIN NATHAN CHASE
GROUND JAPAN (1827-30)
1st season 1828

DAYS ON GROUND	169	149
DAYS IN PORT	20	
SINGLE SIGHTINGS	8	
PLURAL SIGHTINGS	24	
NO. OF TIMES BOATS LOWERED	30	
NO. OF TIMES WHALES STRUCK	20	
NO. OF WHALES TRIED OUT	16	
NO. SUNK	0	
NO. OF BARRELS	549	AV. 36·6

NO. OF SINGLE SIGHTINGS/SPERM DAY	0·0536
NO. OF PLURAL SIGHTINGS/SPERM DAY	0·161
TOTAL NO. OF SIGHTINGS/SPERM DAY	0·2147
(NO. OF SINGLE SIGHTINGS – NO. STRUCK) / NO. OF SINGLE SIGHTINGS	0·375
(NO. OF PLURAL SIGHTINGS – NO. STRUCK) / NO. OF PLURAL SIGHTINGS	0·5
NO. OF TIMES BOATS LOWERED PER SPERM DAY	0·2013
NO. OF WHALES STRUCK/SPERM DAY	0·134
NO. OF WHALES TRIED OUT/SPERM DAY	0·107
NO. OF CATCHER DAYS	14
PERCENTAGE LOST (NO. STRUCK – NO. TRIED) / NO STRUCK	20%

BARRELAGE	
<35	10
36-55	1
56-75	4
>76	0

Fig. 3. Sample Analysis Sheet : General.

returned to Hawaii. Thereafter, there was a shift westwards with whaling continuing on the 'Japan' ground, but also shifting to the area of the Bonin Islands—the southern part of Townsend's 'Coast of Japan' ground. At that time many vessels are recorded as entering the whaling area from the south, e.g. from Guam, or from 'On the Line' grounds close to the equator. Interestingly, very few logbooks examined record catches specifically from the northern section of Townsend's 'Coast of Japan' ground, between 30°N and 40°N, close to the Japanese coast.

In more detail, the logbook data available in this study show that in the 1820s, catching seems to have concentrated, particularly from June to August, in two major areas—a well-defined but small area just to the east of Townsend's 'Japan' ground (at about 175°W) and a less well-defined area extending over much of Townsend's 'Japan' ground (from about 175°E to 150°E). In the 1830s, the distinction between the two areas is less well-defined, and there is a greater spread across the 'Japan' ground, whaling continuing well into September in that area.

In the 1840s, the earlier, small easterly ground seems to have been almost ignored. Whaling concentrated on the main 'Japan' ground from June to September. Between June and August, whaling also occurred in a new area, around the Bonin Islands. In the 1850s, catching in the early months of the season (May and June) was almost entirely on this 'Bonin' ground; there was some activity on the 'Japan' ground in June, July and August. In the 1860s, the small number of whales recorded as taken was solely on the 'Bonin' ground. From 1850 onwards virtually none of the vessels began the season from Hawaii.

Abundance indices

Ideally, a 'good' logbook would contain information on the number of whales sighted each day (with some indication

MORTALITY FACTOR DATA

NAME OF VESSEL	PLOUGHBOY
YEAR ON GROUND	1828
NO. OF WHALES STRUCK	20
NO. OF WHALES TRIED OUT	16
NO. OF WHALES LOST (STRUCK AND NOT RETRIEVED)	4

CATEGORIES :
a) harpooned, not lanced, escaped alive
b) harpooned, not lanced, dead, lost
c) harpooned, lanced, escaped alive
d) harpooned, lanced, dead, lost
e) harpooned, iron drew
f) harpooned, iron broke
g) harpooned, out from....
h) harpooned, listed as "spouting blood"
i) harpooned, not retrieved, insufficient data
j) harpooned, not retrieved, other factors involved

LOG BOOK DATA:

DATE	NO. LOST	
21/5/1828	1	"struck and lost a line"
4/6/1828	1	(e) "struck, lost line, and iron drew"
9/7/1828	1	"struck, lost 3 lines"
11/7/1828	1	"struck twice, got two boats stoved, got one 20 bbl whale"

Fig. 4. Sample Analysis Sheet : Mortality Factor.

of size), the number caught and processed (plus their sex and size), the amount of oil obtained, and the weather conditions. In practice, a 'good' logbook falls short of these standards, but does contain information useful in deriving basic indices of sightings, catch and effort.

'Sightings' are determined by the logkeeper's reference to 'a whale' or 'whales'. The number of whales in a pod is sometimes identified, but for most logs no pod sizes are given. Differentiation is thus only possible on most occasions between 'single' and 'plural' sightings. The former frequently refers to large individuals.

The number of whales killed by any one vessel can be approached from the records of whales 'struck', and from the number of whales recorded as 'tried out'. Many 'good' logs contain information such as 'saw whales, lowered, got two'. There is often, as in that example, no mention of the number of whales 'struck'. However, that number can be obtained from the whale stamps frequently used by

Fig. 5a–e. North West Pacific: Areas of Study – Location of Whales Tried Out.

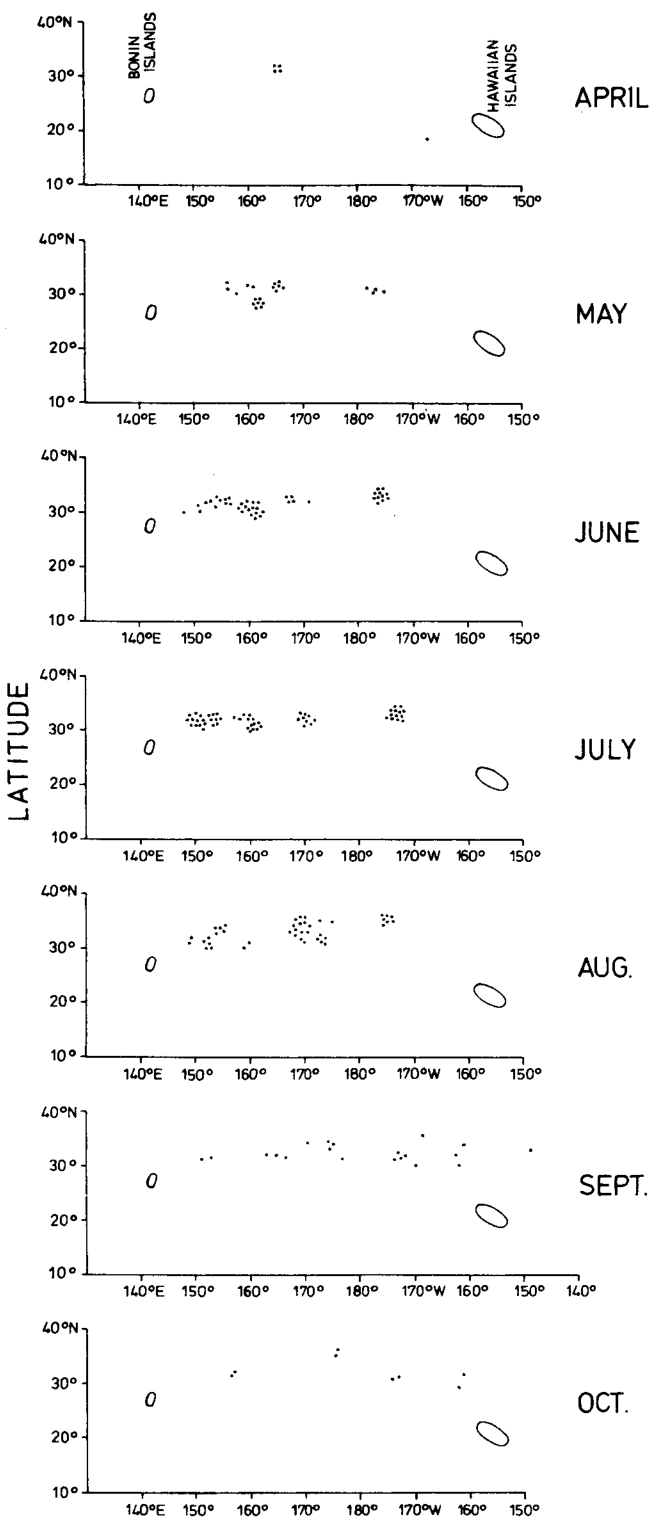


Fig. 5a. 1820–29, n = 180.

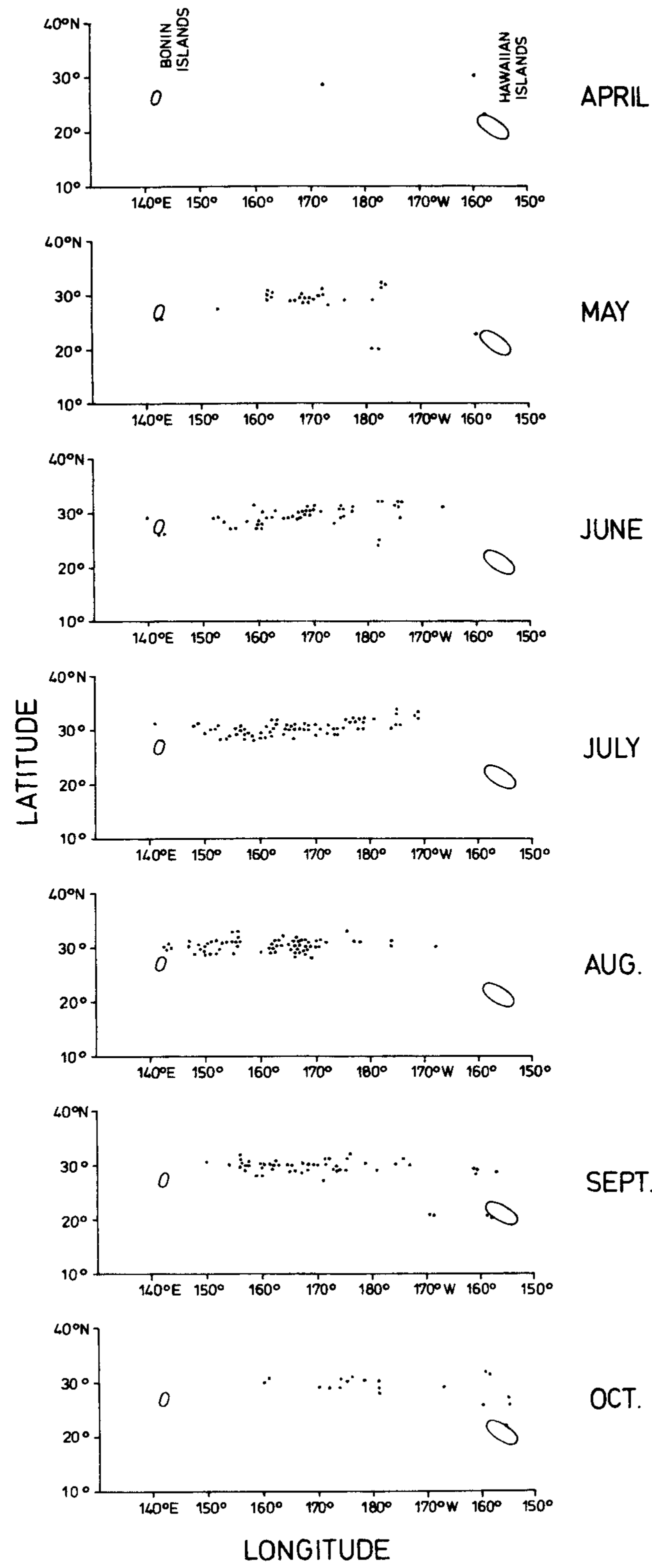


Fig. 5b. 1830–39, n = 383.

logkeepers; then, by subtraction, one can obtain the number of whales 'lost'. Estimation of the number 'lost' that subsequently died is more difficult, but an attempt has been made (see Section on Total Removals, p. 828).

The reasons for unsuccessful chases are sometimes given: 'iron drew'; 'lines parted'; 'boat stove and had to cut'. A few logkeepers record information such as 'whales too shy'; 'too quick'; 'too wild'. Unfortunately the average logkeeper seemed only to record 'saw whales, lowered, got none' on such occasions.

While the logkeepers' whale stamps provide information on the number of whales 'tried out' on a particular day, and some stamps record the number of barrels obtained from that whale, many logkeepers do not record barrelage, or only do so when the yield is particularly high from an individual whale. The flukes of those large animals are

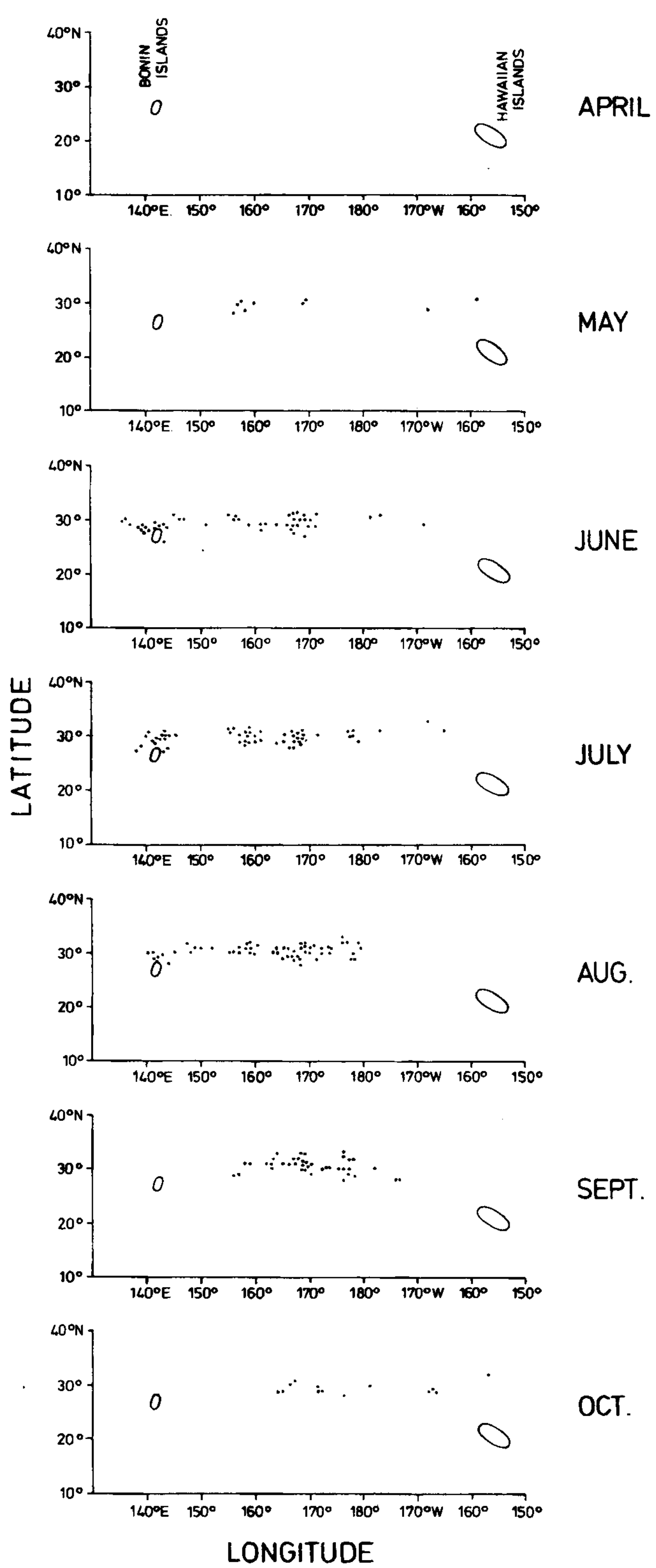


Fig. 5c. 1840–49, n = 219.

