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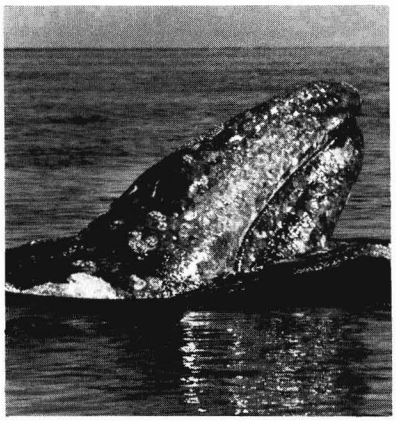
The Status of Endangered Whales

Marine Fisheries REVIEW



On the cover: A gray whale raises its barnacle-encrusted head above the surface of Laguna Ojo de Liebre in Baja California. Photo by D. W. Rice.

Articles — *46(4), 1984*

Special Section: The Status of Endangered Whales **1**

The Status of Endangered Whales: An Overview — *Howard W. Braham* **2**

The Gray Whale, *Eschrichtius robustus* — *Dale W. Rice, Allen A. Wolman*, and *Howard W. Braham* **7**

The Blue Whale, *Balaenoptera musculus* — *Sally A. Mizroch, Dale W. Rice*, and *Jeffrey M. Breiwick* **15**

The Fin Whale, *Balaenoptera physalus* — *Sally A. Mizroch, Dale W. Rice*, and *Jeffrey M. Breiwick* **20**

The Sei Whale, *Balaenoptera borealis* — *Sally A. Mizroch, Dale W. Rice*, and *Jeffrey M. Breiwick* **25**

The Humpback Whale, *Megaptera novaeangliae* — *James H. Johnson* and *Allen A. Wolman* **30**

The Right Whale, *Balaena glacialis* — *Howard W. Braham* and *Dale W. Rice* **38**

The Bowhead Whale, *Balaena mysticetus* — *Howard W. Braham* **45**

The Sperm Whale, *Physeter macrocephalus* — *Merrill E. Gosho, Dale W. Rice*, and *Jeffrey M. Breiwick* **54**

Other Articles

U.S. Tuna Trade Summary, 1983 — *Samuel F. Herrick, Jr.* and *Steven Koplin* **65**

Coral Reef Sanctuaries for Trochus Shells — *Gerald A. Heslinga, Obichang Orak*, and *Marcus Ngiramengior* **73**

Departments

NOAA/NMFS Developments — *U.S.-Canada Boundary, Gloucester Lab Honored, Gulf Reef Fish Rules, Lobster Size Rules, Corals and Coral Reef Protection, Japanese Inquiry, NEFC Studies Salmon, Witch Flounder,* and *EEZ Mapped* **81**

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Departments cont.

Foreign Fishery Developments — *A Review of the British Salmon Industry and Markets* and *EC Fisheries Policy* **85**

Publications — *New NMFS Scientific Reports, Vibrios, Tilapias and Their Culture, FAD's, Marine Ecology, World Fisheries, Shellfish Culture, Canada's Atlantic Fisheries, Sea Turtle Symposium, Algal Biology, Fisheries Technology,* and *The Wadden Sea Ecosystem Studies* **91**

Index **97**

List of Papers, 1984 **100**

The Status of Endangered Whales

A Special Section of the *Marine Fisheries Review*

Sponsored by the
National Marine Mammal Laboratory
Northwest and Alaska Fisheries Center
National Marine Fisheries Service, NOAA
7600 Sand Point Way N.E., Bin C15700
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The Status of Endangered Whales: An Overview

HOWARD W. BRAHAM

Introduction

The Marine Mammal Protection Act (MMPA) of 1972 is the principal U.S. statute for conserving and protecting marine mammals. Under it, the National Marine Fisheries Service (NMFS) of the Department of Commerce's National Oceanic and Atmospheric Administration is responsible for research on and management of all whales, dolphins, and porpoises (collectively called cetaceans) within the U.S. 200-mile Fishery Conservation Zone.

Of the 45 species of cetaceans found in U.S. waters, eight are considered so depleted that the special protection of the Endangered Species Act (ESA) of 1973 is needed beyond the MMPA. These eight, among the world's nine largest cetaceans, are collectively called the "great whales." Listed as "endangered" under the ESA, they include the gray whale, *Eschrichtius robustus* (Lilljeborg, 1861); blue whale, *Balaenoptera musculus* (Linnaeus, 1758); fin whale, *B. physalus* (Linnaeus, 1758); sei whale, *B. borealis* Lesson, 1828; humpback whale, *Megaptera novaeangliae* (Borowski, 1781); right whale, *Balaena glacialis* (Muller, 1776); bowhead whale, *B. mysticetus* Linnaeus, 1758; and sperm whale, *Physeter macrocephalus* (Linnaeus, 1758)[1] (Fig. 1). The ninth great whale, Bryde's whale, *Balaenoptera edeni*, is not listed as either endangered or threatened.

Endangered Species Act

On 10 November 1978, the U.S. Congress passed Public Law 95-632 (Section 4(c)), amending the Endangered Species Act of 1973. One of the changes required the Secretaries of Commerce and Interior to review the status and degree of endangerment of all species listed in the Act at least once each 5 years to determine whether any listed species should be 1) removed from the list, 2) changed from "endangered" to "threatened," or 3) changed from "threatened" to "endangered."

In November 1982, the NMFS began a status review of the 19 endangered and threatened species under its jurisdiction, including the eight endangered great whales. The papers in this special section of the *Marine Fisheries Review* summarize the status reviews of those eight species and provide the biological basis for any final management decisions. Full NMFS status reviews will be made available separately, and will include management conclusions and recommendations for any changes in the listing of any species under the ESA.

These eight papers thus review current knowledge of distribution, migration, stock identity, life history and ecology, exploitation (principally commercial whaling), population abundance, and management concerns of the endangered great whales. We do not present a comprehensive review of the literature, but rather provide summaries of the most accurate and current data. No new analyses were conducted of population trends. The coeditors sought to assemble and publish these papers to achieve the widest dissemination of the information to the public and to the scientific and academic communities.

This introductory paper gives a brief overview of the status review process, summarizes estimates of abundance and general status of stocks, and acknowledges the help of many individuals in conducting the reviews and preparing the succeeding eight papers.

Listing Factors

Under the Endangered Species Act of 1973, a species is considered "endangered" if it is in danger of extinction throughout all or a significant portion of its range, as a result of any one of the five factors specified in Section 4(a)(1) (Table 1). A species is considered "threatened" if it is likely to become endangered in the foreseeable future due to any of those same factors.

Historically, most of the great whales qualified as "endangered" as a result of overexploitation during commercial whaling (listing factor number 2). The results of that exploitation, reflected in the change from initial

Table 1.—Factors for listing a species as "threatened" or "endangered" under the Endangered Species Act of 1973 (Section 4(a)(1)(A-E), 1982 amendment). Only one listing factor need apply to list a species in either category.

Factors
1. The present or threatened destruction, modification, or curtailment of its habitat or range.
2. Overutilization for commercial, recreational, scientific, or educational purposes.
3. Disease or predation.
4. The inadequacy of existing regulatory mechanisms.
5. Other natural or manmade factors affecting its continued existence.

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[1]Listed as *Physeter catodon* in the 1973 version of the ESA.

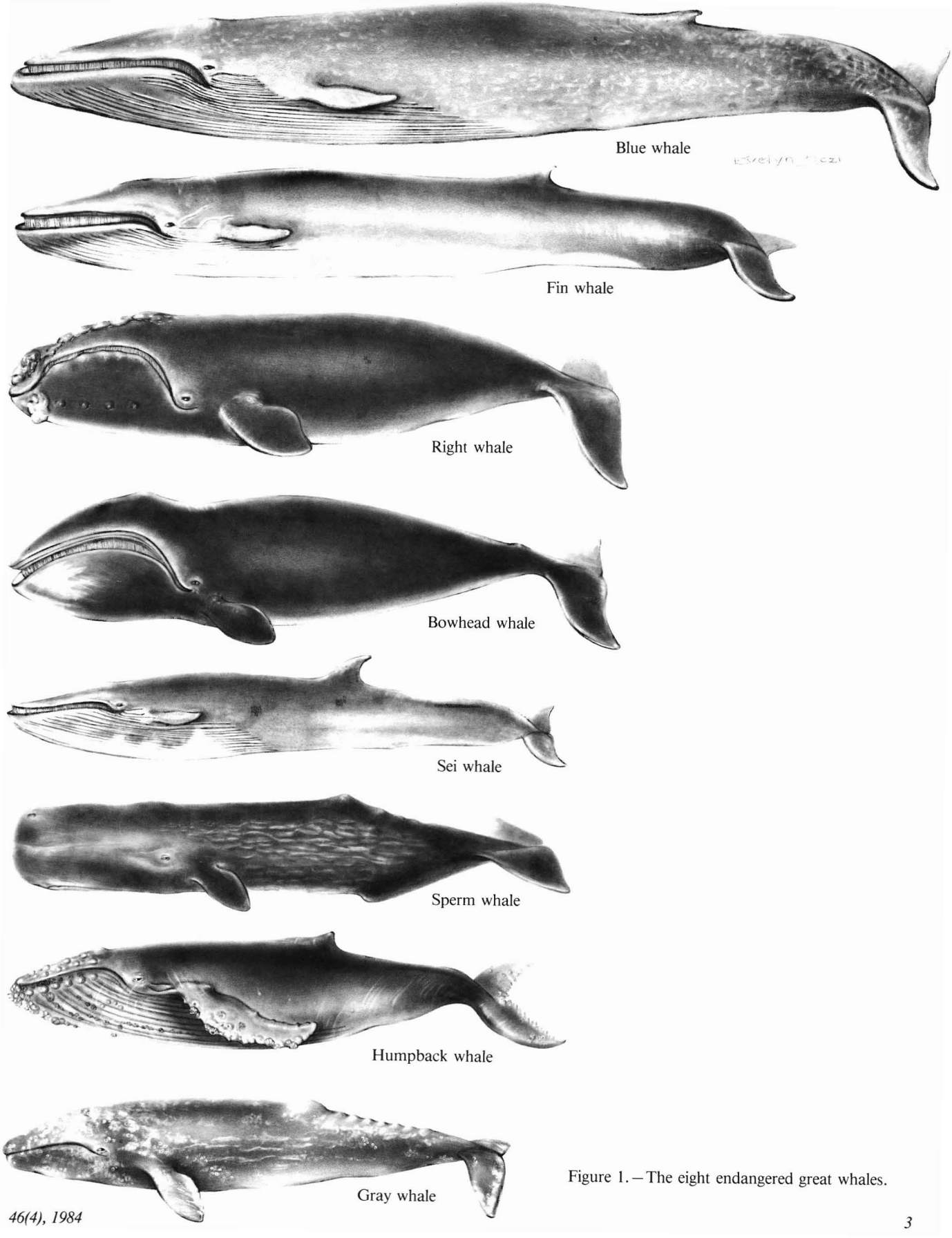

Figure 1.—The eight endangered great whales.

Table 2.—Initial (precommercial whaling) and current population size estimates of large whales currently listed as "endangered" under the ESA. Stock or regional group estimates are those summarized in the following eight papers in this special section of the *Marine Fisheries Review* 46(4):7-64 (n.e. = no published estimate).

Species, stocks, or reporting area(s)	Population sizes		Approximate percent of initial
	Initial	Current	
Gray whale			
Eastern North Pacific	15,000-20,000	13,450-19,210	Recovered
Western North Pacific	n.e.	n.e.[1]	n.e.
Blue whale			
North Atlantic	1,100-1,500	100	6-9%
North Pacific	4,900	1,400-1,900	29-39%
North Indian Ocean	n.e.	n.e.	n.e.
Antarctic[2]	150,000-210,000	1,000-8,000	< 1-5%
Subantarctic Indian Ocean[3]	10,000	5,000	50%
Fin whale			
North Norway	Several thousand	n.e.	n.e.
West Norway/Faeroe Isl.	> 2,700	n.e.[4]	10%?
Spain, Portugal, British Isles	> 5,000	n.e.	n.e.
Denmark Strait	n.e.	1,791-11,584	n.e.
W. North Atlantic	n.e.	3,590-6,300	n.e.
North Pacific	42,000-45,000	14,620-18,630	32-44%
Antarctic[2]	400,000	85,200	21%
Sei whale			
North Atlantic	n.e.	4,957	n.e.
North Pacific	45,000	22,000-37,000	49-82%
Southern Hemisphere[2]	> 63,100-64,400	> 9,800-11,760	15-19%
Humpback whale			
E. North Atlantic	n.e.	n.e.	n.e.
W. North Atlantic	> 4,400	5,257-6,289	Recovered?
Northern Indian Ocean	n.e.	n.e.	n.e.
North Pacific	15,000	< 1,200	8%
Southern Hemisphere	100,000	2,500-3,000	2-3%
Bowhead whale			
E. Greenland-Spitsbergen	25,000	n.e.[1]	< 1%?
Davis Strait	11,000	n.e.[4]	< 5%?
Hudson Bay	680	n.e.[4]	n.e.
Western Arctic	18,000	3,617-4,125	20-23%
Sea of Okhotsk	n.e.[5]	n.e.[4]	5-10%?
Right whale[6]			
North Atlantic	n.e.	n.e.[4]	n.e.
North Pacific	n.e.	n.e.[4]	n.e.
Southern Hemisphere	n.e.	3,000?	n.e.
Sperm whale[7]			
North Atlantic	166,000	99,500	60%
Eastern North Pacific	311,000	274,000	88%
Western North Pacific	309,400	198,100	64%
Southern Hemisphere	590,600	410,700	70%

[1]Thought to be nearing extinction or extremely low.
[2]Six stock units or areas of all oceans in the Southern Hemisphere. For population estimates and status see Masaki and Yamamura (1978), Gulland (1981), and Butterworth (In press).
[3]Pygmy blue whales.
[4]Perhaps in the low hundreds.
[5]Pehaps 6,500-10,000.
[6]Stocks are reported here by general area only. See Braham and Rice (1984) for stock boundaries.
[7]Exploitable population size, and includes males and females (from Tables 4-6 in Gosho et al., 1984); all estimates of initial and current abundance are considered provisional. No estimates are available for the number of immature animals.

(precommercial whaling) population size to current population size are presented in Table 2 for each species.

Listing a species in the ESA is based on the best available scientific data. In the absence of specific data, such as population growth rate, abundance, or known affect on these parameters, other potentially limiting factors to recovery (e.g., habitat destruction, disease, and predation), provided broad coverage for protection under the Act.