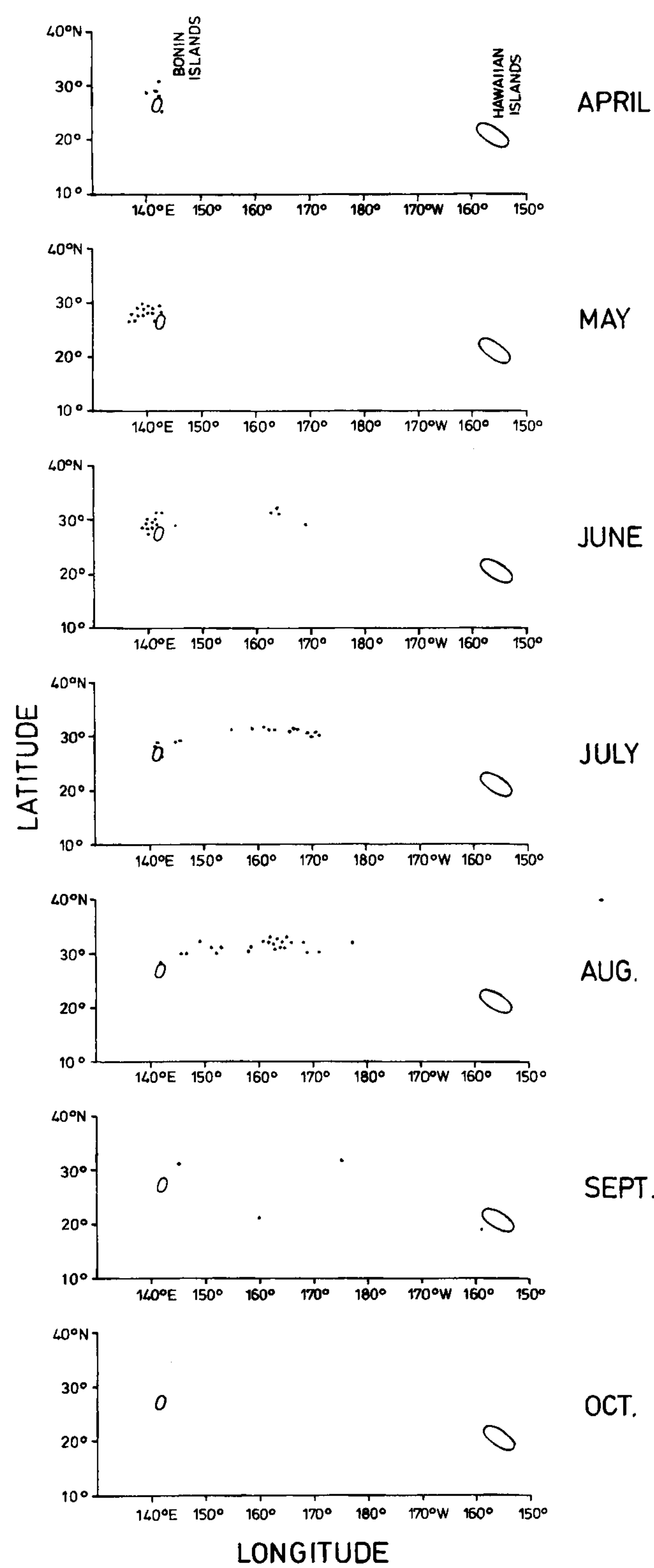


Fig. 5d. 1850–59, n = 77.

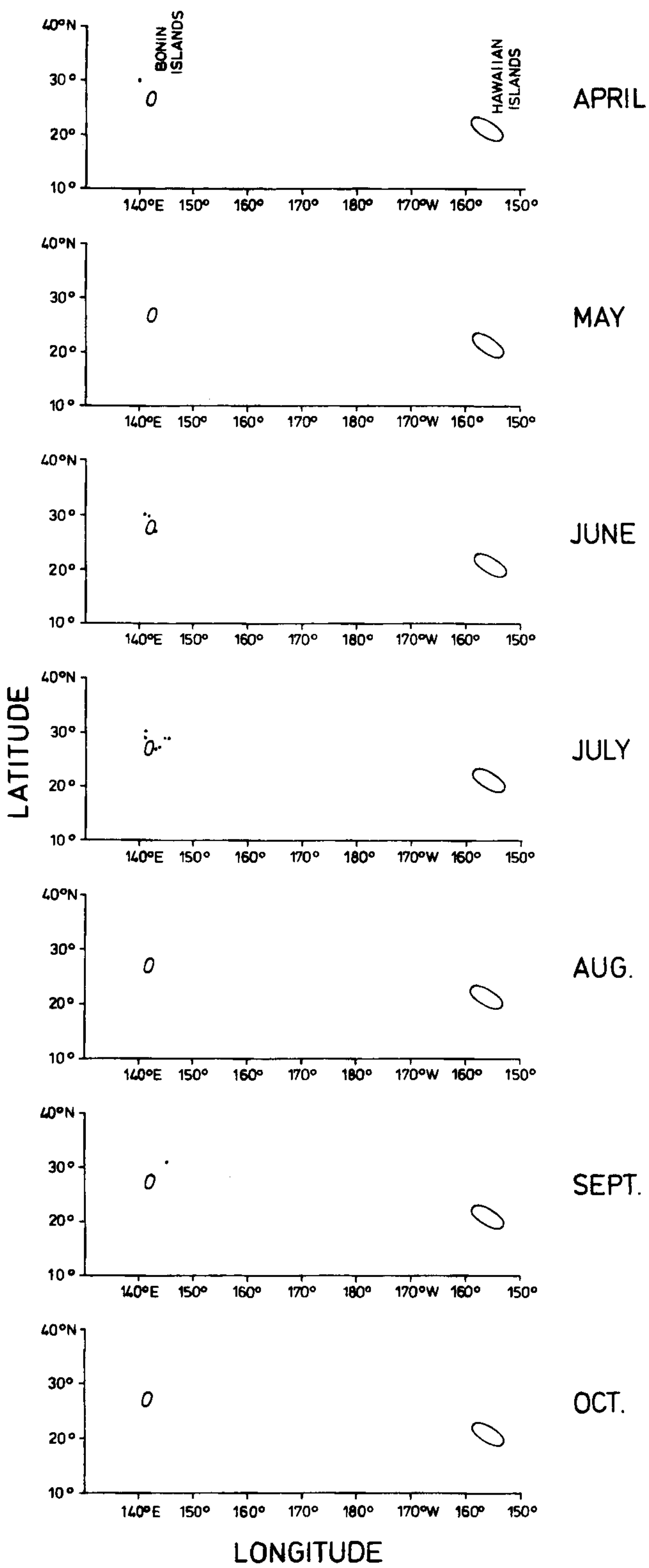


Fig. 5e. 1960–69, n = 11.

often measured, but in none of the logbooks examined in this study are the lengths of whales 'tried out' recorded. Very few logbooks refer to the sex of the animals caught. Most logkeepers refer to the catch in words such as 'got one whale, took him to the ship'.

The number of 'sperm whaling days', as a measure of effort, has been obtained by deducting from the total number of days spent on the ground the number of days on which active searching for whales would have been impossible or highly unlikely, i.e. days of strong gales, rough seas, 'thick conditions'. Days on which trying-out was going on have been included; sightings and catches are recorded on such days. While the frequency of boat lowerings in a day is usually recorded, the number of boats lowered is not often stated. Some more descriptive logbooks list the number of boats lowered in each chase, but they are rare. One can only assume that for plural sightings all or most boats would have been lowered, and that for single sightings fewer would have been used. The possibility still remains that multiple lowerings were less faithfully recorded than single ones; some logkeepers supply a basis for greater accuracy by recording sightings and lowerings in the 'first part' and 'second part' of the day. Where such records are not made, the number of lowerings recorded in a day is likely to be a low estimate.

Using the above, abundance indices have been obtained from the following:

—days on which whales were sighted/days searching (i.e. sperm whaling days)
—'single' sightings/sperm whaling days
—'plural' sightings/sperm whaling days
—'total' sightings/sperm whaling days
—whales 'struck'/sperm whaling days
—whales 'tried out'/sperm whaling days

As shown in Fig. 6, all these indices show some decline over the period. The average sighting rate (days on which whales were sighted/sperm whaling days, Fig. 6(a)) declined steadily, from about 0.2 in the 1820s to 0.05 in the 1860s. On the other hand the sightings and catch data (Figs 6(b)–(f)) both show a decline to about 1845, and stabilisation thereafter.

One question frequently raised concerns the degree to which the efficiency of the catching operation may have changed over the years, through the introduction, for example, of improved technology, e.g. the Temple toggle harpoon. This has been investigated by obtaining 'efficiency indices' over the period from the relationships:

(whales struck—whales tried out)/whales struck
(plural sightings—whales struck)/plural sightings
(single sightings—whales struck)/single sightings

However, as shown in Fig. 7, there are no significant trends in efficiency for any of these indices.

Catch composition

Although no lengths of whales caught are recorded in the logbooks studied it is possible to obtain information on the composition of the catch from the information given on barrelage. To lessen the likelihood of bias where the yield from only remarkably high-yielding animals has been recorded, analyses have been restricted to data from vessels where 70% or more of the catch tried out includes individual barrelage records.

Barrelage records have been divided between catches taken from single and plural sightings respectively. The former would be expected to consist almost exclusively of large whales, of 'school-master' size; the latter of large 'school-master' bulls from breeding schools, of individual cows and juveniles from such schools, and individuals from separate groups of 'bachelor' bulls. That this has some validity is shown by the average yields for each group, i.e. 72 barrels for all single sightings, 51 barrels for all plural sightings.

Plots of the data obtained, in 10 barrel groupings for each 5 year period (Fig. 8) show a change in the catch composition after 1835. Until then, the 'plural sightings'

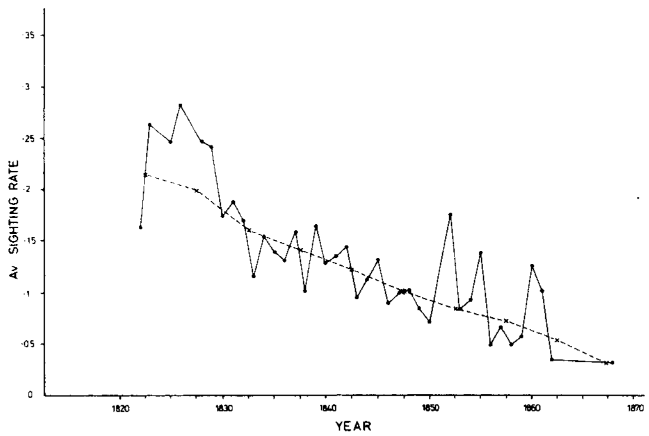


Fig. 6a. Average Sighting rate, 1822–68; Annual and 5-year data points plotted.

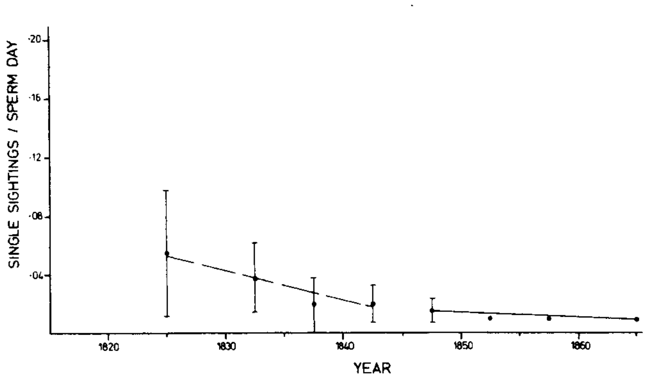


Fig. 6b. 'Single sightings' per sperm whaling day; 5-year mean ± 1 s.d. indicated; straight line regression fitted.

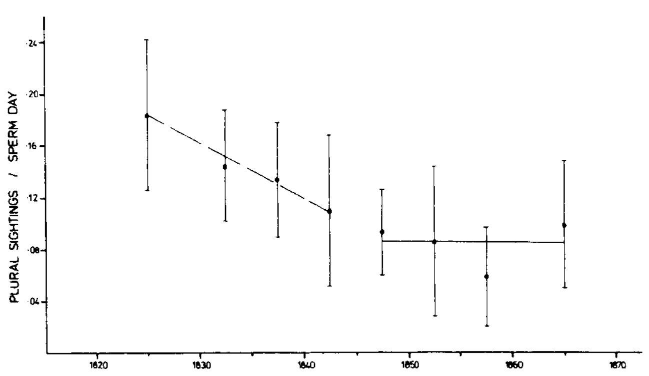


Fig. 6c. 'Plural sightings' per sperm whaling day; 5-year mean ± 1 s.d. indicated.

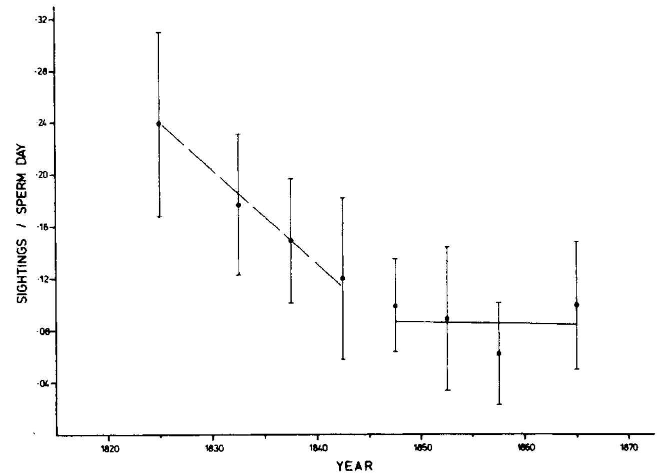


Fig. 6d. Total sightings per sperm whaling day; 5-year mean ± 1 s.d. indicated.

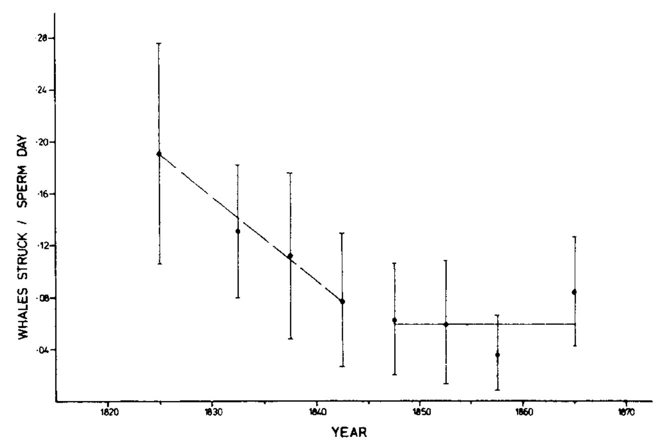


Fig. 6e. Whales struck per sperm whaling day; 5-year mean ± 1 s.d. indicated.

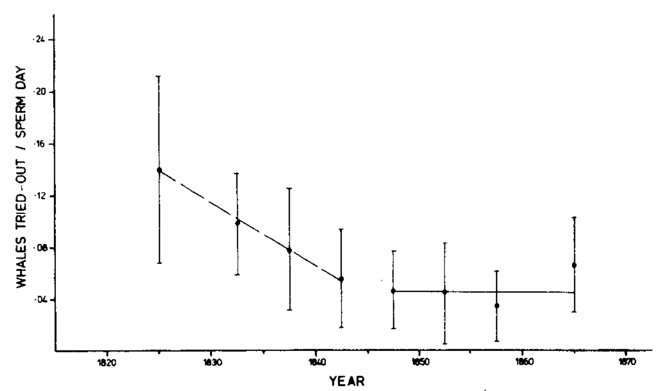


Fig. 6f. Whales tried out per sperm whaling day; 5-year mean ± 1 s.d. indicated.

Fig. 6. Abundance Index: a to f.

distribution is markedly bimodal with 2 main sizes being caught—whales around 30–50 barrels, and around 60–70 barrels. Most of the 'single sightings' are around 70–80 barrels. From then on, and particularly between 1840 and 1855, most of the 'plural sightings' catch is around 30–50 barrels, while only very small numbers in the 'single sightings' category feature at all. There seems to be some reversion to the earlier pattern in the 1850s, but the numbers available are small compared with the earlier period. Other authors (e.g. Best, 1977) have recognised that females and small males yield normally less than 35 barrels, large males greater than 60 barrels, and medium-sized males in the range of 35–60 barrels. On that basis it seems that the pre-1935 catch was mostly on females and small males, and on large males, i.e. probably associated with breeding schools; while from 1840 to 1855 the catch may well have been mostly on medium-sized males, i.e. on groups of 'bachelor bulls' away from the breeding schools.

Such a change in emphasis in the catch (from animals

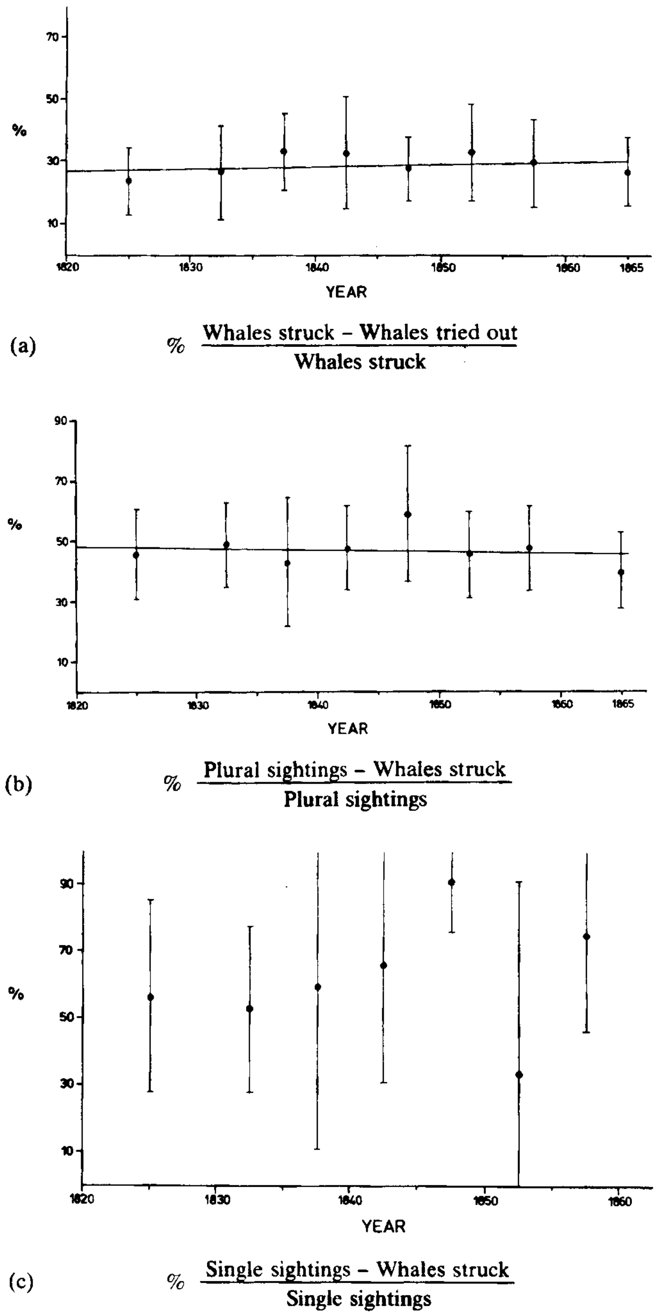


Fig. 7. Efficiency Indices, 1820–1860: 5-year mean ± 1 s.d. indicated; straight line regression fitted.

probably mostly in breeding schools, to mainly bachelor bulls) seems to have occurred at much the same time as the shift in location westwards through the 'Japan' ground, i.e. from about 1840 (see Section—Distribution of Effort, above). Both seem to have occurred at much the same time as one would expect a decline in abundance such as that noted earlier to have begun being noticed by the whalers. Whether such a shift might in fact, have been related to such a decline it is not possible to say from these data.

Total removals

An attempt has been made, in the absence of comprehensive data on catches taken on the grounds over the period, to estimate the total number of whales removed by the fishery, using the relationship

$$T = [A + \left(\frac{C \times D}{B}\right)] M$$

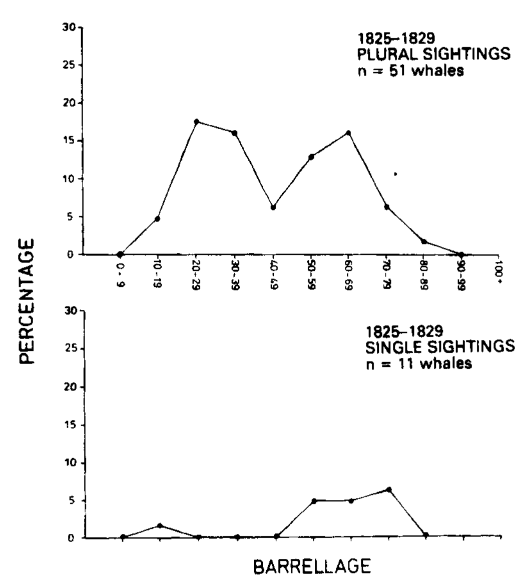
where, for each year

- T = total removals of whales from the stock by whaling
- A = the number of whales tried out in the area by vessels for which 'good' logbook data are available
- B = average oil yield per whale (in A)
- C = number of boats spoken on the grounds, excluding duplicates
- D = average sperm oil production declared per boat spoken (taking the maximum value for duplicate boats spoken)
- M = mortality factor, obtained from data in logbooks recording whales spouting blood, as $\frac{b + c}{b}$

where b = number of whales tried out, and c = number of whales recorded as struck and lost and spouting blood (see Table 2, p. 830).

The above method will give minimum values for the total number of animals removed; not all animals not recorded as spouting blood will have survived, so (b + c) in the mortality factor calculation above should probably be larger. Its maximum value would be the same as (b + a), where a is the number struck and lost, which of course assumes that all whales struck and lost eventually died; results using both alternatives are given in Table 3, indicating that between 24,500 and 34,000 whales may have been taken from the area of study over the period. In addition, not all boats on the grounds in any one year will have been spoken by those for which 'goods' logs are available. Given the time and opportunity to extract data from other sources, e.g. listings such as Wood's Abstracts, one would probably obtain a more reliable record of the actual number of vessels whaling in the area. In particular, one would expect more records of vessels in the northern part of Townsend's 'Coast of Japan Ground' than were available in this analysis. The values obtained in Table 3 are thus themselves likely to be low estimates of the actual number removed in the course of the fishery.

Fig. 8. Catch composition (by barrelage) for 'plural' and 'single' sightings data, by 5-year periods, 1825–1860. (Data from logs recording ≥ 70% of the catch, only).



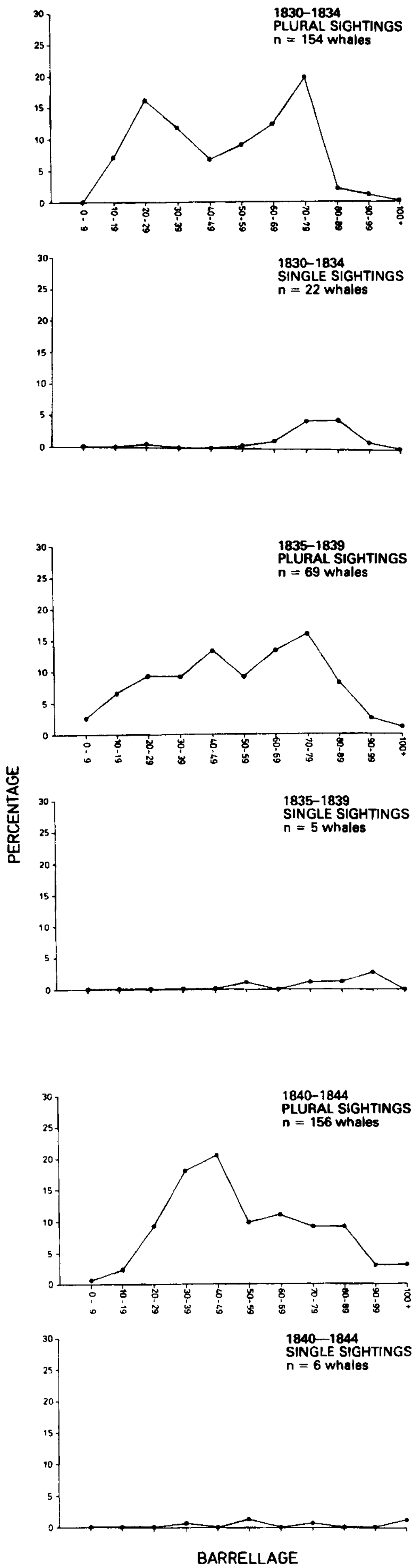


Fig. 8. (continued).

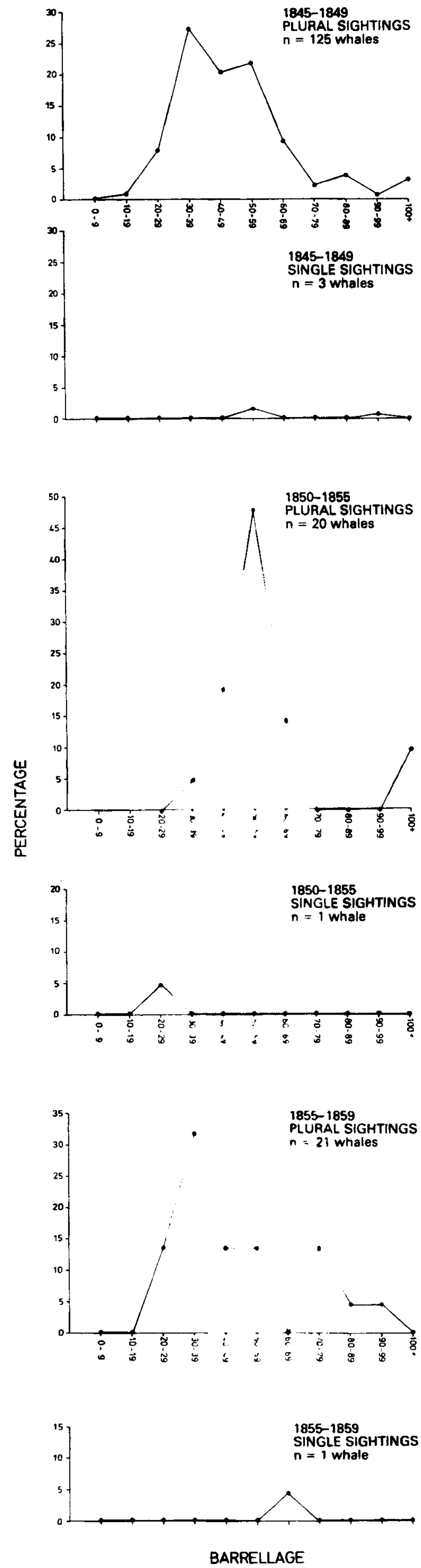


Fig. 8. (continued).

Table 2

Estimation of mortality factor

Vessel	Year	Number struck and lost (a)	Number tried out (b)	No. lost spouting blood (c)	$\frac{b+c}{b}$	$\frac{b+a}{b}$
Ontario	1825	9	29	1 ('sunk')	1.03	1.31
Martha	1831	10	8	1 ('lanced')	1.13	1.80
Pocahontas	1834	9	6	2	1.33	2.50
Ohio	1835	11	21	1	1.05	1.52
Canton	1835	5	14	1	1.20	1.36
Ceres	1837	4	9	1	1.11	2.43
Canton	1836	10	7	2	1.29	1.44
Timoleon	1837	2	4	1	1.25	1.50
Zephyr	1841	5	12	1	1.08	1.42
Fortune	1842	1	1	1	2.00	2.00
Gratitude	1842	5	15	1 ('lanced')	1.07	1.33
Columbia	1842	1	13	1	1.07	1.08
Richard Mitchell	1844	5	14	2	1.14	1.36
Virginia	1845	9	19	2	1.11	1.47
Virginia	1846	4	7	1	1.14	1.57
Total		90	179	19	1.20	1.61

CONCLUSIONS

The pilot study has shown, we believe, that it is possible, given access to the Pacific Manuscripts Bureau microfilms, to obtain a useful sample, if small, of 'good' logbook records, to obtain from those logbooks sufficiently comprehensive information on distribution of catching effort over time, numbers and sizes of whales taken, and trends in abundance from sightings and catch data, to provide information on the progress of the fishery over its major period of operation, and of its likely effect upon the stock or stocks. Approximations to at least a range within which total removals from the stock may lie during the period can also be obtained, although in the present study the estimates obtained are likely to be low ones.

We believe that similar exercises for the other areas for which sufficient logbooks are available should be rewarding, in addition to refinements of and additions to the analyses undertaken of data already obtained in this study.

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Table 3

Estimation of total removals from the area of study (see text for symbols)

Year	A	B	C	D	$\left(\frac{C \times D}{B}\right)$	$A + \left(\frac{C \times D}{B}\right)$	T where M = 1.20	T where M = 1.61
1822	14	45.52*	20	725.8	318.9	332.9	399.5	536.0
23	32	45.52*	11	1,208.3	292.0	324.0	388.8	521.6
24	no data					379.1**	454.9**	610.3**
25	70	53.33	18	1,078.7	364.1	434.1	520.9	698.9
26	37	45.52*	23	1,530.0	773.07	810.1	972.1	1,304.3
27	no data					794.4*	953.3**	1,279.0**
28	47	35.20	19	1,355.5	731.7	778.7	934.4	1,253.7
29	77	48.02	43	1,240.0	1,110.4	1,187.4	1,424.9	1,911.7
1830	128	50.65	52	1,429.4	1,467.5	1,595.5	1,914.6	2,568.8
31	77	46.67	50	1,217.6	1,304.5	1,381.5	1,657.8	2,224.2
32	98	52.76	75	1,158.3	1,646.6	1,744.6	2,093.5	2,808.8
33	24	50.65*	30	799.4	473.5	497.5	597.0	801.0
34	73	47.22	52	1,022.5	1,126.0	1,199.0	1,438.8	1,930.4
35	50	50.65*	27	1,084.0	577.8	627.8	753.4	1,010.8
36	42	51.46	28	1,245.4	677.6	719.6	863.5	1,158.6
37	60	45.13	34	934.6	704.1	764.1	916.9	1,230.2
38	13	50.65*	32	945.2	597.2	610.2	732.2	982.4
39	68	54.40	24	1,198.6	528.8	596.8	716.2	960.8
1840	27	48.61	17	1,063.0	371.3	398.3	478.0	641.3
41	32	49.49*	21	1,318.8	559.6	591.6	709.9	952.5
42	94	50.4	36	1,142.0	815.7	909.7	1,091.7	1,464.6
43	86	53.0	67	926.9	1,171.8	1,257.8	1,509.4	2,025.1
44	58	45.0	35	1,064.3	827.8	885.8	1,063.0	1,426.1
45	44	51.68	17	828.1	272.4	316.4	379.7	509.4
46	20	51.32	7	916.7	125.0	145.0	174.0	233.5
47	31	40.14	18	773.1	346.7	377.7	453.2	608.1
48	42	43.54	18	903.9	373.7	415.7	498.8	669.3
49	31	48.61	8	1,000.0	164.6	195.6	234.7	314.9
1850	10	51.70	10	600.0	116.1	126.1	151.3	203.0
51	no data					79.0**	94.8**	127.1**
52	15	50.42*	3	283.3	16.9	31.9	38.2	51.4
53	8	50.42*	4	916.7	72.7	80.7	96.9	129.9
54	8	55.12	7	966.7	122.8	130.8	157.0	210.6
55	6	52.0	8	1,050.0	161.5	167.5	201.0	269.7
56	16	50.42*	10	425.0	84.3	100.3	120.4	161.5
57	24	51.75	12	480.0	111.3	135.3	162.4	217.8
58	12	50.42*	5	700.0	69.4	81.4	97.7	131.1

	$\left[A + \left(\frac{C \times D}{B}\right)\right]$	T where M = 1.20	T where M = 1.61
1822–29	3,867	4,641	6,226
1830–39	9,737	11,684	15,676
1840–49	5,494	6,592	8,845
1850–58	854	1,025	1,375
Adjustment**	1,253	1,503	2,017
Total	21,205	25,445	34,139

* 10 year average taken where annual data are insufficient.

** To allow for years where no data are available, but catches must have occurred, figures obtained as means of adjacent values.

Appendix A

LOGBOOK EXTRACTION FOR THE 'COAST OF NEW HOLLAND' GROUND

As for the north-western Pacific, Townsend's charts were used as the basis for initial definition of the area of study. Similarly, as work proceeded, it became obvious that the number of logbooks from which useful data could be extracted within the strict limits of Townsend's 'grounds' was likely to be rather small, and the area was extended to include between Latitudes 10° and 40°S an area from 90°E to 140°E, i.e. slightly larger than that currently encompassed in those latitudes by the Commission's Southern Hemisphere sperm whale Division 9.