A discussion of the criteria used for listing certain species as endangered is not the intent of this paper. Considerable thought has gone into this for noncetacean species (e.g., Sparrowe and Wight, 1975; Landry et al., 1979; Anonymous, 1983). However, understanding the general nature and criteria of endangerment is important when evaluating the listing factors for reclassification (as required by Section 4(c)). This necessitates knowing whether the species or population is declining or nearing extinction, and whether the quantity and quality of its habitat is declining as well (Anonymous, 1983). These and other population attributes are central to determining current status, vulnerability, and recovery potential (Sparrowe and Wight, 1975). For certain management goals, it may also be important to consider regional uniqueness and sociological and ecological factors as well (Landry et al., 1979).

Endangered Great Whales

Seven of the endangered cetaceans are baleen whales, which filter their food between fringed baleen plates arranged in a row along each side of the palate. The eighth is the sperm whale, largest of the odontocetes, or toothed whales.

By any standards, the great whales are enormous (Fig. 1). The blue whale is the largest animal known to have lived on earth, some reaching lengths of 98 feet (about 30 m) or more. Reports of blue whales well in excess of 100 feet have not been adequately documented in the literature and may be exaggerated.

It is because of their great size and the large volume of commercial grade oil in the blubber, the valued baleen or whale bone (in some species), and their predictable seasonal occurrence, that these great whales fell victim to commercial whalers. As a result, the populations of these species were severely reduced in most of the world's oceans within the past 200 years. Most stocks were reduced so fast as to be commercially unprofitable within a few decades of fishing.

Although few reliable data exist on the sizes of most stocks at the low point of their fisheries, a comparison of current population size estimates to available estimates just prior to commercial whaling is instructive, especially when considering whether a species or stock fits the criteria for listing under the ESA. But in reviewing the abundance estimates and general status of stocks, I caution the reader to remember that many stock estimates are fraught with sampling and statistical biases which may cause over- or underestimation of the true value. I therefore recommend reading the following papers and the literature

for a more in-depth appreciation of the estimates currently in use.

Status of Stocks: Population Abundance

Frequent reference is made in the following papers to certain terms, perhaps new to the reader, such as "stock" or "population." Generally speaking, populations are geographically isolated breeding units, i.e., two populations of the same species, one in the North Atlantic Ocean and the other in the North Pacific Ocean. A stock is a geographic subdivision of a larger population, and is usually thought of as having some special attribute which sets it apart from others of its kind or is also geographically separated, but not necessarily isolated. For example, a local group, or "stock," may be harvested at one time of the year, such as on its summer feeding ground, but on the winter breeding grounds animals in this group may intermingle with others of the same species. Humpback whales in the North Atlantic, for example, summer in a number of separate "stock" areas, but most winter together in the West Indies. Another definition of stock also includes the attributes of isolation, in which regional groups are apparently isolated from one another year-round, but may reside nearby. An example of this is the geographic separation of the Sea of Okhotsk and western Arctic bowhead whales. Among the eight endangered great whales, there are many stocks (Table 2 does not list all the stocks separately). No species is so isolated as to be represented by only one stock or population and there are the usual disagreements among scientists about certain stock designations or boundaries.

The Endangered Species Act specifically concerns itself with the continued existence of species. However, it has become convenient, and certainly practical, to evaluate the status of populations or stocks of whales, rather than just the species. This is because more information is often available for isolated groups than for either entire populations or the species itself. This imbalance of knowledge has, by necessity, led us into a stratified decision-making process wherein possibly no conclusion could be reached on a species (e.g., if deciding whether to reclassify) but a subdivision of the species, i.e., a population or stock, might be reclassified. The net effect could then be to have an "endangered" species with one or more stocks recovered.

The late Jim Johnson uses a crossbow to affix a plastic streamer-tag to a gray whale in Laguna Ojo de Liebre in Baja California. Photo by C. Goebel.

On the basis of population abundance, as one criterion, a species (or stock) might be considered depleted if its population size is below the lower bound of the optimum sustainable population size (operationally considered by some to be the maximum sustainable yield level), currently defined (e.g., Tillman and Chapman, 1981) as that level yielding maximum net productivity which occurs at or above 60 percent of initial population size. Although reliable quantitative data are not available for all species, a large number of stocks or species can be considered "endangered" if one chooses to use this criterion (Table 2).[2]

Based on population size alone, most stocks of large whales clearly fall within the definition of "endangered," as defined in the ESA on the basis of the listing factors in Table 1. The great whales were listed as endangered as a result of commercial exploitation, as discussed in this volume on a species-by-species basis, or using other criteria in the original documentation published in 1973 (Sec. 15 U.S.C. 1531). These listings were made despite a relatively sparse data base. The purpose of this paper, however, is not to evaluate and recommend whether each species remain classified as endangered, nor whether certain stocks should be reclassified, although some implications of this are presented in the following discussion.

Discussion

From data presented in the following eight papers, and summarized in Table 2, an estimate of the approximate percent of current to initial population size for some great whale stocks is made. In Table 3 an evaluation is made of the possible level of recovery for each stock or species' group.

Only the eastern North Pacific gray whale and perhaps the western North Atlantic humpback whale may have recovered to a population level similar to what it was prior to commercial whaling. On the basis of population size alone, these two stocks plus most sperm whale stocks seem likely candidates for reclassification.

However, population size is not the only criteria to be considered in deciding whether a stock warrants continued protection under the ESA. And, some doubts exist about the accuracy or completeness of data used

[2]"Depleted" was likely the concept applied to the term "endangered" in 1973. I use the concept of "degree of endangerment" as percent depleted, or current vs. initial stock size.

to estimate initial stock sizes, especially for humpback and sperm whales (Table 2). In the case of the gray whale, serious consideration must be given to coastal habitat protection as human activities increase. In addition, about 170-190 gray whales from this stock are killed each year by the Soviet Union, and usually less than 5 are killed annually by Alaska Eskimos.

Western North Atlantic humpback whales, as well, are subject to a small annual subsistence harvest in west Greenland and Bequia (Lesser Antilles), and several are entangled each year in fishing gear along the east coast of the United States and Canada. Sperm whales appear to be abundant relative to their presumed initial population sizes (when compared with most stocks of baleen whales reported in Tables 2 and 3).

Three stocks of great whales may be nearing extinction: Western North Pacific gray whale, east Greenland-Spitsbergen bowhead whale, and North Pacific right whale. Several recent unpublished sightings of gray whales in the western North Pacific and Sea of Okhotsk, of 11 bowheads off Frans Josef Land in the eastern North Atlantic (Braham, 1984), and 2 right whales in the southeastern Bering Sea (Braham and Rice, 1984) suggest that at least a few individuals remain. Unfortunately, there is little direct evidence to indicate that these stocks are either further declining or recovering. The simplest explanation for the increased sightings is increased research.

Further consideration of the status of stocks of all large whales awaits renewed dedication to research on sightings and, perhaps, stranding information.

Table 3.—A generalized evaluation of the possible recovery of endangered whales by stock(s) or regional groupings.

Status
Perhaps recovered[1]
Eastern North Pacific gray whale
Western North Atlantic humpback whale
Status uncertain[2]
North Pacific sei whale
North Atlantic sperm whale(s)
North Pacific sperm whale(s)
Southern Hemisphere sperm whale
Depleted[3]
All stocks of blue whales
Davis Strait bowhead whale
Sea of Okhotsk bowhead whale
Western Arctic bowhead whale
North Pacific humpback whale(s)
Southern Hemisphere humpback whale(s)
Antarctic fin whale
North Pacific fin whale
Western North Atlantic fin whale
Western Norway/Faeroe Islands fin whale
Southern Hemisphere right whale(s)
Southern Hemisphere sei whale(s)
Nearing extinction
East Greenland-Spitsbergen bowhead whale
Western North Pacific gray whale
North Pacific right whale(s)
Insufficient data for judgement
Hudson Bay bowhead whale
Denmark Strait fin whale
North Norway fin whale
Spain-Portugal-British Isles fin whale
Eastern North Atlantic humpback whale
Northern Indian Ocean humpback whale
North Atlantic sei whale
North Atlantic right whale

[1]To estimated population size prior to commercial whaling.
[2]Possibly above or near 60 percent of estimated initial population size.
[3]Well below initial population size estimates, but may include low populations which have shown some increase (e.g., Southern Hemisphere right whales and western Arctic bowhead whale).

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This special section on endangered whales is respectfully dedicated to the memory of James H. Johnson who passed away on 9 December 1983.

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The Gray Whale, *Eschrichtius robustus*

DALE W. RICE, ALLEN A. WOLMAN, and HOWARD W. BRAHAM

Introduction

The gray whale, *Eschrichtius robustus* (Lilljeborg, 1861), is readily recognized by its mottled gray color and lack of a dorsal fin. Instead of this fin, it has a low hump, followed by a series of 10 or 12 knobs along the dorsal ridge of the tail stock; these are easily seen when the animal arches to dive. The adult gray whale is 36-50 feet long and weighs between 16 and 45 tons.

The gray whale is currently confined to the North Pacific Ocean (Fig. 1). Because it uses coastal habitats extensively, the gray whale was especially vulnerable to shore-based whaling operations. Two stocks occur in the North Pacific: The "California" or eastern stock which breeds along the west coast of North America, and the "Korean" or western stock which apparently breeds off the coast of eastern Asia (Rice and Wolman, 1971). Both stocks were severely depleted by the early 1900's. Under legal protection, the eastern stock has recovered substantially—one of the few stocks of great whales to do so. The western stock has not recovered. The gray whale formerly occurred in the North Atlantic (van Deinse and Junge, 1937; Cederlund, 1939; Fraser, 1970; Mitchell and Mead[1]), but has been extinct there for several centuries.

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Distribution and Migration

Eastern North Pacific

Most of the California stock spends the summer feeding, mostly in the northern Bering and southern Chukchi Seas (Pike, 1962; Rice and Wolman,

[1]Mitchell, E. D., and J. G. Mead. 1977. History of the gray whale in the Atlantic Ocean. (Abstr.) *In* Proceedings of the 2nd Conference on the Biology of Marine Mammals, San Diego, California, 12-15 December 1977, p. 11. (Available from first author, Arctic Biological Station, Department of Fisheries and Oceans, 555 St. Pierre Blvd., Ste. Anne de Bellevue, Quebec, H9X 3R4, Canada).

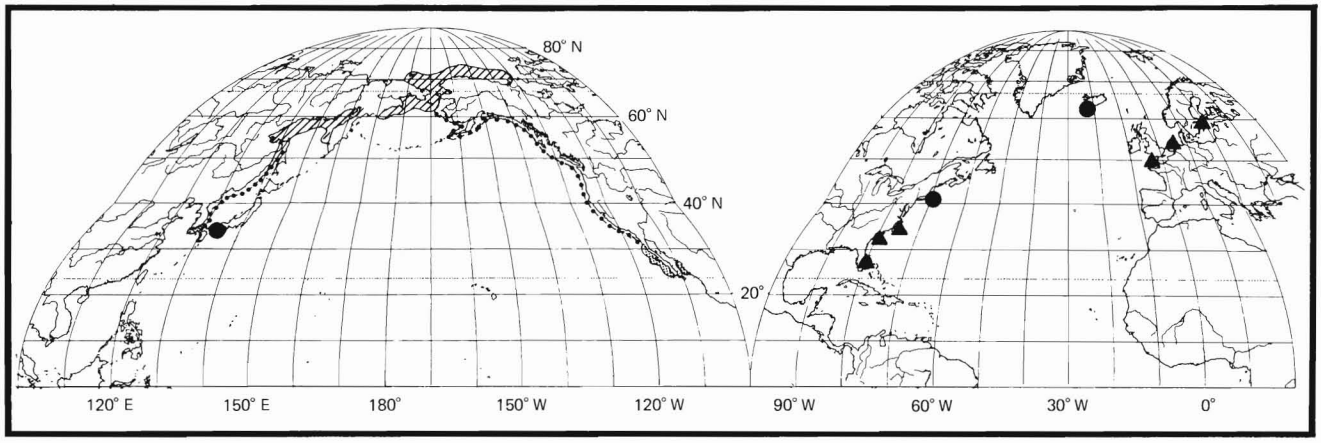


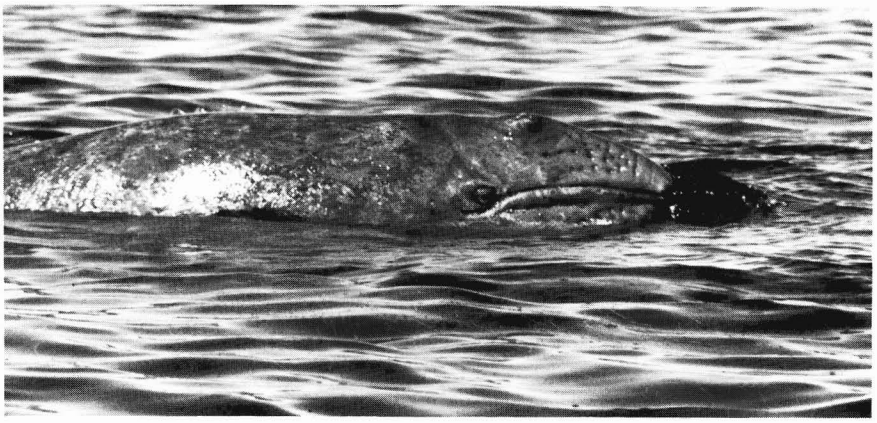
Figure 1.—Geographic distribution of the gray whale. Simple hatching indicates the summer feeding grounds. Small dots indicate the migration routes. Stippling indicates the winter grounds. In the Atlantic, the gray whale has been extinct for at least several hundred years; early historical records are indicated by large dots, subfossil finds by triangles. Perhaps extinct is the population that formerly spent the winter in southern Japan (large dot).

1971; Bogoslovskaya et al., 1981). An unknown number of individuals summer along the west coast of North America in apparently isolated locations south of Alaska from Vancouver Island, Canada, as far south as Baja California, Mexico (Patten and Samaras, 1977; Sprague et al., 1978). In the Beaufort Sea, sightings have been made of small groups as far east as long. 130°W during August (Rugh and Fraker, 1981); in the East Siberian Sea, gray whales were found along the Siberian coast as far west as 174°08'E in late September (Marquette et. al., 1982).