Table 1 records the numbers of logbooks available and examined for the eastern Indian Ocean area defined as above. While the total available on the basis of the number indexed by Langdon is considerably smaller than for the north-western Pacific, the proportion of 'good' logbooks available is much higher. A main reason for this difference is that vessels listed for the eastern Indian Ocean area in Langdon can be readily recognised as having spent considerable time whaling there; this contrasts with the situation in the north-western Pacific where it is not possible to differentiate in the Index between vessels actually whaling on the grounds and those only calling, for example, at Hawaii, or passing through and not significantly whaling in the area. At the same time, however, since priority was given in the pilot study to completing, as far as possible, analyses of north-western Pacific data, the eastern Indian Ocean extractions could not be completed, and only proceeded to the extent indicated in Table 1. Thus the definition of 'good' logbooks in that Table differs from that in the north-western Pacific extractions, and the amount of 'vessel-year' data available can only be estimated at this time.

Appendix A Table 1

Number of logbooks relevant to sperm whaling for the Eastern Indian Ocean, 1835–85

Voyages	Number of logs indexed for Eastern Indian Ocean Area*	Number of logs checked	Number of voyages to the area of study	Number of voyages, begun during the period listed for which** 'good' logbooks were found	Number of vessel-years for which 'good' logbooks were found***
1835–39	23	23	21	18	15
1840–44	30	30	20	18	28
1845–49	19	19	12	10	16
1850–54	8	8	5	5	4
1855–59	30	30	27	22	27
1860–64	13	13	8	6	27
1865–69	9	9	8	8	6
1870–74	7	7	5	5	14
1875→	7	7	5	4	11
Totals	146	146	111	96	148

* Langdon, 1978.
** Determined on basis of legibility of writing, presence of most pages, position and other basic data recorded, presence on ground for a reasonable period, i.e. not just passing through en route for a port, etc.
*** Probable on the basis of examination as in previous column.

Appendix B

VOYAGES TO THE AREA OF STUDY, NORTH WEST PACIFIC 1821–71

Vessel	Years on voyage	Year/s on ground	Master
1820–29			
Ploughboy	1821–24	1822, 1823	William Chadwick
Ploughboy	1824–27	1825	William Chadwick
Ontario	1824–27	1825	Alexander Bunker
Stanton	1824–27	1825, 1826	Josiah Howland
Maria	1825–28	1826	George W. Gardner
George and Susan	1827–29	1828	Edward Gardner
Ploughboy	1827–30	1828, 1829	Nathan Chase
Lima	1827–30	1829	Charles G. Andrews
Maria	1828–31	1829	Ammiel H. Joy
Alexander	1827–30	1829	Samuel Bunker
Harvest	1828–31	1829, 1830	David W. Edwards
1830–39			
Enterprise	1829–32	1830, 1831	John Stetson
Fortune	1829–32	1830, 1831	Swain and Brock
Richard Mitchell	1829–31	1830	David Baker
Montano	1829–32	1830	Benjamin Worth
Orion	1829–32	1830	Shadrack Freeman
Martha	1829–33	1831	Alexander Whippey
Arabella	1830–33	1831, 1832	James Pierson
Young Phoenix	1830–33	1832	Obed. Cathcart
Isabella	1831–34	1832	Joseph Taber Jnr.
Cadmus	1831–34	1832	Frederick C. Taber
Lancaster	1831–34	1832	Obed. Nye Swift
Parker	1831–35	1832	Charles F. Brown
Catherine	1831–35	1832, 1833	John Brown
Hesper	1831–34	1833	George F. Brown
Canton Packet	1832–34	1834	Bradford
George	1832–34	1834	Nehemiah West

Vessel	Years on voyage	Year/s on ground	Master
Alexander Coffin	1832–35	1834	David Baker
Pocahontas	1832–36	1834	Charles G. Barnard
Moss	1833–36	1834	Shubael Clark
Daniel Webster	1833–38	1834	P. Pierson
Arabella	1833–37	1834, 1835, 1836	James Pierson
Ohio	1833–37	1834, 1835	Charles W. Coffin
Canton	1834–38	1835, 1836, 1837	Abraham Gardner
Abigail	1835–38	1837	William H. Raynard
Columbus	1835–36	1836	Peter Coffin
Ceres	1834–37	1835, 1836	Richard Weedon
Nautilus	1834–38	1836, 1837	Obed. Swift
Timoleon	1835–39	1837	John Bunker
General Jackson	1836–39	1837	Crocker
George	1836–39	1837	Thomas Hammond
Orion	1836–40	1837	Elihu Coffin
Columbus	1836–39	1838	Cary
Enterprise	1836–40	1838, 1839	George Haggerty
Elizabeth	1837–41	1838, 1839	Wood
Howard	1838–41	1839	William Worth
Courier	1838–42	1839	Harding
William Wirt	1838–42	1839	Isaac Daggett
Ohio	1837–41	1839, 1840	Charles W. Coffin
1840–49			
Gideon Howland	1838–42	1840	Michael Baker
Columbus	1839–43	1840	William B. Gardner
Zephyr	1839–43	1840, 1841, 1842	Abraham Gardner
Young Eagle	1840–43	1841	Edward C. Austin
Walter Scott	1840–44	1841, 1842, 1843	Cromwell Bunker
Barthol. Gosnold	1840–43	1842	Abraham B. Russell
Fortune	1840–44	1842	William H. Almy
Gratitude	1841–43	1842	Peleg. H. Stetson
Young Phoenix	1840–44	1842, 1843	James A. Shearman
Elizabeth	1841–44	1842, 1843	Isaac G. Hedge
Howard	1841–45	1842, 1843	Alexander Bunker
Columbia	1841–45	1842, 1843, 1844	George Joy
Ocean	1840–44	1843	Elijah Parker
Wilmington and Liverpool Packet	1841–44	1843	Gilbert Place
Benjamin Rush	1841–45	1843	Anthony Gifford
Levi Starbuck	1841–45	1843	Joseph Nye
Nantucket	1841–45	1843	George Gardner
Omega	1843–46	1843	George Haggerty
Balaena	1841–45	1843, 1844	R. Manchester
Ann Alexander	1841–45	1843, 1844	Taber
William and Henry	1841–44	1843, 1844	Ithamar B. Benjamin
Cortes	1842–46	1843, 1844	Hammond
Zephyr	1843–47	1844	Thomas J. Smith
Richard Mitchell	1843–47	1844, 1845	Josiah C. Long
Emerald	1843–47	1844	Obed. Cathcart
George	1843–47	1844, 1845	Joseph McCleave
Frances	1843–47	1845, 1846	E. Gardner
Virginia	1843–47	1845, 1846	Joseph T. Chase
William and Eliza	1844–48	1845, 1846, 1847	W. H. Whitfield
Alabama	1846–50	1847, 1848, 1849	Benjamin Coggeshall
Atkins Adams	1846–50	1847, 1848	Samuel Lane
Alpha	1846–50	1849	Joseph W. Folger
Mechanic	1846–51	1847	Oliver Potter
General Scott	1847–51	1849	Alexander P. Fisher
Milton	1847–51	1848, 1849, 1850	Thomas J. Smith
Phoenix	1847–51	1848	McCleave
Olympia	1847–51	1848, 1849, 1850	Woodward
Abigail	1847–51	1848, 1849, 1850	Young
1850–59			
Mohawk	1850–54	1852, 1853	Oliver C. Swain
Norman	1851–55	1853, 1854	Joseph C. Chase
Martha	1852–57	1854, 1855, 1856	Meader
Emily Morgan	1854–59	1856, 1857, 1858	Joseph B. Chase
Ocean Rover	1855–58	1857	Charles A. Veeder
Antelope	1855–59	1857	Oliver Potter
Henry Taber	1855–59	1856, 1857, 1858	Prince W. Ewer
Norman	1855–60	1857, 1858	Charles C. Ray
Belle	1857–62	1858, 1859, 1860, 1861	Roswell Brown
Edward Cary	1858–64	1859	Francis M. Gardner
1860–69			
Mohawk	1859–63	1861	George Swain
Alpha	1860–65	1861, 1862	William H. Caswell
Camilla	1867–71	1868	Benjamin F. Jones

SC/F82/SpS1

Estimates of Abundance for the Western North Pacific Sperm Whale based upon Historical Whaling Records[1]

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INTRODUCTION

Over the past five years, the Scientific Committee has attempted several times to assess the North Pacific sperm whale population using the large volume of catch per unit effort (CPUE) data available from the modern coastal and pelagic whaling industries. The last agreed-upon estimate (in 1977) of initial population size for the Western Division obtained using these data was 302,000, representing the total number of exploitable males and females (IWC, 1980a). Two further assessments, with results variously ranging from 269,000 to 716,000 Western Division sperm whales (IWC, 1980b; 1980c), were undertaken using CPUEs before the Scientific Committee concluded that population sizes could not be estimated from these data (IWC, 1981; 1982a). Unresolved difficulties cited in using the available CPUEs included (1) the lack of information on school size needed for effort modification; (2) variations in population density, both seasonally and by area, and latitudinal changes in the whaling grounds; and (3) uncertainties in pooling divergent series of Japanese coastal and pelagic CPUE data.

The failure of the CPUE data, and consequently of the models using them, has spurred the development of new methods which are free from the vagaries of defining or measuring an appropriate unit of whaling effort. Indeed, assessments were attempted in 1980 and 1981 using techniques determining the goodness of fit of expected age or length distributions with those observed in the catch (Beddington and Cooke, 1981; Cooke and Beddington, 1982; Shirakihara and Tanaka, 1982). The results of these models have not yet been universally accepted by the Scientific Committee and their further development has been recommended (IWC, 1982b).

The shortcomings of the CPUE data base have also fostered a search for other data sources which might lead to independent estimates of abundance. For example, the Scientific Committee has recommended that data resulting from past mark–recapture experiments be re-analyzed (IWC, 1982b). Another possible source of 'new' information is the data extracted by Bannister *et al.* (1981) from historical whaling records, i.e. logbooks and journals surviving from the era of sail-powered sperm whaling in the Western North Pacific.

Bannister *et al.* (1981) undertook the study of these records in response to a recommendation of the International Workshop on Historical Whaling Records that a pilot project on the 'Japan' grounds be undertaken for sperm whales (IWC, 1983). Bannister's group defined the study area corresponding to the 'Japan' grounds as extending from 140° E to 160° W, in the band between 20° to 40° N. This area corresponds to a major portion of the presently defined Western Division of the North Pacific sperm whale population (Fig. 1). The data extracted enabled Bannister's group to estimate removals from the stock over the historical period and to calculate several indices of abundance, the elements usually required by several currently available assessment models.

Although whaling technology underwent change during the historical era (Best, 1983), the emphasis of whaling did not shift latitudinally upon the 'Japan' grounds either northward or southward, an occurrence which significantly affected the interpretation and usefulness of the modern whaling data for this stock division. Thus the indices of abundance obtained from historical records of whaling on the 'Japan' grounds taken at face value, seemed to provide an appropriate basis for estimating abundance of the Western Division.

MATERIALS USED

Historical whaling records

The search for sperm whales led whalers to round Cape Horn in 1789, and by 1818 they had discovered the rich equatorial whaling grounds of the Central Pacific (Best, 1983). The 'Japan' grounds in the western North Pacific were opened up shortly thereafter in 1820; sperm whaling in the area continued until about 1870.

Bannister *et al.* (1981) examined microfilmed copies of logbooks archived at the Pacific Manuscripts Bureau, Australian National University, Canberra, to locate voyages through their study area from 1820 onward. Of 827 likely logbooks, 111 were for voyages to the 'Japan' grounds. Of these, only 100 contained data of sufficient quality to warrant extraction. A sample of 159 voyage-years (some logbooks contained records of several annual trips to this area) was obtained for the period 1822–1868.

A major assumption of all such analyses is that the information extracted from surviving logbooks and journals is representative of all voyages to the ground being studied. One might conjecture, for example, that surviving records are of a preferred type, perhaps being the records of only the most successful voyages. Experience from analyzing bowhead logbooks has shown, however, that there is no apparent reason for why one type of logbook might survive over another and that the resulting available sample is probably unbiased (Bockstoce and Botkin, 1983).

[1] Revised following the Special Meeting on Western North Pacific Sperm Whale Assessments, Cambridge, England, February 27–March 5, 1982.

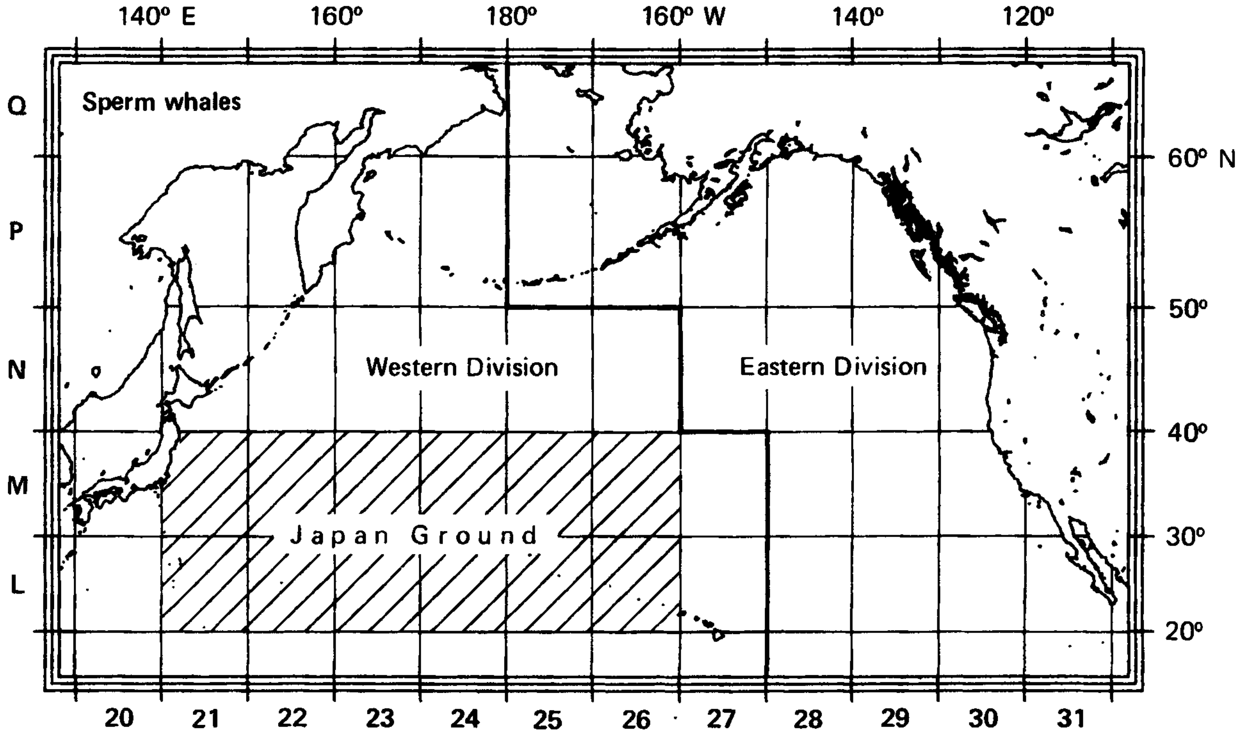

Fig. 1. The area corresponding to the 'Japan' grounds is shown in relation to present stock divisions of the North Pacific sperm whale population.

Catch history

The catch data extracted from logbooks consisted primarily of the numbers of whales actually landed and 'tried out' (processed on deck to obtain oil). The oil production in number of barrels obtained from each animal also was often indicated, and an average oil yield ranging between 40–55 barrels per whale was obtained (Bannister *et al.*, 1981).

Not all chases were successful, even though whales were struck, since lines parted, irons drew, or other mishaps occurred. Logbooks from 14 vessels contained information on the number of struck whales which escaped, as well as annotations about the probable fate of these whales. It was assumed that escaped whales would likely die if they had been 'lanced' (a killing iron was implanted) or observed 'spouting blood,' or if they 'sank'. According to Bannister *et al.* (1981), the available information indicated that landings should be increased by at least 20% to account for the mortalities of these three categories of escaped whales. If one assumed that all escaped whales eventually died, then the records indicated that landings should be increased by no more than 61% to account for all sources of hunting mortality.

Since whaling voyages were lengthy and lonely periods, ships took every opportunity to observe the custom of 'gamming' or 'speaking' to other vessels. Logbook records often noted such encounters, recording the vessel's name, port, and declared oil production. Careful screening of records of such ships 'spoke' to eliminate duplicates resulted in a minimum estimate of the number of vessels on the ground beside those vessels for which logbooks were available (Bannister *et al.*, 1981).