In October and November, the stock begins leaving the Chukchi Sea, exiting the Bering Sea through Unimak Pass, Alaska, mainly in November and December (Rugh and Braham, 1979; Braham, 1984; Rugh, 1984). The whales migrate near shore along the coast of North America from Alaska all the way to central California (92 percent pass within 1.4 km of Cape Sarichef, Unimak Pass, and 94 percent pass within 1.6 km of the Monterey-Point Sur area of central California). After passing Point Conception, Calif., the majority take a more direct offshore route across the southern California Bight to northern Baja California. Southbound migrating gray whales swim at about 7.7 km/hour, and thus travel about 185 km per day (Pike, 1962).

Migrating gray whales are temporally segregated according to sex, age, and reproductive status (Rice and Wolman, 1971). During the southward migration, the sequence of passage off California is as follows: Females in late pregnancy, followed by females that have recently ovulated, adult males, immature females, and then immature males. The earliest southbound migrants (mostly late-pregnant females) usually travel singly, whereas later migrants usually are in pods of two or more. The mean pod size through Unimak Pass is about two.

This stock winters mainly along the west coast of Baja California. The pregnant females assemble in certain shallow, nearly landlocked lagoons and bays where the calves are born from early January to mid-February.



A newborn gray whale calf in Laguna Ojo de Liebre, Baja California, Mexico. Each dimple on the snout and lower lip marks the site of a hair. Photo by D. W. Rice.

The major calving areas are Laguna Guerrero Negro (with 9 percent of the calves), Laguna Ojo de Liebre (53 percent), Laguna San Ignacio (11 percent), and Estero Soledad (12 percent). Minor calving areas (each with <6 percent) are San Juanico Bight, Bahia Magdalena, Bahia Almejas, and Bahia Santa Marina (Rice et al., 1981). Calving rarely occurs during the southbound migration north of Baja California (Rice and Wolman, 1971; Sund, 1975). A few calves are also born on the eastern side of the Gulf of California at Yavaros, Sonora, and Bahia Reforma, Sinaloa, Mexico (Gilmore, 1960). Contrary to many published statements, there is no evidence that San Diego Bay, Calif., was ever a calving area (Henderson, 1972). Recent studies have revealed that the vast majority of gray whales in Baja California (other than cows with calves) spend the winter outside the lagoons in Bahia Sebastian Viscaino and Bahia de Ballenas (Rice et al.[2]).

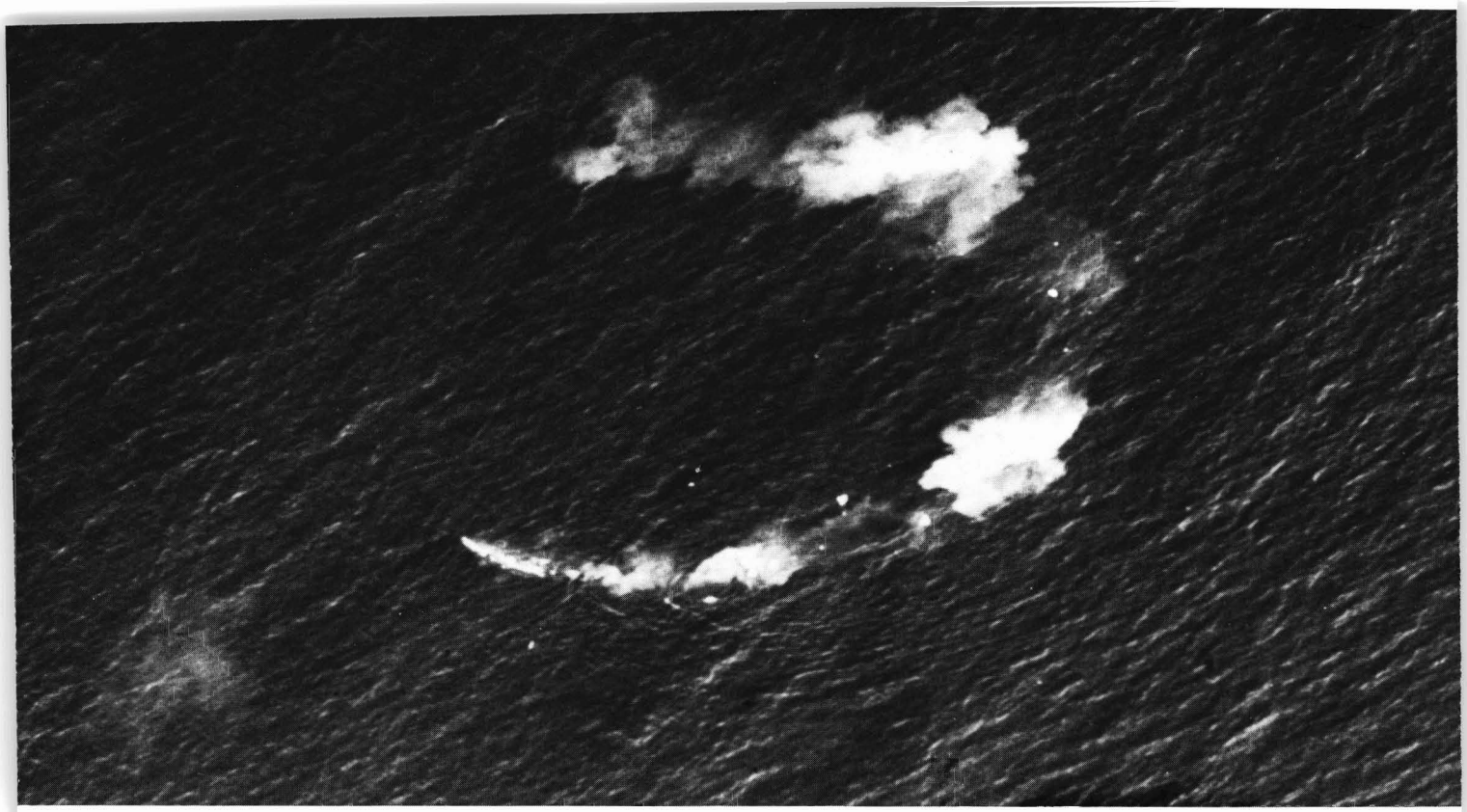
The northbound migration begins in mid-February, and by April whales begin showing up in the southern Bering Sea, which they enter through Unimak Pass (Braham et al., 1977; Braham, 1984). This migration is completely coastal, at least to the east central Bering Sea (Nunivak Island). Most animals in Alaska travel within 1 km of the coast, especially in the southeastern Bering Sea, and at least some apparently feed during migration (Braham, 1984). During the northward migration, the sequence is as follows: Newly pregnant females, followed by anestrous females, adult males, and immature males and females; cows with calves are the last animals to leave the lagoons, and most migrate after the other whales. The peak of the migration passes Point Piedras Blancas, Calif., about 1 May (Poole[3]).

Western North Pacific

The Korean stock formerly occupied the northern Sea of Okhotsk in the summer, as far north as Penzhinskaya Bay, and south to Akademii and Sakhalinskiy Gulfs on the west and the Kikhchik River on the east. Southbound whales migrated along the coast of eastern Asia to winter

[2]Rice, D. W., A. A. Wolman, and D. E. Withrow. 1984. Distribution and numbers of gray whales on their Baja California winter grounds. Unpubl. manuscr. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115.

[3]Poole, M. M. 1981. The northward migration of the California gray whale, *Eschrichtius robustus*, off the central California coast. (Abstr.) *In* Proceedings of the 4th Biennial Conference on the Biology of Marine Mammals, December 14-18, 1981, San Franc., Calif., p. 96. (Available from author, Biology Department, Sonoma State University, Rohnert Park, CA 94928.



Circular mud plume pattern produced by a feeding gray whale in the northern Bering Sea. This behavior is believed to be associated with the whale returning to the location it was just at to resume feeding. Photo by H. W. Braham.

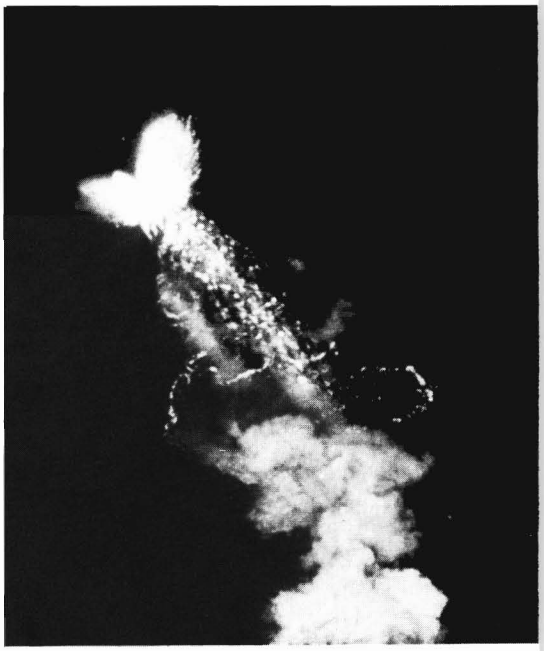
calving grounds off the south coast of Korea, passing Ulsan from late November to late January. Until the turn of this century, another migration route led down the eastern side of Japan to winter grounds in the Seto Inland Sea, Japan (Omura, 1974). Nishiwaki and Kasuya (1970) and Bowen (1974) hypothesized that three recent records of gray whales in Japan involved vagrants of the California stock rather than being Korean stock survivors. It is likely that any remnants of the Korean stock are in such low numbers (Brownell, 1977) as to be below a critical population size sufficient for recovery. This stock therefore may be almost extinct.

Life History and Ecology

Feeding

Gray whales are predominantly bottom feeders that apparently ingest their food by suction (Ray and Schevill, 1974); only rarely do they feed in midwater or at the surface. On their summer grounds in the shallow waters of the Chukchi and Bering Seas, they feed primarily on benthic gammaridean amphipods. Forty-three species have been identified from stomachs, but, depending on area, one of seven species is usually dominant (*Pontoporeia femorata*, *P. affinis*, *Anonyx nugax*, *Ampelisca macrocephala*, *A. eschrichti*, *Nototropis brueggeni*, or *N. ekmani*). In some areas polychaete worms are their main food. Incidentally ingested benthos include gastropods, ascidians, bivalves, priapulids, decapod crustaceans, isopods, sipunculids, hydrozoans, anthozoans, cumaceans, holothurians, sponges, and fish (*Ammodytes* sp.) (Zimushko and Lenskaya, 1970; Bogoslovskaya et al., 1981). Gray whales may play an important role in the rate of turnover of the epibenthos on their summer feeding grounds (Nerini and Oliver, 1983; Nerini, 1984).

Little if any food is consumed during the southbound migration off the U.S. continental coast, although rarely small quantities of decapod nauplii



Aerial view of a feeding gray whale surfacing in the northern Bering Sea, near St. Lawrence Island, Alaska. Note the heart-shaped blow and the trailing mud plume caused when the whale expells water and debris out the side of its mouth when surfacing after feeding on organisms along the bottom of the sea. Photo by H. W. Braham.

(*Pachycheles rudis* and ?*Fabia* sp.) are eaten (Rice and Wolman, 1971). There are reports that they do feed to some extent just before (Sund, 1975) and while on their winter grounds off Baja California (Swartz and Jones, 1982) although the frequency of this behavior is unknown. In the interval between their southward and northward migration past San Francisco, the whales without calves lose from 0.21 percent to 0.37 percent of their body weight per day. This weight reduction is sufficient to account for the estimated energy expenditure during the winter. Blubber thickness and oil yield also decrease during winter. Apparent feeding has been observed during the northbound migration beginning in southeastern Alaska (Braham, 1984), but again the frequency and quantitative evidence associated with energy expenditure for this is unknown.

Reproduction

Females attain puberty at an estimated mean age of 8 years (range, 5-11 years) and a mean body length of about 11.7 m (see Rice and Wolman (1971) for additional details on reproduction).

Female gray whales normally come into estrus biennially in late November and early December. Most individuals ovulate only once each season, although whales failing to conceive after their first ovulation may experience a second estrous cycle the same season. Multiple ovulations are extremely rare. Mean ovulation rates are 1.20 per breeding season for nulliparous females and 0.96 per breeding season (0.52 per year) for parous females. There is little evidence of postpartum ovulation or of ovulation at any other time of the year. However, increase in follicle size following stillbirth or early loss of the calf suggests that females might ovulate following such an event.

Most conceptions occur within a 3-week period during southward migration, with a peak about 5 December; a few occur as late as January on the winter grounds. The pregnancy rate is 0.86 per breeding season or 0.46 per year. The period of gestation is about 13.5 months; fetal growth accelerates during the last half of pregnancy and decelerates just before birth (Rice, 1983). During southward migration, late pregnant females (exclusive of their conceptus) average 25-30 percent heavier than other adult females. Most births occur within a period of 5-6 weeks, with a peak occurring about 27 January; extreme recorded dates are 26 December to 1 March (Swartz and Jones, 1983).

Lactation lasts an average of about 7 months, ending in August. Females are usually in anestrus from August to November or December. However, females that fail to ovulate or conceive during the winter are probably in anestrus for the following 12 months.

Males attain puberty at an estimated mean age of 8 years (range, 5-11 years) and a mean body length of about 11.1 m. The average weight of the testes of adult males during southward migration in December and January is 38 kg, and the mean diameter of the seminiferous tubules is 177μm. During northward migration in February and March, mean testes weight and tubule diameter are 22 kg and 148 μm, respectively. From July through October, the testes average 23 kg. These differences suggest a marked seasonal sexual cycle in the male, with a peak of spermatogenetic activity in late autumn or early winter.

Natural Mortality

No infectious diseases have been reported in gray whales. Epizoites of gray whales include the following (percentage of occurrence in parentheses) (Rice and Wolman, 1971): The barnacle *Cryptolepas rhachianecti* (100) and the cyamids *Cyamus scammoni* (99.7), *C. ceti* (99.4), and *C. kessleri* (98.1). Endoparasites include the trematodes *Lecithodesmus goliath* (0.6), *Ogmogaster pentalineatus* (>22), and *O. antarcticus* (33); two apparently undescribed species of the cestode *Priapocephalus*, one in the small intestine (30) and the other in the large intestine (0.3); the nematode *Anisakis simplex* (0.3); and two acanthocephalans, *Corynosoma* sp. (5.7) and *Bolbosoma* sp. (0.3). Obvious pathogenic effects are produced only by the liver fluke *Lecithodesmus goliath*, but it is not known whether this ever causes mortality.

The killer whale, *Orcinus orca*, appears to be the only predator on gray whales. Evidence from necropsy of 39 gray whales that stranded on St. Lawrence Island indicated that 16 had been killed by killer whales (Fay et al., 1978). The mortality rate from killer whale attacks is unknown. However, the frequency of tooth scars on gray whale carcasses indicates that killer whale attacks are often unsuccessful.

Moderate numbers of gray whale calves strand in and near the nursery lagoons (Swartz and Jones, 1983). A few adults strand every year throughout the range, but the number seems low compared with the size of the population. Rates of mortality due to stranding cannot be calculated.

Total annual mortality estimates for animals older than 8 years, calculated from the age composition as determined by ear-plug readings, were 0.095 for females and 0.081 for males; a similar estimate for sexually mature females, based on ovarian corpora counts, was 0.082 (Rice and Wolman, 1971). These estimates are probably biased upwards because the population was increasing during the 1950's and 1960's when the data were collected. Reilly (1981) estimated the adult natural mortality rate at 0.056 and the juvenile mortality rate at 0.132 during that period. The sex ratio is essentially equal throughout life.

Exploitation and Population Size

History of Exploitation

Eskimos living on the shores of the northern Bering Sea and the Chukchi Sea have hunted whales for perhaps several thousand years. In Alaska, the catch is mostly of bowhead whales, *Balaena mysticetus,* with very few gray whales taken, usually less than one per year (Marquette and Braham, 1982). However, on the Chukotka

coast of the U.S.S.R. the catch has been almost entirely gray whales. Since 1969 gray whales have been taken by the Soviet Government for the Chukchi Eskimos using one modern-style catcher boat (Ivashin and Mineev, 1981). The total aboriginal catch since 1967 has averaged about 165 gray whales per year (Table 1). The current catch limit set by the International Whaling Commission (IWC) is 179 per year.

Several Indian tribes on Vancouver Island and in the State of Washington traditionally hunted gray whales, but have not done so since 1928. Indians farther north along the coast of North America also may have taken a few gray whales (Mitchell, 1979).

From 1846 until about 1900, American whalers exploited gray whales mostly on their wintering grounds, but also took a few in northern waters during the summer. On the basis of available historical records, Henderson (1972) estimated that the total catch from 1846 to 1874 was about 8,100. During the peak of this fishery from 1855 to 1865, the annual catch averaged 474 whales. Catches during the three winter seasons from 1883-84 to 1885-86 were 58, 68, and 41, respectively (Townsend, 1887).

Modern-style whaling began on the west coast of North America in 1905. A few gray whales were taken in the winter off Baja California and California, mostly between 1925 and 1929. Factory ships took an average of 48 gray whales per year in the Bering Sea from 1933 to 1946 (Table 2), after which commercial whaling for gray whales was banned by the International Convention for the Regulation of Whaling.

Between 1959 and 1969, 316 gray whales were killed under Special Scientific Permits off California. From 1966 to 1969 the combined scientific and U.S.S.R. catches averaged 221 per year.

Current and Initial Stock Sizes

Scammon (1874) estimated that the California gray whale population was probably not over 30,000 in 1853-1856, and that by 1874 the number did not exceed 8,000 or 10,000. After a careful analysis of the historical data, however, Henderson (1972) concluded that the population did not exceed 15,000-20,000 prior to the initiation of commercial exploitation in 1846.

In 1885-86, Townsend (1887) estimated that only 160 gray whales migrated south past San Simeon, Calif. Andrews (1914) wrote that "For over 20 years [preceding 1910] the species had been lost to science and naturalists believe it to be extinct." Howell and Huey (1930) said it was

Table 1.—Catches of California gray whales by aboriginal whaling, 1948-82.

Year	U.S.S.R.[1]	Alaska[2]	Total
1948	19		19
1949	26		26
1950	10	1	11
1951	12	1	13
1952	42	2	44
1953	37	1	38
1954	36	3	39
1955	59		59
1956	121	1	122
1957	95	1	96
1958	145	3	148
1959	187	6	193
1960	156		156
1961	207	1	208
1962	147		147
1963	178	1	179
1964	188	2	190
1965	175	1	176
1966	194		194
1967	125		125
1968	135		135
1969	139	1	140
1970	146	5	151
1971	150	3	153
1972	181	1	182
1973	173		173
1974	181	3	184
1975	171		171
1976	163		163
1977	186	1	187
1978	182	2	184
1979	178	4	182
1980	179	3	182
1981	135	0	135
1982	160	4	164

[1]Data from Ivashin and Mineev (1978) and with addition of figures for 1978-82 from unpublished data of the All-Union Research Institute of Marine Fisheries and Oceanography (VNIRO), Moscow.
[2]Data from Marquette and Braham (1982): and unpublished data of the National Marine Mammal Laboratory. Actual values may be low because the taking of gray whales is often not reported.

Table 2.—Catches of California gray whales by modern-style whaling, 1913-47[1]

Year	Baja California	California	Washington	Alaska[2]	Bering and Chukchi Seas[3]	Total
1913				1		1
1914	19					19
1920		2				2
1921		1				1
1922		5				5
1924			1			1
1925	100				33	133
1926	41	1				42
1927	29	3				32
1928	9	1		2		12
1929	2					2
1933				2	2	4
1934					54	54
1935					34	34
1936					102	102
1937					14	14
1938					54	54
1939					29	29
1940					105	105
1941					57	57
1942					101	101
1943					99	99
1945					30	30
1947					1	1

[1]Data summarized from Rice and Wolman (1971), except that the figures for 1943, 1946, and 1947 have been changed to agree with those in Kleinenberg and Makarova (1955).
[2]Gulf of Alaska (shore stations at Port Armstrong and Port Hobron).
[3]Pelagic whaling.

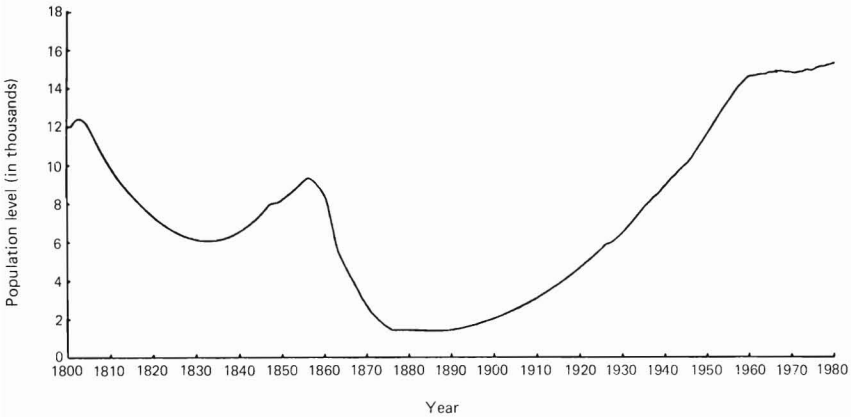


Figure 2.—Gray whale population trajectory based on an estimated maximum population size of 24,000 prior to 1800 and an aboriginal take through that time of 600 whales per year. Peaks and valleys relate to periods of heavy exploitation and recovery from commercial whaling. This modeling best fits the current population census of about 16,000 ± 3,000 (from Reilly, 1981).

" . . . doubtful whether more than a few dozen individuals survive." However, K. W. Kenyon[4] says that he commonly observed gray whales migrating past La Jolla, Calif., during the 1930's.

Systematic shore counts of the southward migration were initiated at San Diego, Calif., in 1952-53, and continued intermittently until 1976-77 (Gilmore, 1960; Rice, 1961). These counts indicated a steadily increasing population until 1959-60.

From 1967-68 to 1973-74, a shore count was made every winter at Yankee Point near Monterey, Calif. where 90 percent of the whales pass within 2 miles of shore and boat traffic is at a minimum. From 1974-75 to 1979-80 the count was made at Granite Canyon, 4 miles south of Yankee Point. A census of the population leaving the summer feeding grounds was made from 1977 to 1979 at Unimak Pass.

The 1977 estimate of the population leaving the Bering Sea was 15,099 ± 2,341 (Rugh and Braham, 1979), and for the 3 years 1977-79 Rugh (1984) estimates 17,000. The population size in 1979-80 off California was estimated at 15,647 (95 percent confidence interval of 13,450-19,201); the rate of annual net increase (less the 1.2 percent harvest mortality) during the preceding 13 years was 2.5 percent, with a standard error of 0.96 (Reilly et al., 1980; Reilly, 1981; Reilly et al., 1983). This indicates that the eastern North Pacific population has recovered to, or now exceeds, its size prior to commercial whaling.

Computer simulation models of the gray whale population size from 1800 through 1980 were run by Reilly (1981). Various forms of dynamic response of vital parameters to population density were used, as well as various carrying capacity levels, and various levels of prehistoric aboriginal removal rate. The model that produced a population trajectory in best agreement with the census data and historical evidence indicated that the carrying capacity (or maximum population size historically) may have been 24,000, and that the population had been reduced to below 12,000 by the year 1800 as a result of aboriginal takes which may have averaged 600 whales per year (Reilly, 1981). The population trajectory generated by this model for the period 1800 to the present is shown in Figure 2. Results of these assessments suggest that the population has not increased to the level that it would reach if there were no current exploitation. The population has recovered, however, to the level (which was presumably stable) that it was at before commercial whaling began in the mid-19th century.

Reilly (1981) estimated the maximum sustainable yield (MSY) as 480 gray whales per year; however, in a recent revision, he gave a new estimate of 320 per year, which would occur at a population size of 11,380 whales[5]. His revised model also predicted that, under an annual take of 180 whales per year, the population would reach 19,000 by the year 2150 and continue rising slowly thereafter, achieving stability at a level of 19,620.

Management

One potential threat to the California gray whale population may be increasing industrial development and vessel traffic in the calving lagoons and in other vital habitats along the migration route and on the feeding grounds. In the recent past, considerable harassment has been caused by commercial cruise boats which take people into the calving lagoons to see the whales and by small pleasure craft brought overland down the new Baja California highway. Harassment now may be under better control than in the past. Under existing U.S. laws, regulation and enforcement are being defined and steps taken to control vessels that interfere with gray whales on their migration path. Between 1972 and 1979, the Mexican Government designated three of the five major calving lagoons in Baja California as gray whale refuges (Reeves, 1977; Swartz and Jones, 1982). These are the lagoons visited by most of the U.S. tour boats and private tourists. The number of vessels allowed in the lagoons at any one time is limited,

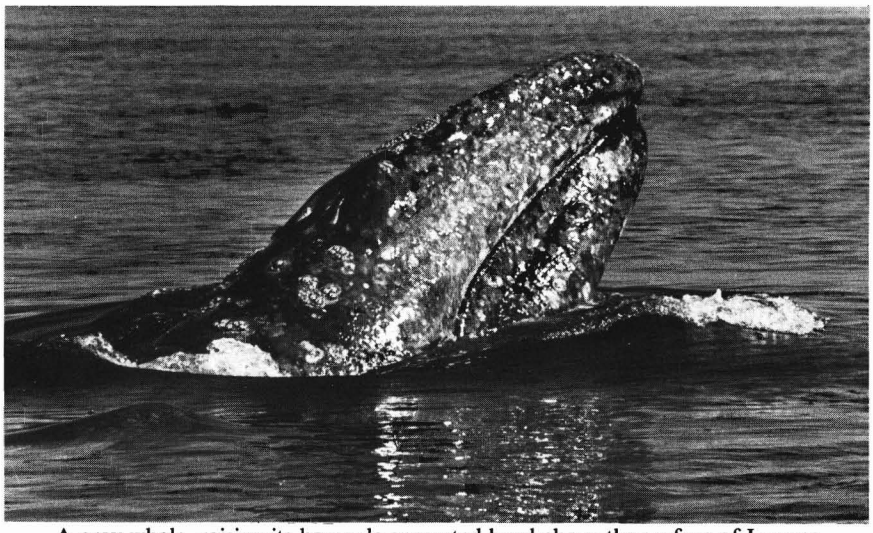
[4]K. W. Kenyon, 11990 Lakeside Place N.E., Seattle, WA 98125. Pers. commun.

[5]Reilly, S. B. 1984. Future trends in gray whale population size. Unpubl. manuscr. Southwest Fisheries Center, Natl. Mar. Fish. Serv., NOAA, P.O. Box 271, La Jolla, CA 92038.

and entry into certain areas is forbidden. Thousands of tourists and a multimillion-dollar industry result from these activities.

Oil and gas exploration is contemplated or under way on the continental shelf from California to the Beaufort Sea, throughout the migration range of this species. Annually, the gray whale population migrates by or through at least eight oil lease areas in U.S. waters alone. On the winter calving grounds, exploratory areas include sites within and adjacent to present calving and rearing areas, such as the offshore waters of Vizcaino Bay, where seismic exploration for gas deposits took place during spring 1981. The effects of oil pollution on the benthic organisms on which these whales feed are unknown. Little is known about what effects, if any, other activities associated with coastal development might have; certain man-made sounds cause migrating whales to deviate from their course (Tyack et al. [6]).

Past industrial activities have shown some impacts. For example, in the calving lagoon of Guerrero Negro, daily dredging and vessel traffic caused the whales to abandon the area from 1957 to 1967. The whales did not return until 6 years after such operations had ceased (Gard, 1974; Bryant and Lafferty, 1980). Current exploitation of phosphorus near the calving lagoon of Magdalena Bay in southern Baja California may be cause for concern (Cordoba, 1981). Because of the scarcity of suitable isolated calving and nursery areas for gray whales, and the whales' specialized feeding habits, future coastal or shallow-water development must be well monitored to determine any effects on any critical stages of this whales' life cycle. For these reasons, habitat protection of the coastal environs remains an important conservation measure.



A gray whale, raising its barnacle encrusted head above the surface of Laguna Ojo de Liebre in Baja California, reveals its paired blowholes. Photo by D. W. Rice.

[6]Tyack, P., C. Clark, and C. Malme. 1983. Migrating gray whales alter their motion in response to sounds associated with oil development. (Abstr.) *In* Proceedings of the 5th Biennial Conference on the Biology of Marine Mammals, November 27-December 1, 1983, Boston, Mass., p. 104. (Available from first author, Woods Hole Oceanogr. Inst., Woods Hole, MA 02543.)