Bannister *et al.* (1981) utilized the available logbook data to estimate the total historical removals as follows:

$$T = \left[A + \left(\frac{CD}{B}\right)\right] M \qquad (1)$$

where, for each year

T = total removals from the stock by whaling
A = number of whales 'tried out' by vessels for which 'good' logbooks were available
B = average oil yield per whale (in A)
C = number of vessels 'spoken' on the grounds, excluding duplicates
D = average sperm oil production declared per vessel 'spoken' (taking the maximum value reported for duplicate vessels 'spoken')
M = mortality factor assumed for escaped whales.

Table 1 gives the estimated removals during the heyday of sperm whaling on the 'Japan' grounds, 1822–58. Only a few ships operated there sporadically afterwards, and beyond 1869 no whaling vessels reported being there. For years where no logbook data were available (1824, 1827, 1851) but for which catches must have occurred, Bannister *et al.* (1981) estimated values as the means of adjacent year's values.

Depending on assumed mortality of escaped whales, the available records indicate that between 24,500 and 34,000 sperm whales may have been taken from the study area over the 37-year period. Bannister *et al.* (1981) regarded these as minimum values since not all ships on the grounds in any one year would have been 'spoken' by those for which 'good' logbooks were available. Consequently, the probable removal was more likely near the top of the range than near the bottom.

Indices of abundance

Bannister *et al.* (1981) easily inferred the total number of days spent on the ground during a voyage from the logbook records. The number of 'sperm whaling days', as measure of effort, was then estimated by deducting from the total the number of days on which active searching for whales would have been impossible or highly unlikely, i.e. days of strong gales, rough seas, or

Table 1

Annual removals and indices of abundance obtained from historical sperm whaling records for the 'Japan' grounds

	Indices of abundance[1]			Estimated removals for different mortality factors[2]	
Year	Average sighting rate	'Sightings' per whaling day	Whales 'tried out' per whaling day	1.20	1.61
1822	0.1667	0.1667	0.1111	399.5	536.0
1823	0.2636	0.2636	0.2909	388.8	521.6
1824	—	—	—	454.9[3]	610.3[3]
1825	0.2468	0.2469	0.1713	520.9	698.9
1826	0.2831	0.2904	0.1360	972.1	1,304.3
1827	—	—	—	953.3[3]	1,279.0[3]
1828	0.2476	0.2476	0.1473	934.4	1,253.7
1829	0.2429	0.2456	0.1045	1,424.9	1,911.7
1830	0.1750	0.1798	0.1231	1,914.6	2,568.8
1831	0.1884	0.2262	0.1190	1,657.9	2,224.2
1832	0.1699	0.1772	0.1016	2,093.5	2,808.8
1833	0.1155	0.1155	0.0676	597.0	801.0
1834	0.1549	0.1578	0.0716	1,438.8	1,930.4
1835	0.1388	0.1498	0.0991	753.4	1,010.8
1836	0.1308	0.1383	0.0858	863.5	1,158.6
1837	0.1466	0.1480	0.0633	916.9	1,230.2
1838	0.1062	0.1091	0.0383	732.2	982.4
1839	0.1673	0.1780	0.0903	716.2	960.8
1840	0.1279	0.1301	0.0616	478.0	641.3
1841	0.1349	0.1376	0.0847	709.9	952.5
1842	0.1442	0.1545	0.0741	1,091.7	1,464.6
1843	0.0946	0.0976	0.0433	1,509.4	2,025.1
1844	0.1126	0.1118	0.0491	1,063.0	1,426.1
1845	0.1313	0.1359	0.0688	379.7	509.4
1846	0.0896	0.0916	0.0407	174.0	233.5
1847	0.0991	0.1062	0.0549	453.2	608.1
1848	0.1026	0.1038	0.0464	498.8	669.3
1849	0.0829	0.0842	0.0421	234.7	314.9
1850	0.0459	0.0460	0.0287	151.3	203.0
1851	—	—	—	94.8[3]	127.1[3]
1852	0.2000	0.2095	0.1429	38.2	51.4
1853	0.0830	0.0830	0.0332	96.9	129.9
1854	0.0925	0.0961	0.0285	157.0	210.6
1855	0.1375	0.1438	0.0375	201.0	269.7
1856	0.0492	0.0480	0.0349	120.4	161.5
1857	0.0665	0.0665	0.0339	162.4	217.8
1858	0.0479	0.0499	0.0230	97.7	131.1

[1] Source: Bannister (pers. comm.)
[2] Making different assumptions about the fate of struck and lost whales.
[3] For years where no data are available, but catches must have occurred, values obtained as means of adjacent values.

fog. Days on which 'trying-out' was going on were included in the measure of effort since sightings of whales and other catches frequently occurred on such days.

Besides the number of whales landed, logbooks often reported on sightings of sperm whales. Though it was the event that was most often recorded, rather than the number seen, Bannister *et al.* (1981) examined the number of these events per unit effort as a possible index of abundance, in addition to the traditional measure of CPUE.

Table 1 gives the three indices of abundance obtained from the historical data available for each season:

- average sighting rate, defined as the number of days on which whales were sighted divided by the number of days spent searching (i.e. sperm whaling days)
- the number of total sighting events divided by the number of sperm whaling days
- the number of whales 'tried out' divided by the number of sperm whaling days.

As indicated in Fig. 2, all three indices suggest that the sperm whale population occupying the study area declined in response to the extensive removals which occurred during the period. The indices also suggest that the decline began slowing after about 1835. Bannister *et al.* (1981) suggested that this latter observation might reflect a shift in the emphasis of sperm whaling. The catch before 1835 apparently was comprised mostly of females, small males, and large males, i.e. probably associated with breeding schools, while after 1840 it was mostly medium-sized males, i.e. probably on groups of 'bachelor bulls' away from breeding schools. Coincidentally, a westward shift in effort occurred through the 'Japan' grounds from about 1840, which was perhaps associated with the shift in target catches.

The outlying values of indices obtained for 1822, 1823, 1852 and 1855 were based on only one vessel-year of logbook data. As a general rule such observations were not used in the estimation procedures.

BIOLOGICAL PARAMETERS

Unfortunately, the historical whaling records do not provide a basis for estimating the values of biological parameters which occurred during that era. We therefore examined recent estimates obtained from the modern era to obtain a reasonable set of values which might have applied.

Since the emphasis of whaling apparently shifted from breeding schools to 'bachelor' schools after about 1840, it seemed necessary to consider two possibilities for the applicable mean age at recruitment.

Since the age at recruitment is highly dependent upon the length limit in effect and since the early whaling industry was not constrained by length limits, for the pre-1840 era when small animals were taken, it seemed reasonable to use the mean age at recruitment which occurred during the modern period when the lowest length limit was in effect. Thus, for the pre-1840 era, we constrained our consideration of modern estimates to those obtained after 1972 when the length limit was decreased from 38 ft to 30 ft (Table 2). We included post-1972 estimates obtained from pelagic data since Smith's (1980) distributions of modern catches indicated that pelagic whaling did not occur in the study area until after 1972. The pooled estimate obtained for both sexes is 12 years. A pooled estimate is used since the early industry apparently selected randomly from the group of sperm whales being chased (IWC, 1983).

For the post-1840 era, when mainly medium-sized males were taken, it seemed reasonable to use the mean age at recruitment of males taken before 1972. The estimate obtained from Table 2 is 15 years.

The average age at maturity of females has been determined to be 10 years at a number of assessment meetings (Table 2). Values of the estimated natural mortality rate have varied only slightly over the past few years (Table 2), and a pooled estimate of 0.06 was obtained for both sexes. The juvenile natural mortality rate was taken as 0.09 (Table 2) and applied for two years (IWC, 1980c).

The Scientific Committee has long assumed that pregnancy rates for the North Pacific population ranged in a density-dependent manner between 0.20 and 0.25. Given these values and other parameter estimates, possible recruitment rates were calculated as follows:

$$r = (1/2) P e^{-2M_j} e^{-(t_r-2)M} \quad (2)$$

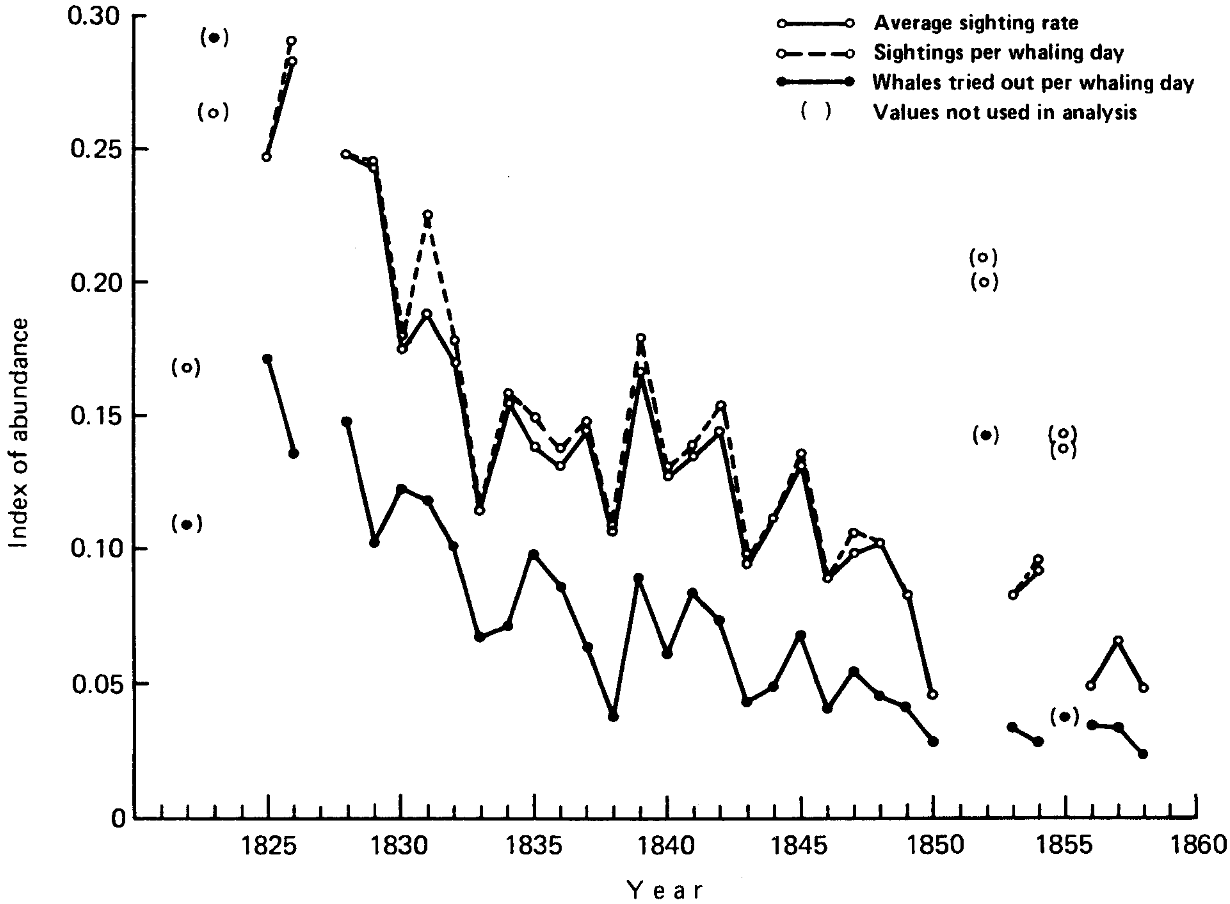

Fig. 2. Three indices of sperm whale abundance obtained from logbook records for voyages to the 'Japan' grounds.

Table 2

Estimates of biological parameters obtained for the North Pacific sperm whale population by the Scientific Committee

Parameter		Estimates from various sources		
		IWC (1980a)	IWC (1980b)	IWC (1980c)
Average age at recruitment				
Post-1972	Male	13[1]	13[1]; pelagic 12	coastal 11
	Female	13[1]	10[1]	10
Pre-1972	Male	15[1]	16[1]	coast. 12; pel. 16, 17
	Female	15[1]	10[1]	10
Average age at maturity (female only)		10	10	10
Natural mortality rate				
Adult		0.0589	0.055	♂: 0.066; ♀: 0.055
Juvenile		0.0589	0.0926	0.0926

[1] From pooled coastal and pelagic data.

where P = pregnancy rate; M_j = juvenile natural mortality rate; t_r = average age at recruitment; M = adult natural mortality rate. Based on this exercise, we believed that values in the range 0.04 to 0.06 would be reasonable for the purposes of testing the sensitivity of various estimation procedures.

ESTIMATION METHODS

Chapman (1974) modified the Leslie model (Leslie and Davis, 1939), relating catch per effort to cumulative removals, to allow for constant recruitment. The modified DeLury model, as it has come to be called, assumes that exploitation began on an unexploited population in equilibrium so that, if the data series are no longer than the age at recruitment, the assumption of constant recruitment holds (i.e. recruitment is proportional to the equilibrium population size). A further necessary condition is that the natural mortality rate (M) be known. The approximate equilibrium level of recruitment is then

$$R = MN_1 \qquad (3)$$

where R = annual recruitment to the stock; M = instantaneous annual natural mortality rate; N_1 = stock size in numbers prior to exploitation. For a full development of the model, one should see Tillman and Breiwick (1977).

Allen (1966) developed a model (expected catch method) to estimate stock size by minimizing the sum of the squared differences between observed and expected catches. The method assumes that the coefficient of catchability, q, remains constant through time. In addition to a catch and effort series (or catch and index of abundance series) and natural mortality rate, a series consisting of the proportion of new recruits entering in each season is needed:

$$N_{t+1} = s_t N_t + w_{t+1} N_{t+1} \quad (4)$$

where s_t = annual (total) survival rate in season t, w_t = proportion of new recruits entering in season t. Allen's (1966) expected catch method can also be formulated in terms of a no-intercept multiple regression model and can be modified to produce estimates based upon the minimization of the squared differences between observed and expected CPUEs (Appendix 1). One should note that indices of abundance based on sightings data can be treated as if they were CPUEs.

Weighted least-squares could also be applied to the above models. Kirkwood (1981) suggested an error model which leads to minimizing the sum of the squared differences between the square root of the observed catch and the square root of the expected catch. For comparative purposes this was done for the modified DeLury and Allen expected catch models using iterative, nonlinear least-squares techniques.

The above models are regression models such that the estimate of the initial population size is the ratio of the regression coefficients. The variance of this ratio can be estimated by the so-called delta method (Seber, 1973) or the Fieller technique (Appendix 2). Although the Fieller confidence intervals are asymmetric, they are preferred over those derived by the delta method since it assumes that the sample size is large and that N_1 is approximately normally distributed.

An alternative sample-reuse technique, the jackknife statistic, may also be used to calculate approximate confidence intervals as well as a possibly less biased estimate of N_1 (see Bissell and Ferguson, 1975, and references contained therein). The jackknife pseudovalues are calculated by successively deleting the ith row from the **y** vector and **X** matrix:

$$p_i^* = n\hat{p} - (n-1)\hat{p}_{-i} \quad (5)$$

where p_i^* is the ith pseudo-value, $\hat{p}$ is the estimate of N_1 using all the data, and $\hat{p}_{-i}$ is the estimate of N_1 by deleting the ith row of the **y** vector and **X** matrix. The jackknife estimate, $\hat{p}_J$, is the mean of the pseudo-values and can be useful in eliminating the bias of order $(1/n)$ in ratio-type estimates. The variance of the jackknife estimate is given by

$$\text{var}(\hat{p}_J) = \sum_i (p_i^* - \hat{p}_J)^2/n(n-1). \quad (6)$$

Jackknife estimates (N_J) of N_1 and the corresponding 95% confidence intervals were calculated for each of the above models.

RESULTS

Modified DeLury model

Table 3 gives the estimates of initial abundance obtained using the modified DeLury model alone and in conjunction with the jackknife procedure. All of the jackknife estimates, though quite similar, are slightly less than those obtained using the DeLury model alone and also have slightly narrower confidence intervals. These observations apply as well to the Allen model results considered in the next sections.

Within the series of periods examined, the best 'fit' seems to occur for the period 1825–38. Beyond 1838, there is a tendency for values of R^2 to decline and for confidence intervals to widen. This is not an unexpected occurrence since the period 1825–38 most nearly coincides with the average age at recruitment, 12, which defines the period length for which it might be reasonable to assume that recruitment is constant at the virgin equilibrium stock level, as required by the modified DeLury model.