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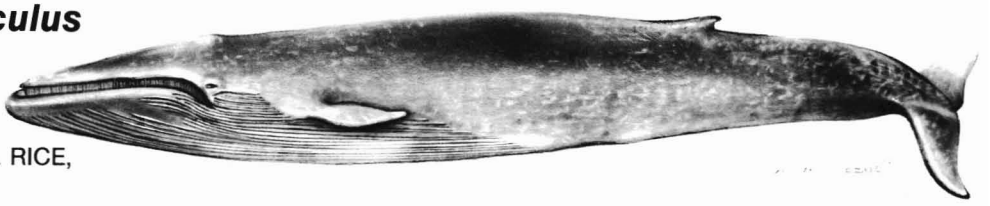
The Blue Whale, *Balaenoptera musculus*



SALLY A. MIZROCH, DALE W. RICE, and JEFFREY M. BREIWICK

Introduction

The blue whale, *Balaenoptera musculus* (Linnaeus, 1758), is not only the largest of the whales, it is also the largest living animal, and may range in size to over 30 m (100 feet) and weigh up to 160 metric tons (t) (Mackintosh, 1942). Blue whales are entirely bluish-gray in color, except for the white undersides of the flippers. They are members of the family Balaenopteridae, all of which have fringed baleen plates rather than teeth. Baleen whales graze through swarms of small crustaceans known as krill, and capture the krill in their baleen as water is filtered through. Like most balaenopterids, blue whales exhibit no well defined social or schooling structure, and in most of their range they are generally solitary or found in small groups (Tomilin, 1957).

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Distribution and Migration

Blue whales are found in all oceans and undertake extensive north-south migrations each year, traveling from winter grounds in low latitudes to summer feeding grounds in the Arctic or Antarctic high latitudes. Since most whaling occurred on the high-latitude feeding grounds, the distribution of these whales in these areas is fairly well known.

In Antarctic waters, for example, blue whales and minke whales, *Balaenoptera acutorostrata*, are found in the coldest waters closest to the ice edge, with fin, *B. physalus*, and sei whales, *B. borealis*, distributed, respectively, in somewhat lower latitudes (Mackintosh, 1965). A distinct subspecies called the pygmy

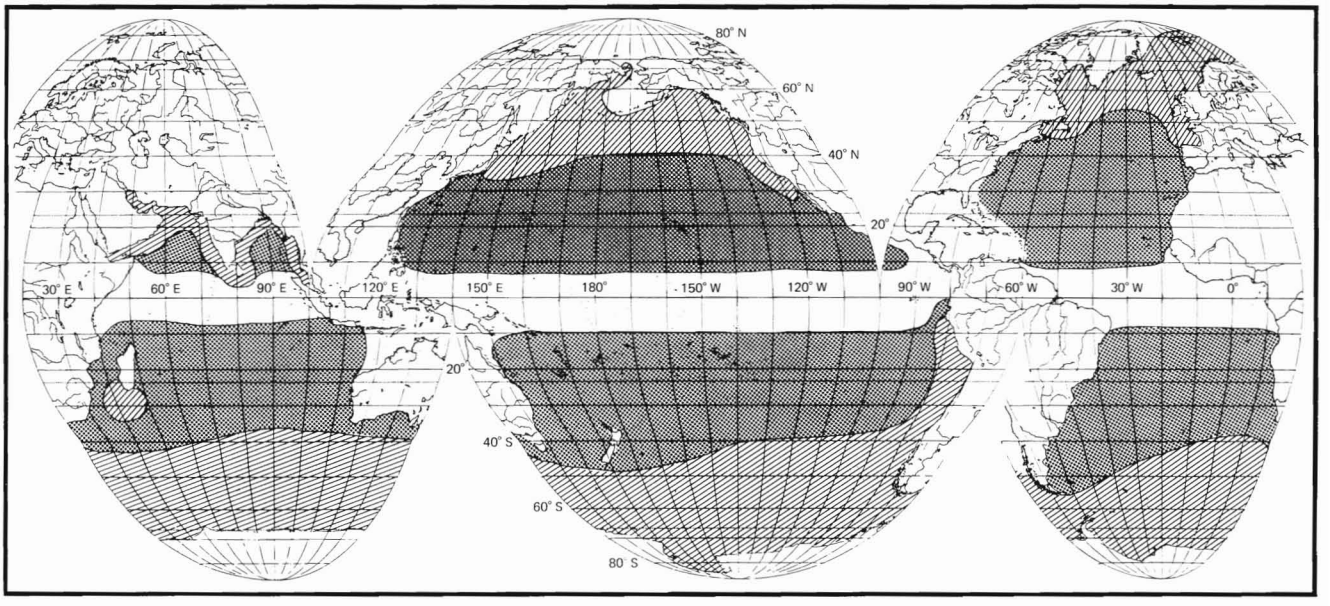
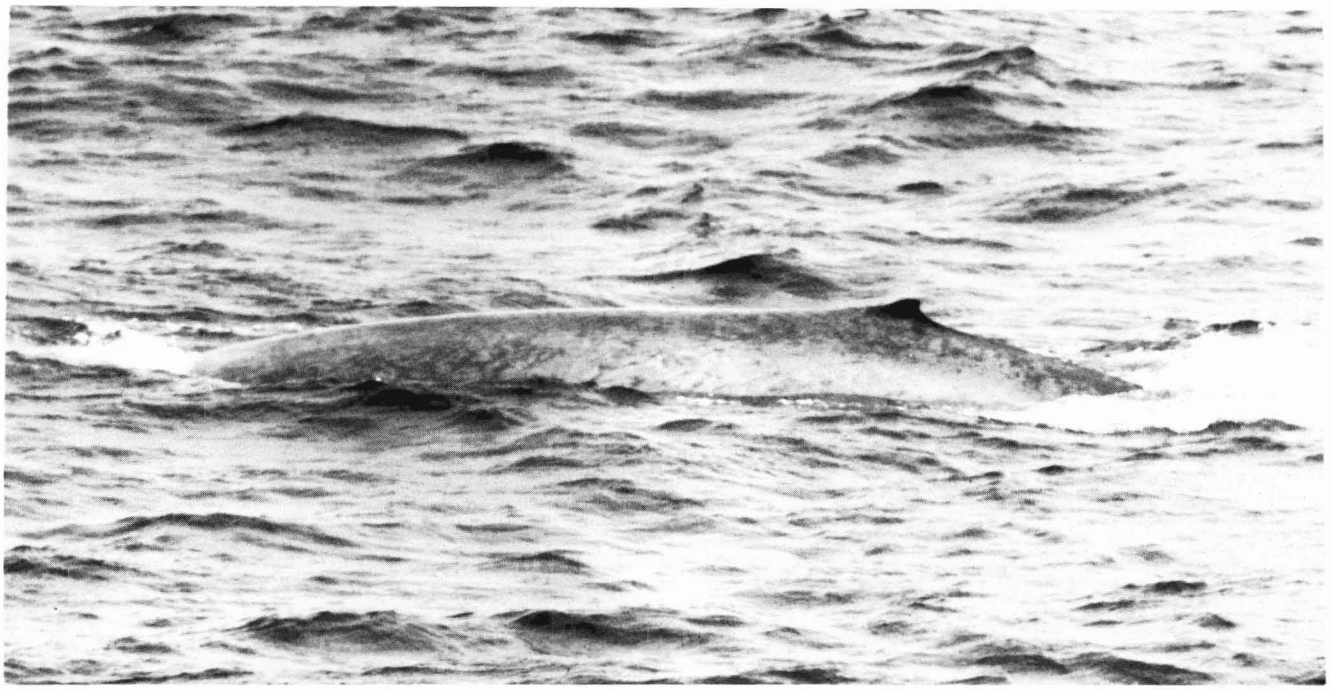


Figure 1.—Geographical distribution of the blue whale. Simple hatching indicates the summer feeding grounds. Stippling indicates distribution during autumn, winter, and spring; records are scarce during these seasons, and the distribution is, to a large extent, speculative.



A blue whale surfacing in the North Atlantic off Spain reveals its mottled back and small step-like dorsal fin. Photo by S. Mizroch.

blue whale, *B. m. brevicauda*, inhabits the southern Indian Ocean south to lat. 55°S (Ichihara, 1966).

The Northern Hemisphere distribution of blue whales is not as clear-cut. Jonsgård (1966) reports blue whales at the edge of the pack ice in the North Atlantic. Nishiwaki (1966), using catch statistics, fixes the northern limits in the North Pacific at the Aleutian Islands, although Sleptsov (1961) saw blue whales as far north as the Chukchi Sea.

The winter distribution of blue whales remains something of a mystery. Since blue whales migrate to and from winter grounds in the open ocean, away from coastlines where they may be observed, scientists have yet to delineate these areas in either the Northern or Southern Hemispheres (Jonsgård, 1966; Mackintosh, 1966). Summer and assumed winter distributions are shown in Figure 1.

Stock Identity

The stocks of blue whales can be grouped into four large geographic regions: The North Pacific, North Atlantic, northern Indian Ocean, and Southern Hemisphere. Within these large areas there are further stock separations.

North Pacific

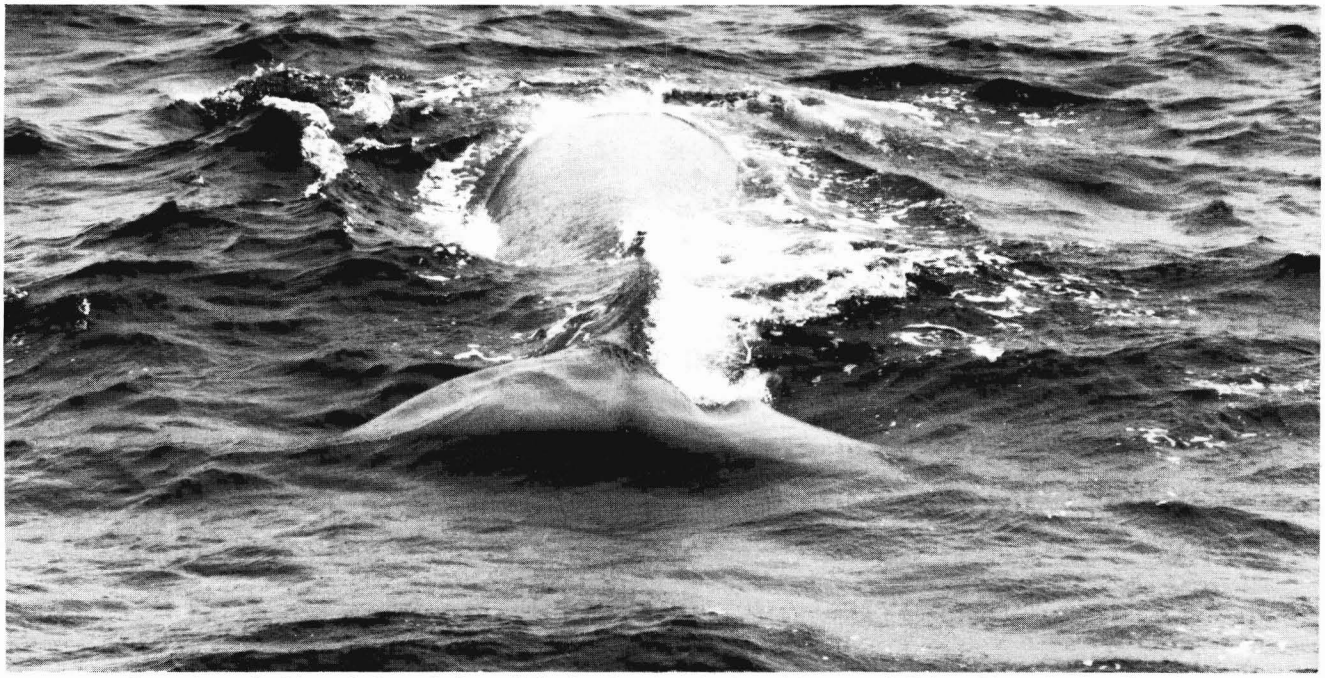
Blue whales have been hunted in Japanese and Korean waters, off Kamchatka, in the Aleutian Islands, and in smaller numbers off California and British Columbia, but very little is known of movements and stock boundaries of blue whales in the North Pacific. They are found from the Chukchi Sea south to the waters off Taiwan and Costa Rica (Rice, 1978; Leatherwood, et al., 1982), but there is no speculation as to stock units in this broad area, and the International Whaling Commission (IWC) has not set specific boundaries.

North Atlantic

Blue whales have been hunted off northern Norway, Svalbard (Spitsbergen), Iceland, the British Isles (primarily the Hebrides), and Newfoundland. The pattern of exploitation generally was of high catches in one location over a 10- to 15-year period, followed by a sharp decline in catches, after which time the industry moved to another location and repeated the pattern (Tønnessen and Johnsen, 1982). Jonsgård (1955) concluded that these localized depletions in blue whale stocks were a result of excessive hunting, and assumed some separation in stock units. No specific studies have been conducted to test this, however, and the IWC considers the North Atlantic stock as one unit for management purposes.

Northern Indian Ocean

Blue whales have been reported year-round in the Gulf of Aden, Persian Gulf, and Arabian Sea, eastward across the Bay of Bengal to Burma and the Strait of Malacca. Nothing is known of the seasonal movements of these animals. A temporarily stranded female gave birth to a calf in Trincomalee Harbour, Sri Lanka, in



Rear view of a blue whale surfacing off Spain, showing the broad lunate tail flukes. Photo by S. Mizroch.

December 1946. The blue whales in this area probably constitute a separate stock and have never been hunted.

Southern Hemisphere

The main feeding areas in the Antarctic were separated into five (and later six) statistical areas by the IWC. These areas were developed based on distributions of humpback whale, *Megaptera novaeangliae* (Mackintosh, 1966), and may or may not indicate stock differences in other balaenopterids, such as blue whales. Mark-recapture experiments are inconclusive, and although many whales are recovered near where they were marked, some are recovered one or more areas away. Brown (1962) hypothesized that blue and fin whales disperse more on the feeding grounds than do humpback whales, and consequently there is overlap among various breeding stocks. Since blue whales, unlike humpbacks, have no well defined breeding areas, it is impossible to delineate the Southern Hemisphere breeding stock units. For management purposes, however, the IWC considers the whales in each of the IWC statistical areas to be separate stock units.

Life History and Ecology

Feeding

Most blue whales spend the summer in high latitudes and the cold currents on the eastern sides of the oceans, where food production is high. They often range offshore, but less so than fin whales, and tend to be nomadic. The blue whale is virtually monophagous, and feeds almost exclusively on euphausiids, or krill, that congregate in dense shoals near the surface—notably: *Euphausia superba*, *E. crystallorophias*, and *E. vallentini* in the Antarctic; *E. pacifica*, *Thysanoessa inermis*, *T. longipes*, and *T. spinifera* in the North Pacific; and *Meganyctiphanes norvegica* and *T. inermis* in the North Atlantic (Nemoto, 1959). The only exception appears to be off the coast of Baja California, where they have been seen feeding on shoals of the pelagic red crab, *Pleuroncodes planipes* (Rice, 1978).

Blue whales, like most other baleen whales, migrate several thousand miles toward equatorial waters in the autumn. During the winter they fast for several months, living off their fat reserves.