The following table synthesizes modified DeLury estimates obtained for the period 1825–38 given our 3 indices of abundance and 2 catch factors (accounting for the different assumptions about mortality of struck and lost whales):

Index of abundance	Catch factor 1	Catch factor 2
1	19,000	25,000
2	19,500	26,000
3	18,000	24,000

The results for indices 1 and 2, which are both based on sightings data, are very similar, with differences of less than 1,000 whales occurring between comparable estimates of abundance. This same pattern occurs for the Allen model estimates, and hence, we have only contrasted indices 1 and 3 in this and following sections.

Index of abundance 1, based on sightings, gives somewhat higher estimates than does index 3, based on CPUEs. Moreover, index 1 gives a better 'fit' in terms of higher values of R^2, the coefficient of determination; smaller values of CV, the coefficient of variation (values of 10–20% are reasonable); and somewhat narrower confidence intervals. As might be expected, though, the major influence on results is the catch factor used, with factor 2 giving estimates which are several thousand whales greater than factor 1.

Allen's expected catch model

Tables 4, 5 and 6 present the results obtained from Allen's expected catch model when w, the proportion of new recruits entering the population, is held constant throughout each period examined. This assumes that recruitment does not behave in a density-dependent manner. Values of w of 0.04, 0.05 and 0.06 were used to test the sensitivity of the model to changes in this parameter.

All of the estimates obtained by this procedure are much higher than those obtained using the modified DeLury model (Table 3). Moreover, all of the R^2 values obtained are also much higher.

Another notable feature of these results is that, within each index of abundance and catch factor examined, the values of the estimates increase as the length of the period used is increased. In contrast, the DeLury estimates all tend to have the same value despite the length of period used. Within each index and catch factor used, the Allen expected catch estimates also tend to converge in the last three periods examined.

In their respective analyses of bowhead historical data, Bockstoce and Botkin (1983) and Tillman *et al.* (1983) discussed how to treat the problem of a violation of the assumption of a closed population (inherent in all of these

Table 3

Results of modified DeLury model ($M = 0.06$)

Season	Index of abundance[1]	Catch factor	N_1[2]	N_J	R^2	CV[3]	Confidence intervals		
							Delta	Jackknife[4]	Fieller
1825–1835	1	1	18.8	18.7	0.863	0.128	(14.0, 23.6)	(14.2, 23.1)	(15.4, 25.4)
1825–1838	1	1	18.9	18.8	0.886	0.097	(15.2, 22.6)	(15.7, 22.0)	(16.4, 22.9)
1825–1840	1	1	19.9	19.8	0.852	0.104	(15.8, 24.1)	(16.3, 23.3)	(17.3, 24.3)
1825–1845	1	1	20.2	20.1	0.861	0.084	(16.8, 23.6)	(17.4, 22.8)	(18.1, 23.3)
1825–1850	1	1	18.6	18.5	0.793	0.094	(15.1, 22.1)	(16.2, 20.8)	(16.7, 21.5)
1825–1858	1	1	18.4	17.9	0.504	0.166	(12.3, 24.5)	(14.7, 21.1)	(15.5, 24.7)
1825–1835	2	1	20.0	19.6	0.786	0.168	(13.3, 26.7)	(13.5, 25.7)	(15.5, 30.9)
1825–1838	2	1	19.6	19.4	0.837	0.120	(14.9, 24.3)	(15.7, 23.2)	(16.5, 25.1)
1825–1840	2	1	20.6	20.4	0.801	0.124	(15.5, 25.7)	(16.2, 24.6)	(17.4, 26.5)
1825–1845	2	1	20.7	20.6	0.821	0.098	(16.7, 24.8)	(17.5, 23.7)	(18.2, 24.6)
1825–1850	2	1	18.9	18.8	0.755	0.105	(14.9, 22.8)	(16.3, 21.4)	(16.7, 22.3)
1825–1858	2	1	18.7	18.2	0.470	0.177	(12.1, 25.3)	(14.8, 21.6)	(15.6, 26.0)
1825–1835	3	1	19.7	18.7	0.753	0.184	(12.4, 27.0)	(11.6, 25.9)	(15.0, 32.4)
1825–1838	3	1	17.9	17.5	0.788	0.141	(12.9, 23.0)	(13.1, 21.9)	(14.9, 24.1)
1825–1840	3	1	18.5	18.1	0.776	0.133	(13.6, 23.5)	(14.1, 22.2)	(15.6, 24.1)
1825–1845	3	1	18.6	18.4	0.796	0.106	(14.7, 22.6)	(15.6, 21.2)	(16.4, 22.3)
1825–1850	3	1	17.3	17.2	0.773	0.100	(13.8, 20.7)	(15.1, 19.2)	(15.5, 20.0)
1825–1858	3	1	16.9	16.5	0.510	0.164	(11.3, 22.4)	(13.7, 19.2)	(14.4, 22.2)
1825–1835	1	2	25.2	25.0	0.863	0.128	(18.8, 31.7)	(19.0, 31.0)	(20.7, 34.0)
1825–1838	1	2	25.4	25.3	0.886	0.097	(20.4, 30.3)	(21.0, 29.5)	(22.0, 30.7)
1825–1840	1	2	26.8	26.6	0.852	0.104	(21.2, 32.3)	(21.8, 31.3)	(23.2, 32.7)
1825–1845	1	2	27.1	26.9	0.861	0.084	(22.5, 31.6)	(23.3, 30.6)	(24.3, 31.2)
1825–1850	1	2	24.9	24.8	0.793	0.094	(20.2, 29.6)	(21.7, 27.9)	(22.3, 28.8)
1825–1858	1	2	24.7	24.0	0.504	0.166	(16.5, 32.8)	(19.7, 28.3)	(20.8, 33.1)
1825–1835	2	2	26.8	26.3	0.786	0.168	(17.8, 35.8)	(18.1, 34.4)	(20.8, 41.4)
1825–1838	2	2	26.2	26.1	0.837	0.120	(20.0, 32.5)	(21.0, 31.1)	(22.1, 33.6)
1825–1840	2	2	27.6	27.4	0.801	0.124	(20.8, 34.5)	(21.8, 33.0)	(23.3, 35.5)
1825–1845	2	2	27.8	27.6	0.821	0.098	(22.4, 33.3)	(23.4, 31.9)	(24.5, 33.0)
1825–1850	2	2	25.3	25.2	0.755	0.105	(20.0, 30.6)	(21.8, 28.7)	(22.5, 29.9)
1825–1858	2	2	25.1	24.4	0.470	0.177	(16.2, 34.0)	(19.9, 29.0)	(20.9, 34.8)
1825–1835	3	2	26.4	25.1	0.753	0.184	(16.7, 36.2)	(15.5, 34.7)	(20.1, 43.5)
1825–1838	3	2	24.1	23.5	0.788	0.141	(17.3, 30.8)	(17.6, 29.3)	(19.9, 32.3)
1825–1840	3	2	24.9	24.3	0.776	0.133	(18.2, 31.5)	(18.9, 29.8)	(20.9, 32.3)
1825–1845	3	2	25.0	24.7	0.796	0.106	(19.7, 30.3)	(21.0, 28.5)	(22.0, 29.9)
1825–1850	3	2	23.1	23.0	0.773	0.100	(18.5, 27.8)	(20.3, 25.8)	(20.8, 26.8)
1825–1858	3	2	22.6	22.1	0.510	0.164	(15.2, 30.1)	(18.4, 25.8)	(19.3, 29.7)

[1] Indices of abundance: 1, average sighting rate; 2, 'sightings' per whaling day; 3, whales 'tried out' per whaling day (effort derived from catch and index of abundance).

[2] N_1, N_J (jackknife estimate of N_1) and confidence intervals are in thousands.

[3] Estimated coefficient of variation of N_1 based on delta method variance.

[4] Refers to N_J only. The other confidence intervals are for N_1.

models). That is, over a long history of exploitation whaling might be conducted upon a number of sub-populations, rather than on a single closed population, occupying a particular ground. In this circumstance the concensus was that one should utilize as much of the data available within an historical series as possible to estimate the total size of the population within the ground studied. Consequently we have chosen as 'best' Allen model estimates those resulting from the period 1825–1858.

The following table synthesizes the Allen expected catch estimates; in all cases, the lower estimate is that resulting from applying the jackknife procedure as well:

Catch factor	Index of abundance	Value of w		
		0.04	0.05	0.06
1	1	57,000–61,000	42,500–44,000	33,500–34,000
	3	42,000–44,000	34,000–35,000	28,500–29,000
2	1	77,000–82,000	57,000–59,000	45,000–46,000
	3	56,500–59,000	46,000–47,000	38,000–39,000

As with the modified DeLury estimates, index of abundance 1 gives higher estimates than does index 3. As indicated by values of R^2, index 1 also gives a somewhat better 'fit' than does index 3, although there is not a consistent pattern for values of CV and widths of confidence intervals. Again, which catch factor is used has a major influence on results, with catch factor 2 giving the highest estimates.

The sensitivity of model results to changes in w also depends upon which catch factor is used. Varying w down to 0.04 from 0.05 or up to 0.06 represents a change of $\pm 20\%$. The following table synthesizes the percentage changes in estimates resulting from varying w (the plus or minus sign indicates the direction of change):

Catch factor	Value of w	
	0.04	0.06
1	(+) 34–39%	(−) 21–23%
2	(+) 23–26%	(−) 16–17%

Catch factor 2 not only gives the highest estimates, it is also least sensitive to changes in w.

(continued on p. 266)

Table 4

Results of Allen's expected catch model ($M = 0.06$, $w = 0.04$)

Season	Index of abundance[1]	Catch factor	N_1[2]	N_J	R^2	CV[3]	Confidence intervals: Delta	Jackknife[4]	Fieller
1825–1835	1	1	37.9	37.4	0.990	0.279	(16.7, 59.0)	(18.2, 56.7)	(25.6, 108.5)
1825–1838	1	1	41.1	40.3	0.990	0.209	(24.0, 58.3)	(24.2, 56.5)	(30.5, 73.1)
1825–1840	1	1	46.6	44.4	0.987	0.240	(24.2, 69.0)	(22.2, 66.7)	(33.3, 94.4)
1825–1845	1	1	60.2	53.9	0.984	0.184	(38.0, 82.4)	(23.8, 84.0)	(46.2, 94.4)
1825–1850	1	1	61.3	56.7	0.984	0.161	(41.6, 81.0)	(30.6, 82.9)	(48.6, 88.3)
1825–1858	1	1	61.1	57.2	0.984	0.143	(43.6, 78.5)	(32.8, 81.5)	(49.6, 83.3)
1825–1835	3	1	35.2	23.9	0.985	0.293	(14.6, 55.7)	(— , 60.5)	(23.7, 112.6)
1825–1838	3	1	30.0	27.0	0.979	0.167	(20.0, 40.0)	(13.2, 40.8)	(24.1, 43.8)
1825–1840	3	1	32.4	28.5	0.974	0.183	(20.5, 44.2)	(11.2, 45.7)	(25.6, 49.5)
1825–1845	3	1	42.3	40.5	0.967	0.156	(29.1, 55.5)	(30.3, 50.7)	(34.8, 58.3)
1825–1850	3	1	43.9	41.8	0.965	0.141	(31.5, 56.4)	(31.0, 52.7)	(36.7, 58.0)
1825–1858	3	1	44.1	42.1	0.965	0.127	(32.9, 55.3)	(31.6, 52.6)	(37.5, 56.0)
1825–1835	1	2	50.8	50.2	0.990	0.279	(22.4, 79.2)	(24.4, 76.1)	(34.4, 145.6)
1825–1838	1	2	55.2	54.1	0.990	0.209	(32.2, 78.2)	(32.4, 75.8)	(40.9, 98.1)
1825–1840	1	2	62.6	59.6	0.987	0.240	(32.5, 92.6)	(29.8, 89.5)	(44.7, 126.7)
1825–1845	1	2	80.8	72.3	0.984	0.184	(51.0, 110.5)	(31.9, 112.7)	(62.0, 126.6)
1825–1850	1	2	82.2	76.1	0.984	0.161	(55.8, 108.7)	(41.0, 111.2)	(65.2, 118.5)
1825–1858	1	2	81.9	76.7	0.984	0.143	(58.5, 105.4)	(44.0, 109.3)	(66.5, 111.7)
1825–1835	3	2	47.2	32.1	0.985	0.293	(19.6, 74.8)	(— , 81.2)	(31.8, 151.0)
1825–1838	3	2	40.3	36.2	0.979	0.167	(26.8, 53.7)	(17.7, 54.7)	(32.4, 58.7)
1825–1840	3	2	43.4	38.2	0.974	0.183	(27.6, 59.3)	(15.1, 61.3)	(34.3, 66.4)
1825–1845	3	2	56.8	54.4	0.967	0.156	(39.1, 74.5)	(40.7, 68.0)	(46.6, 78.2)
1825–1850	3	2	58.9	56.1	0.965	0.141	(42.3, 75.6)	(41.5, 70.7)	(49.2, 77.8)
1825–1858	3	2	59.2	56.5	0.965	0.127	(44.1, 74.2)	(42.4, 70.6)	(50.3, 75.1)

[1] Indices of abundance: 1, average sighting rate; 3, whales 'tried out' per whaling day (effort derived from catch and index of abundance).
[2] N_1, N_J (jackknife estimate of N_1) and confidence intervals are in thousands.
[3] Estimated coefficient of variation of N_1 based on delta method variance.
[4] Refers to N_J only. The other confidence intervals are for N_1.

Table 5

Results of Allen's expected catch model ($M = 0.06$, $w = 0.05$)

Season	Index of abundance[1]	Catch factor	N_1[2]	N_J	R_2	CV[3]	Confidence intervals: Delta	Jackknife[4]	Fieller
1825–1835	1	1	31.5	31.6	0.990	0.237	(16.6, 46.4)	(18.3, 44.8)	(22.6, 67.1)
1825–1838	1	1	33.5	33.2	0.990	0.171	(22.0, 44.9)	(22.8, 43.6)	(26.3, 50.8)
1825–1840	1	1	36.8	36.0	0.987	0.189	(22.9, 50.8)	(22.6, 49.3)	(28.3, 59.2)
1825–1845	1	1	43.7	47.1	0.984	0.131	(32.2, 55.2)	(26.5, 55.7)	(36.5, 57.2)
1825–1850	1	1	44.2	42.4	0.984	0.113	(34.2, 54.2)	(30.3, 54.6)	(37.8, 55.0)
1825–1858	1	1	43.9	42.5	0.984	0.100	(35.1, 52.7)	(31.6, 53.5)	(38.2, 52.9)
1825–1835	3	1	29.5	22.9	0.985	0.248	(14.9, 44.1)	(— , 46.2)	(21.2, 66.4)
1825–1838	3	1	25.9	23.8	0.979	0.145	(18.4, 33.4)	(14.2, 33.4)	(21.6, 34.7)
1825–1840	3	1	27.5	25.1	0.974	0.157	(18.9, 36.2)	(13.5, 36.7)	(22.7, 38.1)
1825–1845	3	1	34.2	33.2	0.967	0.128	(25.5, 42.9)	(27.0, 39.3)	(29.4, 42.8)
1825–1850	3	1	35.2	34.0	0.965	0.115	(27.1, 43.2)	(27.6, 40.4)	(30.7, 42.7)
1825–1858	3	1	35.2	34.2	0.965	0.102	(28.0, 42.5)	(28.2, 40.2)	(31.2, 41.6)
1825–1835	1	2	42.2	42.3	0.990	0.237	(22.2, 62.2)	(24.6, 60.1)	(30.4, 90.1)
1825–1838	1	2	44.9	44.5	0.990	0.171	(29.5, 60.3)	(30.5, 58.5)	(35.3, 68.1)
1825–1840	1	2	49.4	48.2	0.987	0.189	(30.7, 68.1)	(30.3, 66.1)	(38.0, 79.4)
1825–1845	1	2	58.7	55.1	0.984	0.131	(43.3, 74.0)	(35.5, 74.7)	(48.9, 76.8)
1825–1850	1	2	59.3	57.0	0.984	0.113	(45.8, 72.7)	(40.7, 73.2)	(50.7, 73.7)
1825–1858	1	2	58.9	57.1	0.984	0.100	(47.1, 70.7)	(42.3, 71.8)	(51.3, 71.0)
1825–1835	3	2	39.5	30.7	0.985	0.248	(19.9, 59.1)	(— , 62.0)	(28.4, 89.0)
1825–1838	3	2	34.7	32.0	0.979	0.145	(24.6, 44.8)	(19.1, 44.9)	(28.9, 46.6)
1825–1840	3	2	36.9	33.7	0.974	0.157	(25.4, 48.5)	(18.1, 49.2)	(30.4, 51.1)
1825–1845	3	2	45.9	44.5	0.967	0.128	(34.2, 57.6)	(36.2, 52.8)	(39.5, 57.4)
1825–1850	3	2	47.2	45.6	0.965	0.115	(36.4, 58.0)	(37.1, 54.2)	(41.2, 57.2)
1825–1858	3	2	47.3	45.9	0.965	0.102	(37.6, 57.0)	(37.8, 54.0)	(41.9, 55.8)

[1] Indices of abundance: 1, Average sighting rate; 3, whales 'tried out' per whaling day (effort derived from catch and index of abundance).
[2] N_1, N_J (jackknife estimate of N_1) and confidence intervals are in thousands.
[3] Estimated coefficient of variation of N_1 based on delta method variance.
[4] Refers to N_J only. The other confidence intervals are for N_1.

Table 6

Results of Allen's expected catch model ($M = 0.06$, $w = 0.06$)

Season	Index of abundance[1]	Catch factor	N_1[2]	N_J	R^2	CV[3]	Confidence intervals: Delta	Jackknife[4]	Fieller
1825–1835	1	1	26.8	27.0	0.990	0.207	(15.7, 37.8)	(17.5, 36.6)	(20.2, 48.1)
1825–1838	1	1	28.0	28.0	0.990	0.145	(19.9, 36.2)	(20.8, 35.1)	(23.0, 38.6)
1825–1840	1	1	30.2	29.9	0.987	0.155	(20.8, 39.6)	(21.2, 38.5)	(24.5, 42.7)
1825–1845	1	1	34.1	32.7	0.985	0.102	(27.2, 41.0)	(24.5, 40.9)	(29.9, 40.8)
1825–1850	1	1	34.3	33.5	0.984	0.087	(28.3, 40.3)	(26.9, 40.0)	(30.7, 39.6)
1825–1858	1	1	34.0	33.5	0.984	0.077	(28.8, 39.3)	(27.7, 39.2)	(30.9, 38.5)
1825–1835	3	1	25.2	21.0	0.985	0.215	(14.4, 36.1)	(5.1, 37.0)	(19.0, 46.6)
1825–1838	3	1	22.6	21.2	0.979	0.128	(16.8, 28.4)	(14.3, 28.1)	(19.4, 28.6)
1825–1840	3	1	23.9	22.2	0.974	0.137	(17.3, 30.4)	(14.1, 30.4)	(20.3, 30.8)
1825–1845	3	1	28.5	27.8	0.967	0.109	(22.3, 34.7)	(23.8, 31.8)	(25.4, 33.6)
1825–1850	3	1	29.1	28.4	0.965	0.097	(23.5, 34.8)	(24.4, 32.4)	(26.3, 33.5)
1825–1858	3	1	29.1	28.5	0.965	0.086	(24.1, 34.2)	(24.9, 32.2)	(26.6, 32.8)
1825–1835	1	2	35.9	36.3	0.990	0.207	(21.1, 50.8)	(23.5, 49.1)	(27.1, 64.6)
1825–1838	1	2	37.6	37.5	0.990	0.145	(26.7, 48.5)	(28.0, 47.1)	(30.8, 51.8)
1825–1840	1	2	40.6	40.1	0.987	0.155	(28.0, 53.2)	(28.5, 51.6)	(32.9, 57.3)
1825–1845	1	2	45.7	43.9	0.985	0.102	(36.4, 55.0)	(32.9, 54.9)	(40.1, 54.7)
1825–1850	1	2	46.0	44.9	0.984	0.087	(38.0, 54.0)	(36.1, 53.7)	(41.2, 53.2)
1825–1858	1	2	45.7	44.9	0.984	0.077	(38.6, 52.7)	(37.1, 52.6)	(41.4, 51.7)
1825–1835	3	2	33.8	28.2	0.985	0.215	(19.3, 48.4)	(6.8, 49.6)	(25.5, 62.6)
1825–1838	3	2	30.3	28.4	0.979	0.128	(22.5, 38.1)	(19.1, 37.7)	(26.1, 38.4)
1825–1840	3	2	32.0	29.8	0.974	0.137	(23.2, 40.8)	(18.9, 40.7)	(27.2, 41.3)
1825–1845	3	2	38.2	37.3	0.967	0.109	(29.9, 46.5)	(32.0, 42.7)	(34.0, 45.0)
1825–1850	3	2	39.1	38.1	0.965	0.097	(31.5, 46.7)	(32.8, 43.5)	(35.2, 44.9)
1825–1858	3	2	39.1	38.3	0.965	0.086	(32.4, 45.8)	(33.3, 43.2)	(35.7, 44.1)

[1] Indices of abundance: 1, average sighting rate; 3, whales 'tried out' per whaling day (effort derived from catch and index of abundance).
[2] N_1, N_J (jackknife estimate of N_1) and confidence intervals are in thousands.
[3] Estimated coefficient of variation of N_1 based on delta method variance.
[4] Refers to N_J only. The other confidence intervals are for N_1.

Table 7

Results of Allen's expected CPUE model ($M = 0.06$, $w = 0.04$)

Season	Index of abundance[1]	Catch factor	N_1[2]	N_J	R^2	CV[3]	Confidence intervals: Delta	Jackknife[4]	Fieller
1825–1835	1	1	32.4	31.7	0.990	0.183	(20.5, 44.3)	(19.7, 43.8)	(24.1, 54.2)
1825–1838	1	1	36.5	35.9	0.989	0.149	(25.6, 47.4)	(26.4, 45.5)	(28.9, 52.2)
1825–1840	1	1	44.4	42.7	0.982	0.194	(27.2, 61.6)	(26.4, 59.0)	(33.2, 73.7)
1825–1845	1	1	57.5	54.8	0.978	0.194	(35.1, 79.9)	(33.6, 75.9)	(43.2, 93.9)
1825–1850	1	1	57.0	55.2	0.977	0.145	(40.5, 73.4)	(40.6, 69.8)	(46.1, 78.1)
1825–1858	1	1	56.9	55.6	0.976	0.120	(43.3, 70.6)	(43.9, 67.3)	(47.8, 72.6)
1825–1835	3	1	34.8	31.4	0.983	0.261	(16.7, 53.0)	(11.2, 51.6)	(23.5, 86.9)
1825–1838	3	1	33.0	31.5	0.980	0.175	(21.5, 44.5)	(20.3, 42.7)	(25.4, 51.0)
1825–1840	3	1	38.1	36.2	0.975	0.192	(23.5, 52.7)	(21.7, 50.7)	(28.9, 62.0)
1825–1845	3	1	47.7	45.6	0.968	0.186	(30.0, 65.3)	(29.3, 61.9)	(36.6, 74.5)
1825–1850	3	1	48.4	47.3	0.968	0.138	(35.1, 61.7)	(36.6, 57.9)	(39.8, 64.5)
1825–1858	3	1	47.9	47.1	0.968	0.110	(37.4, 58.4)	(39.3, 54.9)	(41.1, 59.0)
1825–1835	1	2	43.5	42.6	0.990	0.183	(27.6, 59.4)	(26.4, 58.8)	(32.4, 72.8)
1825–1838	1	2	49.0	48.2	0.989	0.149	(34.4, 63.5)	(35.4, 61.1)	(38.8, 70.1)
1825–1840	1	2	59.6	57.3	0.982	0.194	(36.5, 82.7)	(35.4, 79.2)	(44.6, 98.9)
1825–1845	1	2	77.2	73.5	0.978	0.194	(47.2, 107.2)	(45.1, 101.8)	(58.0, 126.0)
1825–1850	1	2	76.4	74.1	0.977	0.145	(54.3, 98.5)	(54.5, 93.6)	(61.8, 104.8)
1825–1858	1	2	76.4	74.6	0.976	0.120	(58.0, 94.7)	(59.0, 90.2)	(64.1, 97.4)
1825–1835	3	2	46.7	42.1	0.983	0.261	(22.4, 71.1)	(15.0, 69.2)	(31.5, 116.5)
1825–1838	3	2	44.2	42.3	0.980	0.175	(28.8, 59.7)	(27.2, 57.3)	(34.1, 68.4)
1825–1840	3	2	51.1	48.6	0.975	0.192	(31.5, 70.7)	(29.1, 68.0)	(38.7, 83.2)
1825–1845	3	2	63.9	61.2	0.968	0.186	(40.2, 87.7)	(39.3, 83.0)	(49.1, 100.0)
1825–1850	3	2	64.9	63.4	0.968	0.138	(47.0, 82.8)	(49.1, 77.7)	(53.4, 86.5)
1825–1858	3	2	64.2	63.2	0.968	0.110	(50.1, 78.3)	(52.8, 73.7)	(55.1, 79.1)

[1] Indices of abundance: 1, average sighting rate; 3, whales 'tried out' per whaling day (effort derived from catch and index of abundance).
[2] N_1, N_J (jackknife estimate of N_1) and confidence intervals are in thousands.
[3] Estimated coefficient of variation of N_1 based on delta method variance.
[4] Refers to N_J only. The other confidence intervals are for N_1.

Table 8

Results of Allen's expected CPUE model ($M = 0.06$, $w = 0.05$)

Season	Index of abundance[1]	Catch factor	N_1[2]	N_J	R^2	CV[3]	Confidence intervals: Delta	Jackknife[4]	Fieller
1825–1835	1	1	27.2	26.9	0.990	0.152	(19.0, 35.5)	(18.9, 35.0)	(21.4, 40.1)
1825–1838	1	1	30.1	29.8	0.989	0.122	(22.8, 37.5)	(23.8, 35.9)	(25.0, 39.3)
1825–1840	1	1	35.1	34.3	0.983	0.152	(24.5, 45.8)	(24.7, 43.9)	(28.1, 49.7)
1825–1845	1	1	42.4	41.4	0.978	0.141	(30.4, 54.4)	(30.8, 51.9)	(34.7, 57.4)
1825–1850	1	1	41.9	41.2	0.977	0.105	(33.1, 50.7)	(34.2, 48.2)	(36.3, 51.0)
1825–1858	1	1	41.3	40.8	0.976	0.085	(34.3, 48.3)	(35.6, 46.0)	(36.9, 47.7)
1825–1835	3	1	28.9	27.0	0.983	0.219	(16.3, 41.6)	(13.2, 40.7)	(20.8, 56.2)
1825–1838	3	1	27.7	26.8	0.979	0.148	(19.5, 36.0)	(19.2, 34.4)	(22.4, 38.8)
1825–1840	3	1	31.2	30.2	0.974	0.158	(21.3, 41.0)	(20.9, 39.4)	(25.0, 44.5)
1825–1845	3	1	37.2	36.2	0.968	0.145	(26.4, 47.9)	(27.1, 45.4)	(30.5, 50.2)
1825–1850	3	1	37.6	37.0	0.968	0.107	(29.5, 45.6)	(31.3, 42.7)	(32.6, 45.5)
1825–1858	3	1	36.9	36.6	0.968	0.084	(30.7, 43.1)	(32.7, 40.5)	(33.2, 42.3)
1825–1835	1	2	36.5	36.1	0.990	0.152	(25.4, 47.6)	(25.4, 46.9)	(28.6, 53.9)
1825–1838	1	2	40.4	40.0	0.989	0.122	(30.6, 50.3)	(31.9, 48.2)	(33.5, 52.8)
1825–1840	1	2	47.1	46.1	0.983	0.152	(32.8, 61.4)	(33.2, 58.9)	(37.7, 66.7)
1825–1845	1	2	56.9	55.5	0.978	0.141	(40.8, 73.0)	(41.4, 69.6)	(46.5, 77.0)
1825–1850	1	2	56.2	55.3	0.977	0.105	(44.5, 68.0)	(45.9, 64.7)	(48.7, 68.4)
1825–1858	1	2	55.4	54.8	0.976	0.085	(46.0, 64.8)	(47.8, 61.7)	(49.5, 64.1)
1825–1835	3	2	38.8	36.2	0.983	0.219	(21.8, 55.8)	(17.7, 54.6)	(27.9, 75.5)
1825–1838	3	2	37.2	36.0	0.979	0.148	(26.2, 48.2)	(25.8, 46.2)	(30.0, 52.0)
1825–1840	3	2	41.8	40.5	0.974	0.158	(28.6, 55.0)	(28.0, 52.9)	(33.5, 59.7)
1825–1845	3	2	49.8	48.6	0.968	0.145	(35.4, 64.3)	(36.3, 60.9)	(40.9, 67.4)
1825–1850	3	2	50.4	49.7	0.968	0.107	(36.6, 61.1)	(42.0, 57.3)	(43.8, 61.0)
1825–1858	3	2	49.6	49.1	0.968	0.084	(41.2, 57.9)	(43.9, 54.4)	(44.6, 56.7)

[1] Indices of abundance: 1, average sighting rate; 3, whales 'tried out' per whaling day (effort derived from catch and index of abundance).
[2] N_1, N_J (jackknife estimate of N_1) and confidence intervals are in thousands.
[3] Estimated coefficient of variation of N_1 based on delta method variance.
[4] Refers to N_J only. The other confidence intervals are for N_1.

Table 9

Results of Allen's expected CPUE model ($M = 0.06$, $w = 0.06$)

Season	Index of abundance[1]	Catch factor	N_1[2]	N_J	R^2	CV[3]	Confidence intervals: Delta	Jackknife[4]	Fieller
1825–1835	1	1	23.4	23.3	0.990	0.130	(17.3, 29.5)	(17.6, 28.9)	(19.1, 31.8)
1825–1838	1	1	25.5	25.4	0.989	0.103	(20.3, 30.8)	(21.3, 29.4)	(21.9, 31.4)
1825–1840	1	1	28.9	28.5	0.983	0.124	(21.7, 36.1)	(22.4, 34.6)	(24.2, 37.3)
1825–1845	1	1	33.4	32.9	0.979	0.111	(26.0, 40.8)	(26.9, 38.9)	(28.8, 41.1)
1825–1850	1	1	33.0	32.6	0.977	0.082	(27.5, 38.4)	(28.7, 36.5)	(29.7, 37.6)
1825–1858	1	1	32.2	32.0	0.976	0.067	(27.9, 36.5)	(29.3, 34.7)	(29.8, 35.4)
1825–1835	3	1	24.6	23.4	0.982	0.189	(15.3, 33.9)	(13.6, 33.3)	(18.6, 41.4)
1825–1838	3	1	23.8	23.2	0.979	0.129	(17.7, 30.0)	(17.8, 28.6)	(19.9, 31.1)
1825–1840	3	1	26.3	25.7	0.974	0.135	(19.2, 33.4)	(19.4, 32.0)	(21.9, 34.5)
1825–1845	3	1	30.3	29.8	0.967	0.119	(23.1, 37.5)	(24.2, 35.5)	(26.0, 37.6)
1825–1850	3	1	30.5	30.2	0.968	0.088	(25.1, 35.8)	(26.9, 33.6)	(27.4, 34.9)
1825–1858	3	1	29.9	29.7	0.967	0.069	(25.8, 34.0)	(27.6, 31.9)	(27.7, 32.8)
1825–1835	1	2	31.4	31.2	0.990	0.130	(23.2, 39.5)	(23.7, 38.7)	(25.6, 42.6)
1825–1838	1	2	34.3	34.0	0.989	0.103	(27.2, 41.3)	(28.6, 39.5)	(29.4, 42.2)
1825–1840	1	2	38.7	38.2	0.983	0.124	(29.1, 48.4)	(30.0, 46.4)	(32.5, 50.1)
1825–1845	1	2	44.8	44.1	0.979	0.111	(34.9, 54.7)	(36.1, 52.2)	(38.6, 55.1)
1825–1850	1	2	44.2	43.8	0.977	0.082	(36.9, 51.5)	(38.6, 49.0)	(39.9, 50.5)
1825–1858	1	2	43.3	43.0	0.976	0.067	(37.5, 49.0)	(39.3, 46.6)	(40.0, 47.6)
1825–1835	3	2	33.0	31.5	0.982	0.189	(20.5, 45.5)	(18.2, 44.7)	(24.9, 55.5)
1825–1838	3	2	32.0	31.2	0.979	0.129	(23.7, 40.2)	(23.9, 38.4)	(26.7, 41.8)
1825–1840	3	2	35.3	34.5	0.974	0.135	(25.8, 44.7)	(26.0, 42.9)	(29.4, 46.3)
1825–1845	3	2	40.6	40.0	0.967	0.119	(30.9, 50.3)	(32.4, 47.6)	(34.9, 50.5)
1825–1850	3	2	40.9	40.6	0.968	0.088	(33.7, 48.1)	(36.1, 45.0)	(36.8, 46.9)
1825–1858	3	2	40.1	39.9	0.967	0.069	(34.6, 45.6)	(37.0, 42.8)	(37.2, 44.0)

[1] Indices of abundance: 1, average sighting rate; 3, whales 'tried out' per whaling day (effort derived from catch and index of abundance).
[2] N_1, N_J (jackknife estimate of N_1) and confidence intervals are in thousands.
[3] Estimated coefficient of variation of N_1 based on delta method variance.
[4] Refers to N_J only. The other confidence intervals are for N_1.