Reproduction

The basic reproductive cycle of the blue whale is biennial. Mating takes place over a 5-month period during the winter. Females appear to be seasonally monoestrous, but if they fail to conceive, they may ovulate two or three times during one estrous cycle. The single calf, born after a gestation period of about 1 year, measures about 7 m (23 feet) long. The calf is weaned late the following summer when it is about 7 months old and 16 m (53 feet) long. Both sexes attain sexual maturity at an age 5-15 years.

Natural Mortality

Important natural mortality factors are unknown. The blue whale is relatively free of ectoparasites and endoparasites (Rice, 1978). They do not even harbor the stomach worms, *Anisakis* sp., which are nearly ubiquitous in virtually all other cetacean species; presumably this is because blue whales do not eat fish, which are the host of the infective stage of the worms. Predation on blue whales by killer whales, *Orcinus orca*, is rare. Natural mortality rates have not been established, but may be considered to be similar to those of the fin whale—about 4 percent per year in adults (Allen, 1980).

Exploitation and Population Size

History of Exploitation

Large-scale exploitation of blue whales did not begin until the introduction of the explosive harpoon and the steam-powered catcher boat in Norway in 1864. This marked the beginning of the modern phase of whaling, in which whalers had the tools to hunt the faster swimming, less buoyant rorquals.

North Pacific

Although the Japanese did not enter the era of modern whaling until the turn of the century, they enjoyed some success catching rorquals (most likely other than blue whales) in earlier times using a sophisticated netting technique. Blue whale catches by the Japanese, using modern techniques, peaked in 1912 (236), declined substantially the next year (58), increased in 1914 (123), and declined thereafter until they ceased entirely when IWC regulations prohibited their capture after 1965 (Tønnessen and Johnsen, 1982).

Modern whaling off the Pacific coast of North America began in 1905 in Victoria, B.C., with a Norwegian crew contracted by Canadian businessmen. The early catches were mostly humpback whales, but some numbers of blue whales were also taken. According to Tønnessen and Johnsen (1982), the peak catch of blue whales (239) in the northeastern Pacific occurred off California in 1926. The catch of blue whales south of the Aleutians averaged about 50 a year until 1930. In these areas, as in the North Atlantic, catches rose, peaked, and declined in a fairly short period. During the late 1950's and early 1960's, Japan caught about 70 blue whales per year near the Aleutians, but by 1966 IWC regulations prevented the capture of blue whales.

North Atlantic

When modern whaling began in the North Atlantic, blue whales were the preferred species due to their great size. The first catches occurred off northern Norway in the late 1860's, but by 1882 whalers were catching more fin than blue whales, presumably because of declines in blue whale stocks (Committee for Whaling Statistics, 1931). This pattern was repeated as the industry expanded to Iceland, the Faroe Islands, Newfoundland, Svalbard (Spitsbergen), and islands off the British coasts. Catches of blue whales in each of these areas were generally high the first 5-10 years, after which catches of fin whales predominated for a few years, and then catches declined altogether, and the industry would move to another whaling ground.

In the peak years, catches of blue whales numbered well over 300 per year in the North Atlantic, but by the post-World War I years, catches began to average only 40-50 per year. By 1952, catches fell to 15 or less per year, and the capture of blue whales in this area was banned entirely in 1960.

Southern Hemisphere

Whaling in the Southern Hemisphere began in 1904, and early catches were predominantly humpback whales. By 1913, however, humpback whale catches had begun to decline, and the blue and fin whale catches began to increase. In 1925, the first floating factory ship able to process whales on board was introduced in the Antarctic, enabling the industry to process whales wherever they were found. Since catcher boats were no longer limited to operating near land stations or moored factory ships, blue whale catches, which had ranged from about 2,000 to 6,000 per year from 1914 through 1924, suddenly increased from 12,734 in 1928-29 to 29,410 in 1930-31.

Although the scale was different, the general pattern of exploitation in the Antarctic was the same as everywhere else. By 1936-37, only 14,304 blue whales were taken, and by 1937-38 the fin whale catch (28,009) was nearly double the blue whale catch (14,923) (Fig. 2). Afterward, the blue whale catch declined steadily until it ceased with the ban on blue whale catches in 1967.

Current and Pre-exploitation Stock Sizes

Gambell (1976) evaluated various rough estimates of current and pre-exploitation blue whale stock sizes and presented the following summarized figures:

	Pre-exploitation stock	*Current stock*
N. Atlantic	1,100-1,500	100
N. Pacific	4,900	1,600 (1,400-1,900)
S. Hemisphere		
Antarctic blue	180,000 (150,000-210,000)	5,000
pygmy blue	10,000	5,000

Management

There has been little new information on blue whale abundance since hunting ceased in 1967. While there have been numerous sightings of blue whales off Mexico (Baja California) during the last several years, there are little or no useful census data for population assessment.

Blue whale populations have not been assessed by the IWC since the mid-1970's. Estimates of the

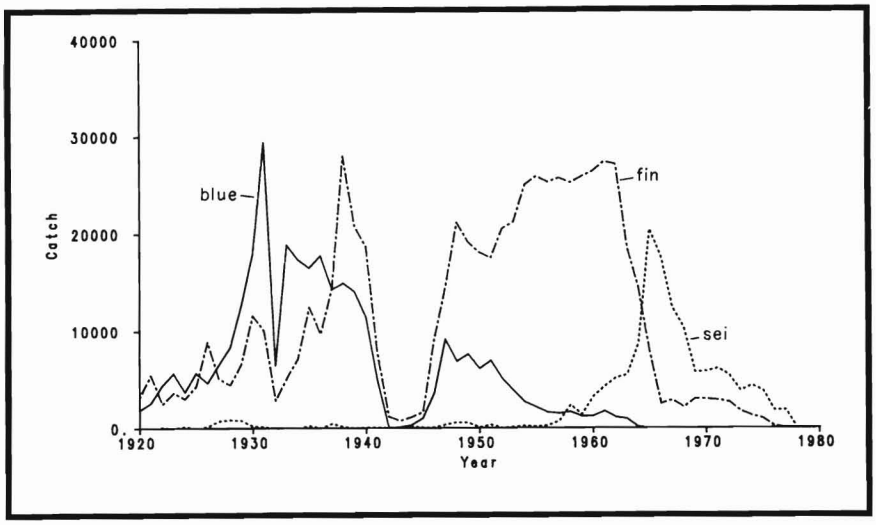


Figure 2.—Catch of blue, fin, and sei whales in the Antarctic, 1920-75 (from the Bureau of International Whaling Statistics).

biological parameters of blue whales are probably no longer current and therefore may have little or no validity at present. In addition, there are no useful indices of abundance covering the period since blue whale hunting ceased in 1967. Although there are occasional sightings of blue whales, there have been no recent surveys to assess the stocks. The few sightings in the Southern Hemisphere indicate that they are still at very low levels relative to their estimated pre-exploitation population size. Given the relative scarcity of blue whales based on opportunistic sightings, the low population estimates relative to their initial abundance, and the low intrinsic rate of increase noted for this and other baleen whale populations, to date, there is no evidence that the blue whale stocks in the Southern Hemisphere and North Pacific are recovering. A local stock of blue whales appears to be doing well in the Gulf of St. Lawrence and is the object of whale-watching trips.

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The Fin Whale, *Balaenoptera physalus*

SALLY A. MIZROCH, DALE W. RICE, and JEFFREY M. BREIWICK

Introduction

The fin whale, *Balaenoptera physalus* (Linnaeus, 1758), is the second largest of the whales in the family Balaenopteridae, second only to the blue whale, *B. musculus*. Fin whales range in length up to 27 m (88 feet) (Mackintosh, 1942), and are generally gray above and white below. Like all balaenopterids, they have fringed baleen plates instead of teeth, and generally feed on swarms of small crustaceans or fish, which are captured in their baleen as water is filtered through. Fin whales do not exhibit as well defined a social or school structure as do toothed whales, and are usually found solitary or in small groups (Tomilin, 1957).

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Distribution and Migration

The general migratory pattern of fin whales, like most balaenopterids, is a movement between poleward feeding areas in the summer months and lower latitudes in the winter months. Northern and Southern Hemisphere fin whale stocks are thought to be reproductively isolated from one another, as their migration schedules are 6 months out of phase. A chart of the general distribution is given in Figure 1.

From observations made in the Antarctic feeding areas during the austral summer, it appears that there is a progression of arrivals by species, with fin whales arriving on the feeding grounds after the blue whales, but before the sei whales, *B. borealis*. Within the fin whale population, migration differs by sexual class, with pregnant females arriving early and leaving early (Mackintosh, 1965). There is some evidence that immature

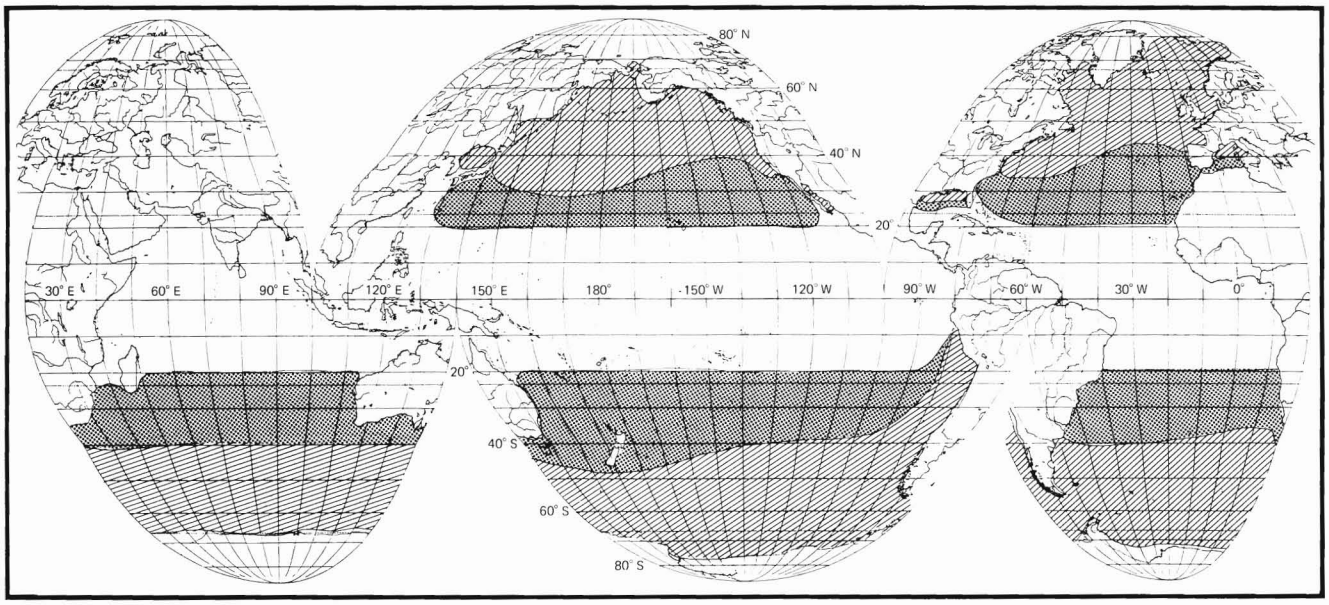


Figure 1.—Geographic distribution of the fin whale. Simple hatching indicates the summer feeding grounds. Stippling indicates distribution during autumn, winter, and spring; records are scarce during these seasons, and the distribution is to a large extent speculative.

whales do not migrate into as high a latitude as do the older whales (Mackintosh, 1965).

Catch statistics indicate that in the Antarctic, and presumably in the Northern Hemisphere as well (Cetacean and Turtle Assessment Program[1]), fin whales are distributed over a wider range of latitudes than either the blue or sei whales. Fin whales can be found from the ice edge in Arctic and Antarctic waters to lower latitudes of around 20° N and S (Jonsgård, 1966a; Mackintosh, 1966; Leatherwood et al., 1982).

Because their migrations are conducted in the open ocean rather than along coastlines, it is difficult to track fin whales from summer feeding areas back to their winter grounds. Consequently, we have scant knowledge of the location of winter breeding grounds.

Stock Identity

Because hunting occurs in feeding rather than breeding areas, the stocks described herein refer to feeding aggregations rather than breeding groups. There is a chance that whales that summer on different feeding grounds intermingle on the same breeding grounds. However, given the history of exploitation in the North Atlantic (e.g., where the industry moved from area to area after successively overharvesting what appeared to be localized populations), there are indications that there is some separation between the stocks found on different feeding grounds (Mackintosh, 1965; Jonsgård, 1966b; Mitchell, 1974; Gaskin, 1982; Tønnessen and Johnsen, 1982).

North Pacific

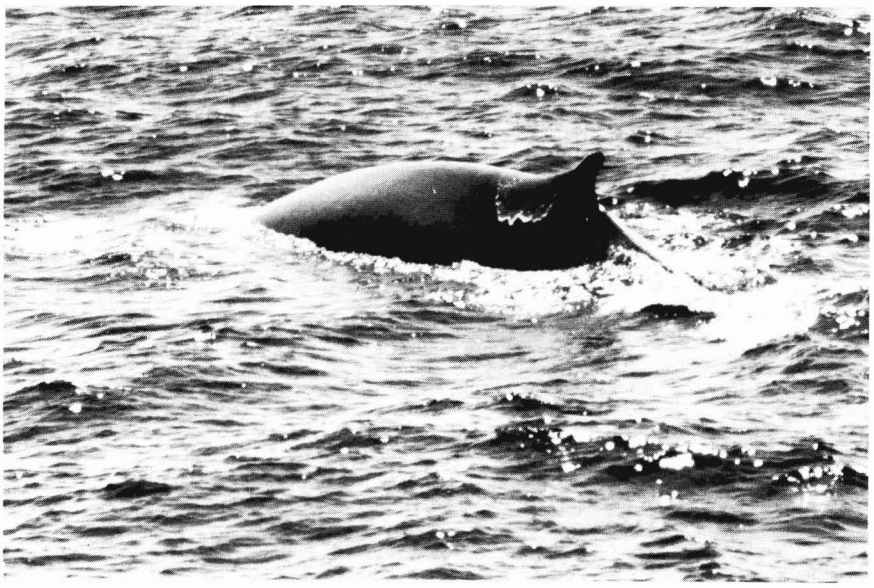
Although the International Whaling Commission (IWC) considers the North Pacific as one management unit, Fujino (1960) describes several fin whale subpopulations in this region. According to histological and marking experiments, he has found an eastern and western group that may intermingle around the Aleutian Islands, as well as an isolated stock in the East China Sea. Fujino also surmises, based on marking studies, that the stock off British Columbia may be isolated as well. Mark recoveries indicate, however, that the animals that winter off southern California range from central California to the Gulf of Alaska in summer, and an isolated population may be resident in the Gulf of California. There may well be other subgroups, but there has been little research directed to this question.

North Atlantic

The International Whaling Commission recognizes the following stocks in the North Atlantic: North Norway, West Norway and Faroe Islands, Spain—Portugal—British Isles, East Greenland—Iceland, West Greenland, Newfoundland—Labrador, and Nova Scotia. There is no evidence that indicates mixing among these stocks. For example, no whales marked off north Norway have been captured off Iceland (IWC, 1983). However, no electrophoretic (or other) studies have yet been presented that would indicate whether these stocks show genetic differences (Arnason, 1981). In addition, Schmidly (1981) speculates that there may be an isolated stock in the northern Gulf of Mexico.

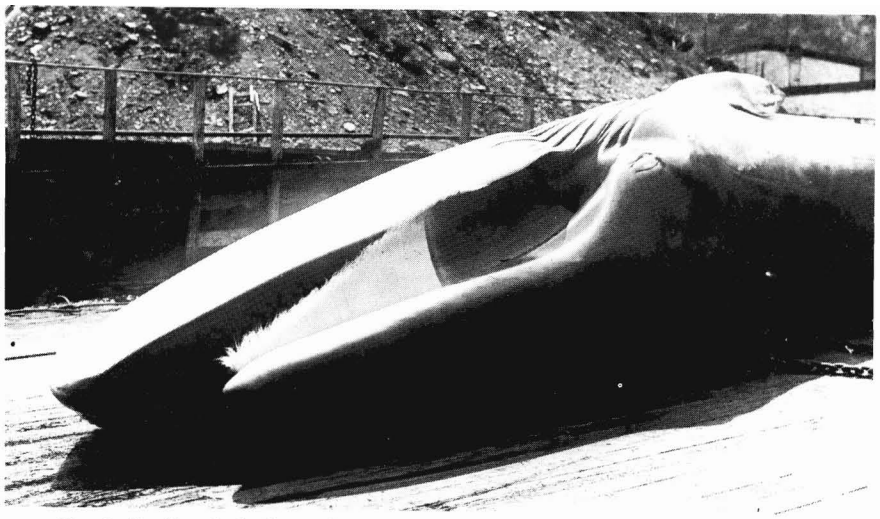
Southern Hemisphere

The Antarctic has been divided by the IWC into six (formerly five) statistical areas. They are based (to some degree) on humpback whale, *Megaptera novaeangliae*, breeding and feeding concentrations (Mackintosh, 1942; 1966), but these areas also apply somewhat to fin whale populations (Brown, 1962). Since the Antarctic harvests (and hence most research) occurred on feeding grounds rather than breeding grounds, catch and mark-recapture data (Brown, 1962) tell us only of dispersal while feeding. Evidence indicates that fin (and blue) whales disperse more than humpback whales while feeding; consequently, different breeding groups are likely to overlap in the various



A fin whale, surfacing in the North Atlantic off Spain, reveals its prominent dorsal fin which gives the species its name. Photo by S. Mizroch.

[1]Cetacean and Turtle Assessment Program. 1982. A characterization of marine mammals and turtles in the middle and North Atlantic areas of the U.S. outer continental shelf. Unpubl. manuscr., 450 p. plus appendices. Graduate School of Oceanography, Univ. R.I., Kingston, RI 02881. (Prep. for U.S. Dep. Inter. Bur. Land Manage. under Contract AA551-CT8-48.)



Head of a fin whale (lower jaw uppermost). The characteristic white plates on the front half of the right baleen plate row are clearly visible. Source: Historical Photography Collection, University of Washington Libraries.

areas (Mackintosh, 1942, 1966; Brown, 1962). Breeding areas have not yet been identified, so it is not clear how closely the statistical areas relate to breeding groups. For management purposes, however, the IWC considers each statistical area to represent one stock unit.

Life History and Ecology

Feeding

During the summer, most fin whales inhabit high latitudes and the cold eastern boundary currents where food production is high. They range mostly offshore and tend to be nomadic. They feed primarily on species of euphausiids, or krill, that congregate in dense shoals near the surface—notably *Euphausia superba* in the Antarctic; *E. pacifica*, *Thysanoessa inermis*, *T. longipes*, *T. spinifera* in the North Pacific; and *Meganyctiphanes norvegica* and *T. inermis* in the North Atlantic (Nemoto, 1959). In the Northern Hemisphere, fin whales often supplement their diet with small schooling fishes such as capelin, *Mallotus villosus*; anchovies, *Engraulis mordax*; and herring, *Clupea harengus*, and may even feed exclusively on fish in some areas (Jonsgård, 1966b; Mitchell, 1975; Kawamura, 1982).

In the autumn, fin whales migrate several thousand miles toward equatorial waters. They fast almost completely for several months during the winter, living off their fat stores.

Reproduction

The reproductive strategy of fin whales is closely integrated and synchronized with their annual feeding cycle. Their basic reproductive cycle is biennial, consisting of mating during the winter, birth of the large single precocial calf about a year later on the winter grounds, and weaning of the calf before the end of the following summer on the feeding grounds (Mackintosh and Wheeler, 1929; Laws, 1961).

Conception occurs over a 5-month period during the winter. Females are usually monestrous, but if they fail to conceive, they may, in rare cases, ovulate two or three times during one estrous cycle. A postpartum estrus is very rare. Mean length at birth is about 6 m (20 feet). Calves are weaned at an age of 7-11 months (Mackintosh and Wheeler, 1929; Best, 1966) when they have attained a mean body length of about 12 m (40 feet). Both male and female fin whales attain sexual maturity between 5 and 15 years of age (Lockyer, 1972). Mature females bear a calf every 2 or 3 years.

Natural Mortality

Important natural mortality factors are unknown. The fin whale is relatively free of ectoparasites. Except for kidney worms, *Crassicauda* sp., the few endoparasitic helminths that infest the fin whale usually appear to be nonpathogenic. Predation on adult fin whales by killer whales, *Orcinus orca*, is rare but may occur more often in younger animals.

Natural mortality rates are difficult to estimate, but appear to be about 4 percent/year in adults and perhaps somewhat greater in immature animals (Allen, 1980).

Exploitation and Population Size

History of Exploitation

Since fin whales, like most other balaenopterids, are fast swimmers and sink when killed, they were difficult for most whalers to catch, until modern whaling techniques using the explosive harpoon and the steam powered catcher boat were introduced in Norway in 1864. However, the Japanese perfected a technique in the mid-17th century in which whales were netted, attached to a float, and then hauled to shore for processing. With this method they were able to catch a number of fin and sei whales, but on a much smaller scale than possible with modern techniques (Tønnessen and Johnsen, 1982).

North Pacific

Although small numbers of fin whales were taken by the Japanese from around the middle of the 17th century, large numbers were taken only after modern whaling was introduced to Japan at the start of the 20th century. Catches of fin whales off Japan peaked at 1,040 in 1914, and then continued at levels ranging from 300 to 400/year until World War II. After World War II, catches began to decline, and ended entirely in 1975 when the IWC prohibited the capture of fin whales in that area.

Annual catches in the North Pacific

Ocean and Bering Sea ranged from 1,000 to 1,500 from the mid-1950's to the mid-1960's, after which they declined sharply and ended entirely in 1976, when catches were prohibited.

Catches of fin whales off the west coast of North America occurred mostly around California, British Columbia, and Alaska. Until 1955, most whaling occurred off British Columbia, after which catches off California began to increase. All fin whale catches off the west coast of North America had stopped by 1972.

North Atlantic

Modern whaling began off northern Norway in the late 1860's and spread to Iceland, the Faroe Islands, Newfoundland, Svalbard (Spitsbergen), and islands off the British coasts. In the three northernmost areas and the Hebrides, the initial target species was the blue whale, but as blue whale stocks were locally depleted, fin whale catches began to increase. In the other areas, fin whales dominated from the start. Annual fin whale catches fluctuated from around 300 to 1,300 from 1910 to 1970. By then, most catches came from Iceland, Newfoundland, and Labrador. In 1921, fin and sperm, *Physeter macrocephalus*, whaling began off the coast of Spain and Portugal. However, early catches were excessive in this region, and by 1927 local stocks had been depleted to a point of commercial extinction. In the 1950's, fin whaling resumed off northwestern Spain. By 1973, catches off the Canadian coasts had stopped, and currently fin whales are taken only off east and west Greenland, Iceland, and Spain.

Southern Hemisphere

Modern whaling in the Southern Hemisphere began in 1904, targetting initially on the humpback whale. By 1913, however, catches of blue and fin whales had overtaken humpback whale catches. Annual catches of fin whales ranged from around 2,000 to 5,000 from 1911 through 1924, but increased substantially after 1925 due to the introduction of the floating factory ship. While blue whale catches declined in the late 1930's, fin whale catches rose to over 28,000 in 1937 (Fig. 2). As the whaling industry developed again after World War II, fin whale catches rose and averaged around 25,000/year from 1953 to 1961. By 1962, catches began to decline and the industry began concentrating on the sei whale. By 1974, less than 1,000 fin whales were caught, and by 1976 the IWC had prohibited the capture of fin whales in the Southern Hemisphere.

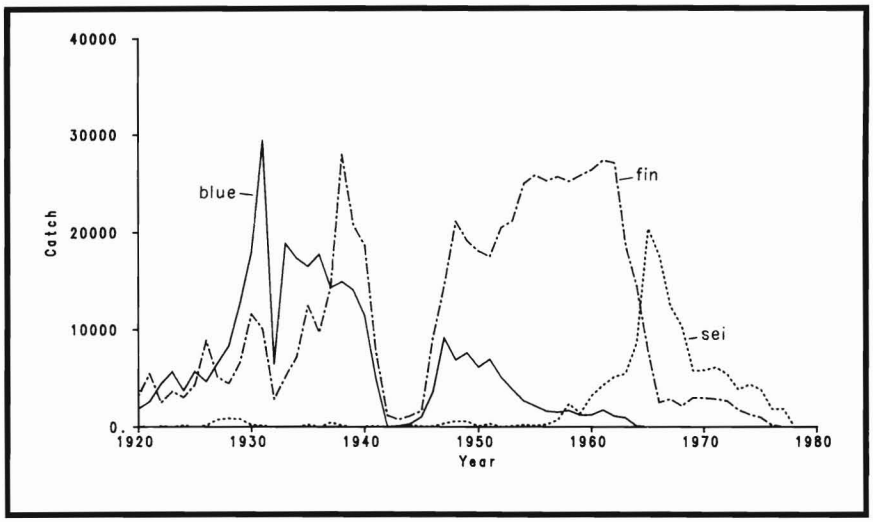


Figure 2.—Catch of fin, sei, and blue whales in the Antarctic, 1920-75 (from the Bureau of International Whaling Statistics).

Current and Pre-exploitation Stock Sizes

North Pacific

The North Pacific fin whale population is estimated to have ranged from 42,000-45,000 before whaling began to 14,620-18,630 currently (Ohsumi and Wada, 1974).

North Atlantic

Rorvik and Jonsgård (1981) presented rough estimates of pre-exploitation and current population sizes of fin whales in the northeast Atlantic (Table 1). Mitchell (1974) presents some estimates of current stock sizes in the northwest Atlantic, ranging from around 3,590 to 6,300.

Southern Hemisphere

Estimates of current and pre-exploitation population sizes of fin whales by IWC statistical area in the Antarctic (Table 2) are from Chapman (1976) and the Report of the IWC Scientific Committee (IWC, 1979).

Table 1.—Pre-exploitation and current population sizes of fin whales in the northeast Atlantic.

	Population estimate	
Area	Pre-exploitation	Current
North Norway	Several thousand	?
Western Norway and Faroe Islands	>2,700	Low hundreds
Spain, Portugal, and Scottish Islands	≥ 5,000	?
Denmark Strait	?	1,791-11,584

Table 2.—Estimates of pre-exploitation and current fin whale population sizes by IWC statistical area in the Antarctic.

	Population estimate	
Area	Pre-exploitation	Current
I (60°-119°W)	12,000	3,100
II (0°-59°W)	124,000	19,400
III (0°-69°E)	152,000	38,800
IV (70°-129°E)	60,000	8,400
V (130°E-170°W)	28,000	3,100
VI (120°-169°W)	24,000	12,400
Total	400,000	85,200

Management

Fin whales are currently taken only in the North Atlantic. A small aboriginal take is allowed in east Greenland, and the IWC has also set a quota for the west Greenland and Spain-Portugal-British Isles stocks. Research on stock estimation and biological parameters has continued on these and other North Atlantic stocks such as the Canadian east coast stock, which supported a fishery from 1965 to 1972.

Stocks of fin whales in the Southern Hemisphere and the North Pacific were classified as protected stocks in the mid-1970's. Additional information on these stocks has come mainly from sightings.

In the Southern Hemisphere and North Pacific, fin whale stocks were well below estimated pre-exploitation levels at the time fin whaling ceased. Recovery data for these stocks has been scarce since whaling ceased in the mid-1970's. What little sighting information is available has been difficult to interpret. These stocks probably remain at much less than half their pre-exploitation levels.

In the North Atlantic, pre-exploitation levels of fin whale stocks are poorly known. Most of the stocks experienced episodic catch histories, and only during the last 20 years have the catch histories been well documented and the biological and catch-effort data necessary for stock size estimation collected. Current stock size estimates are available for most of these stocks, although few of them are very reliable. Current research has concentrated on stock estimation and biology of the Canadian east coast stocks, the Icelandic stock, the west Greenland stock, and Spain-Portugal-British Isles stock. A major problem, addressed by several researchers, is the degree of intermingling between the various North Atlantic stocks. Indeed, the question is open as to whether or not there is just one biological stock which occurs as a patchy continuum.