Allen's expected CPUE model

Tables 7, 8 and 9 give the results obtained from Allen's expected CPUE model when w is held constant during each period examined. All of these estimates of initial stock size are once again much higher than those reported for the modified DeLury model (Table 3). Comparing these results with those from Allen's expected catch model (Tables 4, 5, 6), index of abundance 1 gives estimates which are slightly lower while index 3 gives estimates which are slightly higher.

The following table synthesizes the Allen expected CPUE estimates for the period 1825–58. The lower estimates are those resulting from applying the jackknife procedure; in some cases the jackknife estimate and the usual Allen model estimate are almost identical:

Catch factor	Index of abundance	Value of w 0.04	0.05	0.06
1	1	55,000–57,000	41,000	32,000
	3	47,000–48,000	37,000	30,000
2	1	75,000–76,000	54,000–56,000	43,000
	3	63,000–64,000	49,000–50,000	40,000

As previously found, index of abundance 1 gives higher estimates and has higher values of R^2, suggesting a better 'fit', than does index 3. Moreover, catch factor 2 yields considerably higher estimates than does catch factor 1. The sensitivity of this model to changes in w is similar to the results reported for Allen's expected catch model.

Kirkwood's weighted least-squares procedure

For comparative purposes, we present the following table of results obtained by applying Kirkwood's weighted least-squares procedure to the previous models:

Catch factor	Index of abundance	Model: Modified DeLury	Allen expected catch $w = 0.05$
1	1	19,000	43,000
	3	17,000	38,000
2	1	25,000	58,000
	3	23,000	51,000

Comparing the earlier modified DeLury results (Table 3), the estimates for index of abundance 1 are virtually the same while those for index 3 are higher. Comparing the earlier Allen expected catch results (Table 5 for $w = 0.05$), the estimates for index 1 are the same while those for index 3 are lower.

SYNTHESIS

A possible confounding factor in the preceeding analyses is that a westward shift in effort occurred after about 1840, coinciding with a change in the emphasis of whaling from breeding schools to 'bachelor' schools. This change in the industry shows up as a slowing in the rate of decline of our indices of abundance (Fig. 2). Consequently, the inherent assumption of a closed population may be in doubt.

As previously noted, in similar circumstances for bowhead historical data, Tillman *et al.* (1983) concluded that modified DeLury procedures were not the best ones to use. Rather they preferred to examine as long a series of data as possible using Allen's least squares methods. Following their lead, we have likewise concluded that the low DeLury estimates obtained here are probably unlikely.

As noted in the section on biological parameters, the shift in emphasis of whaling after 1840 also implied a change in the mean age at recruitment. From equation (2) a t_r of 12 years results in recruitment rates ranging from about 0.05 to 0.06, depending on the assumed pregnancy rate; a t_r of 15 years results in rates ranging from about 0.04 to 0.05. The correct assessment model would somehow adjust recruitment rates downward during the time series. However, a means of quantifying this adjustment is not readily apparent, although it is possible to judge qualitatively the consequences of inappropriately applying constant rates in the Allen models used. Holding a constant rate of 0.06 would tend to yield estimates of abundance which were too low, while a constant rate of 0.04 would tend to give estimates which were too high. Thus the range of recruitment rates examined (0.04–0.06) should define upper and lower bounds to our estimates of abundance.

Another problem with the foregoing analyses is that the estimated removals were probably minimum values since not all ships on the 'Japan' grounds would have been 'spoken' by those for which 'good' logbooks were still available. Under this circumstance, we believe that the most reasonable estimates of removals are those based upon catch factor 2, i.e. in which landings were increased by 61% to account for the mortality of struck and lost whales.

The results indicated in all cases that index of abundance 1, the average sighting rate, provided a better 'fit' in terms of values of R^2 than did index 3, whales 'tried out' per whaling day. Moreover, index 1 was less sensitive to changes in w in the Allen models and also to changes in models (see results for applying Kirkwood's procedure). Also, we believed that indices of abundance based on sightings data were less likely to be biassed by the changes in whaling technology which occurred (e.g. see Best, 1983) than were those based upon catch-effort data.

The following table synthesizes Allen model estimates using catch factor 2, index 1 and constant values of w ranging from 0.04 to 0.06 (confidence limits in terms of percentages are given in parentheses):

Allen model	Estimate	Value of w 0.04	0.05	0.06
Expected catch	N_1	81,900 (±29%)	58,900 (±20%)	45,700 (±15%)
	N_J	76,700 (±43%)	57,100 (±26%)	44,900 (±17%)
Expected CPUE	N_1	76,400 (±24%)	55,400 (±17%)	43,300 (±13%)
	N_J	74,600 (±21%)	54,800 (±13%)	43,300 (±8%)

Of course, these estimates are based on the assumption that w does not behave in a density-dependent manner. Table 10 shows the results of assuming that w would increase by 2.5% per year after starting at an initial value of 5%. Although not strictly a density-dependent model, it does serve to show that somewhat lower estimates would result, with values of 42,000 for the expected catch method and of 39,000 for the expected CPUE method.

Table 10

Results of Allen's expected catch and expected CPUE model ($M = 0.06$, $w = 0.05$ but increased by 2.5% per year, and using catch factor 2)

Season	Model	Index of abundance[1]	N_1[2]	N_J	R^2	CV[3]	Confidence intervals: Delta	Jackknife[4]	Fieller
1825–1835	Expected catch	1	38.4	38.7	0.990	0.210	(22.3, 54.4)	(24.9, 52.5)	(28.7, 70.3)
1825–1838	Expected catch	1	39.3	39.2	0.990	0.142	(28.1, 50.5)	(29.2, 49.1)	(32.3, 53.8)
1825–1840	Expected catch	1	42.1	41.6	0.988	0.149	(29.6, 54.7)	(29.9, 53.4)	(34.4, 58.4)
1825–1845	Expected catch	1	44.1	42.3	0.986	0.086	(36.5, 51.6)	(32.4, 52.1)	(39.6, 50.7)
1825–1850	Expected catch	1	43.6	43.0	0.985	0.072	(37.3, 49.9)	(36.5, 49.4)	(40.0, 48.6)
1825–1858	Expected catch	1	42.4	42.2	0.982	0.065	(36.9, 47.8)	(37.5, 46.9)	(39.3, 46.4)
1825–1835	Expected CPUE	1	33.9	33.7	0.990	0.138	(24.5, 43.2)	(24.9, 42.4)	(27.2, 47.4)
1825–1838	Expected CPUE	1	36.4	36.2	0.989	0.105	(28.8, 44.0)	(30.1, 42.2)	(31.1, 45.1)
1825–1840	Expected CPUE	1	40.8	40.3	0.984	0.120	(31.0, 50.5)	(31.9, 48.7)	(34.3, 52.1)
1825–1845	Expected CPUE	1	44.8	44.4	0.982	0.093	(36.4, 53.1)	(37.9, 50.8)	(39.5, 52.8)
1825–1850	Expected CPUE	1	42.1	41.8	0.979	0.068	(36.4, 47.9)	(37.7, 46.0)	(38.9, 46.5)
1825–1858	Expected CPUE	1	38.7	38.5	0.968	0.058	(34.2, 43.2)	(35.9, 41.1)	(36.7, 41.3)

[1] Indices of abundance: 1, average sighting rate.
[2] N_1, N_J (jackknife estimate of N_1) and confidence intervals are in thousands.
[3] Estimated coefficient of variation of N_1 based on delta method variance.
[4] Refers to N_J only. The other confidence intervals are for N_1.

Table 11

Comparison of estimated average annual production reported by vessels 'spoken' and obtained from vessels having oil production records in their logbooks

Year	Estimated average annual production by type of vessel: Vessels 'spoken'[1]	Logbook vessels[2]	Year	Estimated average annual production by type of vessel: Vessels 'spoken'[1]	Logbook vessels[2]
1822	726	—	1840	1,063	328
1823	1,208	—	1841	1,318	616
1824	—	—	1842	1,142	526
1825	1,079	1,209	1843	927	304
1826	1,530	—	1844	1,064	290
1827	—	—	1845	828	455
1828	1,355	828	1846	917	342
1829	1,240	740	1847	773	311
			1848	904	305
			1849	1,000	251
1830	1,429	1,081			
1831	1,218	855	1850	600	172
1832	1,158	739	1851	—	—
1833	799	711	1852	283	—
1834	1,023	431	1853	917	240
1835	1,084	805	1854	967	221
1836	1,245	573	1855	1,050	312
1837	935	289	1856	425	155
1838	945	337	1857	480	248
1839	1,198	617	1858	700	200

[1] Source: column D in table 3 from Bannister *et al.* (1981).
[2] Source: Bannister (pers. comm.).

DISCUSSION

Based on the most 'reasonable' set of historical data and using the most 'reasonable' estimation procedures, one might conclude that 40,000–80,000 is a likely range of estimates of initial abundance for the Western Division of North Pacific sperm whales. Statistically these appear to be quite good estimates, with values of R^2 all greater than 95% and with confidence intervals for the most part under $\pm 25\%$. However, in contrast to the agreed estimate of 302,000 derived from the modern data, this range of historical estimates seems quite low.

The shift in emphasis of whaling to males after about 1840 not only confounds the analysis of these historical data, as previously noted, but also raises difficulties when interpreting the results. On examining Fig. 8 in Bannister *et al.* (1981), it is apparent that, apart from the first decade, sperm whales yielding less than 30 barrels [and so possibly female according to data in Best (1983)] were only a relatively small proportion of the catch. Thus our historical estimates may refer principally to males, and the appropriate comparison should then be with the male estimate of 137,700 obtained from the modern CPUE data (IWC, 1980a). Even so the historical estimates still seem low.

One explanation for these low values might be that the catch history has been seriously underestimated. Bannister *et al.* (1981) admit the possibility of underestimation and suggest that listing such as Wood's Abstracts be searched to obtain a more reliable record of the actual number of vessels whaling on the 'Japan' grounds. However, we doubt that such an exercise would turn up enough 'new' vessels to correct removal estimates by the order of magnitude required.

Another suggestion is that the average oil production declared per vessel 'spoken', term D in equation (1), might underestimate the annual production of 'spoken' vessels and, hence, the number of whales taken since these vessels would be reporting during, rather than at the end of, a season. However, Table 11 clearly shows that the declared oil production of 'spoken' vessels consistently and significantly exceeded that of vessels having oil production records in their logbooks. Thus using the maximum value declared by a duplicate vessel, as was done by Bannister *et al.* (1981), may actually have overestimated the total historical removals.

Another possible speculation is that the carrying capacity of the North Pacific sperm whale population may have increased significantly between the historical and modern episodes of whaling. However, we can find no information giving this supposition any great substance. Finally, one cannot yet discount the possibility that the modern data have resulted in significant overestimates of abundance for this stock division.

Given the plethora of problems encountered in analyzing and interpreting these historical whaling data, we conclude that using them for assessment purposes is at least as problematical as using the modern CPUE data.

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Appendix 1

ALLEN'S EXPECTED CATCH METHOD

Allen's (1966) population estimate by comparison of catch method results from minimizing the sum of the squared differences between observed and expected catches. His equation (12) is

$$N_t = A_t[N_1 - f(C)_{t-1}]$$

where N_t is the population size at the start of season t and A_t and $f(C)_{t-1}$ are functions of M (natural mortality rate), W (the proportion of new recruits in the next season) and C (total catch).

By noting that

$$E(C_t) = qx_t(N_t - C_t/2)$$
$$= qN_1 x_t A_t - qx_t[A_t f(C)_{t-1} + C_t/2],$$

where x_t is the effort (corresponding to the observed catch) expended in season t, this can be written as a no-intercept linear regression model:

$$Y = XB,$$

where Y is a column vector of observed catches, $X = [X_1 X_2]$ is an $n \times 2$ matrix whose columns are given by:

$$X_1 = x_t A_t \quad \text{and} \quad X_2 = x_t[A_t f(C)_{t-1} + C_t/2]$$

and

$$B = [qN_1 q]^T.$$

Thus,

$$\hat{B} = (X^T X)^{-1} X^T Y \quad \text{and} \quad \hat{N}_1 = \hat{B}_1 / -\hat{B}_2,$$

where B_i is the ith component of B.

Assuming X is a non-random matrix and that the other usual assumptions necessary for the construction of confidence intervals hold, either the delta method or the Fieller technique (Appendix 2) may be used to calculate approximate 95% confidence intervals for $\hat{N}_1$ (Seber, 1973).

In practice, however, the X matrix contains estimated (or assumed) values (W) and the confidence intervals must be treated as only very approximate.

By dividing the X matrix by the appropriate efforts (x_t) the above model can also be employed to estimate N_1 by minimizing the sum of the squared differences between observed and expected catches per unit effort.

Appendix 2

THE FIELLER TECHNIQUE FOR THE NO-INTERCEPT REGRESSION MODEL

Following Seber (1973, 1977) who describes the Fieller technique for estimating confidence limits for the ration of two regression coefficients, B_0/B_1 in the model $Y = B_0+B_1x$, a similar result can be derived for the ratio B_1/B_2, where $Y = B_1x_1+B_2x_2$. In matrix form this can be written $Y = [X_1 X_2] B = XB$. Let

$$\phi = -B_1/B_2 \quad \text{and} \quad z = \hat{B}_1+\hat{B}_2\phi.$$

Then

$$E[z] = 0 \quad \text{and} \quad \begin{aligned} \text{var}\,[z] &= \text{var}\,(\hat{B}_1)+\phi^2\,\text{var}\,(\hat{B}_2) \\ &\quad +2\phi\,\text{cov}\,(\hat{B}_1,\hat{B}_2) \\ &= \sigma^2(c_{11}+\phi^2c_{22}+2\phi c_{12}) \\ &= \sigma^2 w \end{aligned}$$

where c_{ij} is the ijth element of the matrix $(X^TX)^{-1}$.

Since $z = \hat{B}_1+\hat{B}_2\phi$ is $N(0,\sigma^2w)$ then

$$T = (\hat{B}_1+\hat{B}_2\phi)/Sw^{\frac{1}{2}} \sim t_{n-2}$$

and a $100(1-\alpha)\%$ confidence set for z is given by

$$T^2 \leqslant (t_{\alpha/2,\,n-2})^2.$$

This set reduces to the interval $\phi_1 \leqslant \phi \leqslant \phi_2$ where ϕ_1 and ϕ_2 are the roots of the quadratic

$$\phi^2[\hat{B}_2^2-t^2S^2c_{22}]+\phi 2[\hat{B}_1\hat{B}_2-t^2S^2c_{12}] +\hat{B}_1^2-t^2S^2c_{11} = 0$$

if and only if the coefficient of ϕ^2 in the above equation is positive (Seber, 1977).

Seber (1973, 1977) defined a confidence set only for the intercept model $Y = B_1+B_2x$. The above formulation is general in that it is also valid for the above intercept model, where the X matrix is $[1\,x]$, i.e. a column vector of 1's and a column vector of observed x's.

Using a Taylor expansion of $-\hat{B}_1/\hat{B}_2$ (Seber, 1973) an estimate of the approximate bias of this ratio is

$$(S^2/\hat{B}_2^2)\,[c_{12}-(\hat{B}_1/\hat{B}_2)\,c_{22}]$$

which is positive for the modified DeLury model and the Allen expected catch model. Again, this result is valid for both the intercept and the no-intercept model (assuming the X matrix is properly defined).