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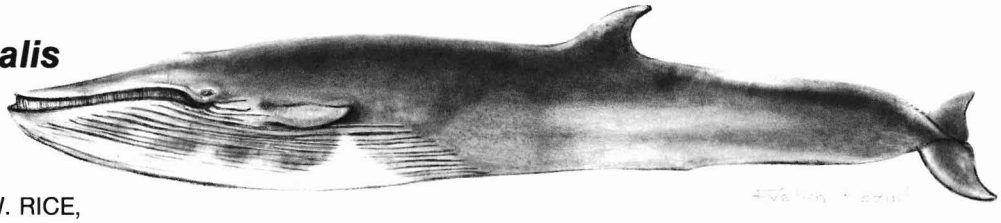
The Sei Whale, *Balaenoptera borealis*



SALLY A. MIZROCH, DALE W. RICE, and JEFFREY M. BREIWICK

Introduction

The sei whale, *Balaenoptera borealis* Lesson, 1828, can range in length up to 18.5 m (60 feet), which makes it the third largest whale in the family Balaenopteridae, following the blue, *B. musculus*, and fin, *B. physalus*, whales. Sei whales are gray with a variable white area extending from the chin to the umbilicus. All the balaenopterids have fringed baleen plates instead of teeth, and feed on swarms of small zooplankton which they capture in their baleen as water is filtered through. Sei whales, like other baleen whales, do not have a well-defined school or social structure, and are generally found in small groups or as solitary individuals (Tomilin, 1957).

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Distribution and Migration

Like most balaenopterids, sei whales are found in all oceans and migrate long distances north-south from high-latitude summer feeding grounds to lower latitude winter areas (Fig. 1). Populations north and south of the Equator are presumed to be separate, as their migration schedules are 6 months out of phase.

Unlike most other balaenopterids, sei whales tend to be restricted to more temperate waters, and consequently are generally found within a smaller range of latitudes. Although there have been sporadic reports of sei whales close to the ice edge, this is thought to be uncommon (Jonsgård, 1966).

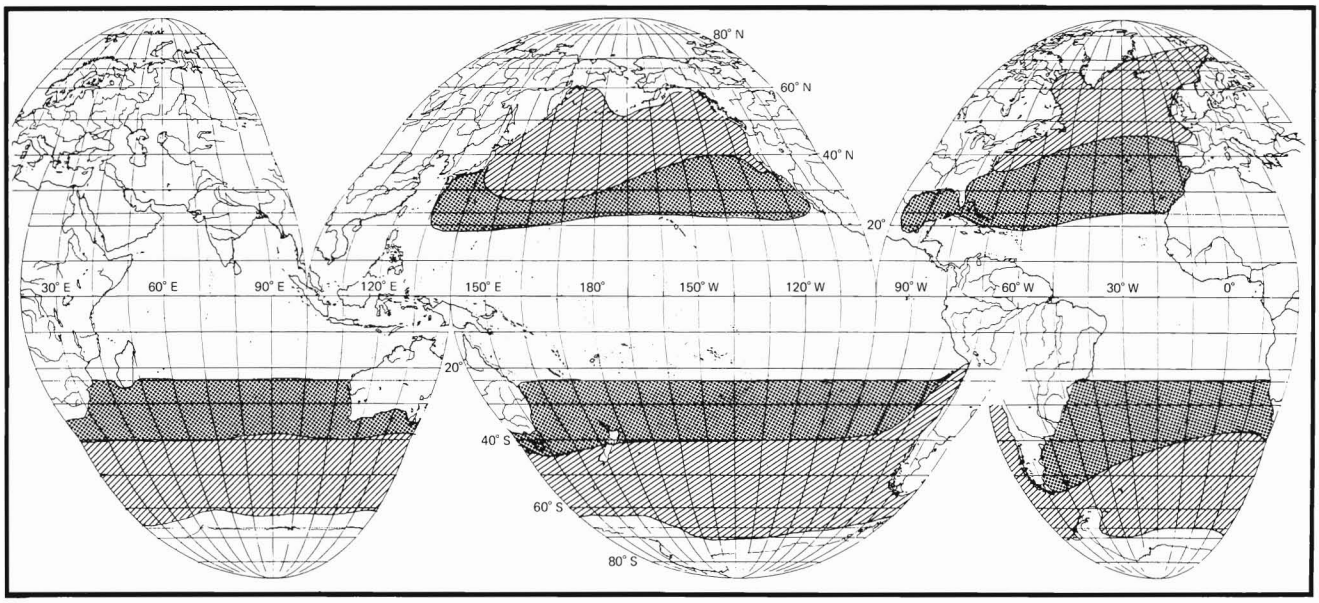
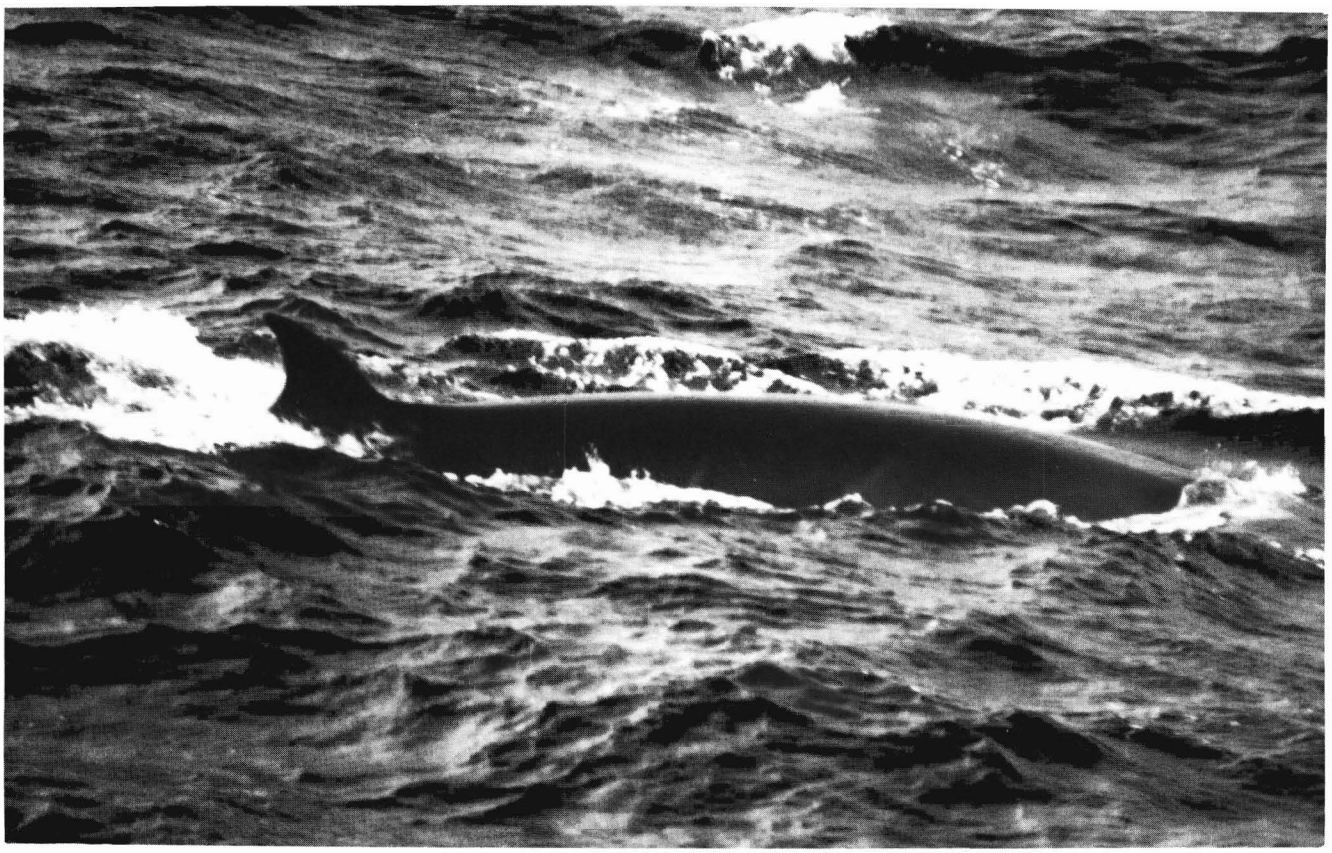


Figure 1.—Geographical distribution of the sei whale. Simple hatching indicates the summer feeding grounds. Stippling indicates distribution during autumn, winter, and spring; records are scarce during these seasons, and the distribution is to a large extent speculative.



A sei whale surfacing in Antarctic waters, showing the tall, sickle-shaped dorsal fin characteristic of this species. Photo by G. Joyce.

In the North Pacific, sei whales winter in waters from lat. 20°N to lat. 23°N, and summer from lat. 35°N to 40°N (with a few individuals found at lat. 50°N) (Masaki, 1976). In the Antarctic, the summer distribution (inferred from catch statistics) is mainly from lat. 40°S to 50°S, and the winter distribution is as yet unknown. In the North Atlantic, the northern (summer) limit is thought to be lat. 72°N, although little is known of southern (winter) distribution (Jonsgård, 1966).

There is evidence of differential migration by reproductive class, with pregnant females leading waves of migration both into and out of the feeding grounds (Matthews, 1938; Gambell, 1968). Pregnant females also tend to be found in higher latitudes (Masaki, 1976).

Although sei whale feeding areas are fairly well defined in all oceans, the location of wintering areas remains to a large degree a mystery, since sei whales migrate in the open ocean and are difficult to observe from shore.

Stock Identity

Since most hunting (and hence research, which is usually conducted in association with whaling activities) occurs on feeding rather than breeding grounds, the groupings observed are generally feeding rather than breeding aggregations. The relationship of breeding groups to feeding groups is poorly understood.

North Pacific

At one time the International Whaling Commission (IWC) considered the whales in the North Pacific as two stock units, but since the capture of sei whales was prohibited, the IWC considers only one stock unit for management purposes. Research indicates, however, that there may be at least three stocks found within this large area. Masaki (1976; 1977) suggests boundaries west of 175°W between 175°W and 155°W, and east of 155°W, based on mark-recapture studies, catch distribution, and differences in baleen plate morphology.

North Atlantic

The IWC recognizes the following stocks in the north Atlantic: Nova Scotia, Iceland-Denmark Strait, and northeast Atlantic. There is also an in-

dication, inferred from catches, mark recoveries, and migration patterns, of a separation between the Nova Scotia stock and the one off northeast Newfoundland and Labrador (Mitchell and Chapman, 1977). Schmidly (1981) speculates that a Gulf of Mexico/Caribbean stock exists, but this is questionable due to possible confusion with Bryde's whales, *Balaenoptera edeni* (Leatherwood and Reeves, 1983).

Southern Hemisphere

By convention, sei whales are considered to belong to six separate stocks in the Antarctic, based on the six IWC statistical areas developed using blue, fin, and humpback whale, *Megaptera novaeangliae*, data (Brown, 1962; Mackintosh, 1966). Mark-recovery data indicate links between sei whales in various areas, e.g., the Brazilian coast and the western half of Area II; the Natal coast of South Africa with the eastern half of Area III and the western half of Area IV; and the western and southeastern Australian coasts and Area IV (IWC, 1977). Other than this information, we know nothing of potential breeding areas in the Southern Hemisphere, and therefore cannot delineate breeding stocks. Consequently, sei whales are managed separately by IWC area.

Life History and Ecology

Feeding

During the summer, sei whales inhabit much the same range as fin whales in the higher latitudes and the cold currents on the eastern sides of the oceans, where food production is high. In general they range even farther offshore than fin whales, and tend to be nomadic. Sei whales specialize on copepods when available (mainly *Calanus tonsus*, *C. simillimus*, and *Drepanopus pectinatus* in the Antarctic; *C. cristatus*, *C. plumchrus*, and *C. pacificus* in the North Pacific; *C. finmarchicus* in the North Atlantic) (Nemoto, 1959; Kawamura, 1973, 1974). They are more euryphagous than fin whales, however, and if copepods are absent, they feed on euphausiids, or krill, that congregate in dense shoals near the surface—notably *Euphausia superba* and *E. vallentini* in the Antarctic; *E. pacifica*, *Thysanoessa inermis*, *T. longipes*, and *T. spinifera* in the North Pacific; and *Meganyctiphanes norvegica* and *T. inermis* in the North Atlantic. In some parts of the Northern Hemisphere, they also feed extensively on small schooling fishes such as anchovies, *Engraulis mordax*; sauries, *Cololabis saira*; and jack mackerel, *Trachurus symmetricus*.

In autumn, sei whales migrate several thousand miles toward equatorial waters. During the winter they eat very little or fast for several months, living off their fat reserves (Mackintosh, 1965).

Reproduction

The reproductive strategy of sei whales is similar to that of most other balaenopterid whales. The mating season covers about 5 months during the winter. Most females ovulate only once, but if they do not conceive, they may ovulate two or three times during one season. The single calf is born after a gestation period of about 1 year, when it is about 4.4 m (14.5 feet) long. The calves are weaned on the summer feeding grounds when they are 6-9 months old, and have attained a length of about 9.0 m (30 feet). Both sexes attain sexual maturity between 5 and 15 years of age. Adult females bear a calf every 2 or 3 years. (Gambell, 1968; Masaki, 1976; Rice, 1977; Lockyer and Martin, 1983).

Natural Mortality

Important natural mortality factors are unknown. The sei whale is usually relatively free of ectoparasites, but is very often heavily infected with endoparasitic helminths; presumably this is because its diet is more catholic than that of the fin or blue whale (Rice, 1977). Some of these endoparasitic worms are frequently pathogenic, affecting especially the liver and kidneys. A disease of unknown origin affects 7 percent of the sei whales off California, and causes them to shed their baleen plates; this greatly impairs their feeding ability. Predation on sei whales by killer whales, *Orcinus orca*, appears to be rare. Natural mortality rates are difficult to estimate, but appear to be about 7.5 percent per year in adults, perhaps somewhat greater in immature animals (Allen, 1980).

Exploitation and Population Size

History of Exploitation

The earliest exploitation of sei whales likely occurred in waters off northern Japan, starting around the middle of the 17th century. The Japanese method of capturing the nonbuoyant, fast-swimming rorquals (including sei, fin, and humpback whales) involved netting the animal before killing it, and then towing it to shore for processing for human consumption. Until the introduction of modern whaling in Norway in 1864, the Japanese were the only whaling nation that could effectively capture rorquals (Tønnessen and Johnsen, 1982).

North Pacific

Since modern whaling was introduced in Japan at the beginning of the 20th century, the sei whale has accounted for a large proportion of the total whale catch in Japanese waters. Catches ranged from about 300 to 600 per year from 1911 through 1955, and rose to 1,340 in 1959, remaining at high levels until a large drop in 1971. Sei whales off Japan were protected after 1975. Catches of sei whales by Japanese and Soviet fleets in the North Pacific and Bering Sea jumped from 260 in 1962 to over 4,500 in 1968 and 1969, after which catches declined rapidly. Whaling ceased after 1975 when this stock of sei whales was protected.

Except for harvests off British Columbia in the late 1950's through the mid-1960's, sei whale catches off the coasts of North America were fairly insignificant compared to fin and humpback whale catches. Catches in this region rose from 39 in 1958 to over 600 in 1964 and 1965, after

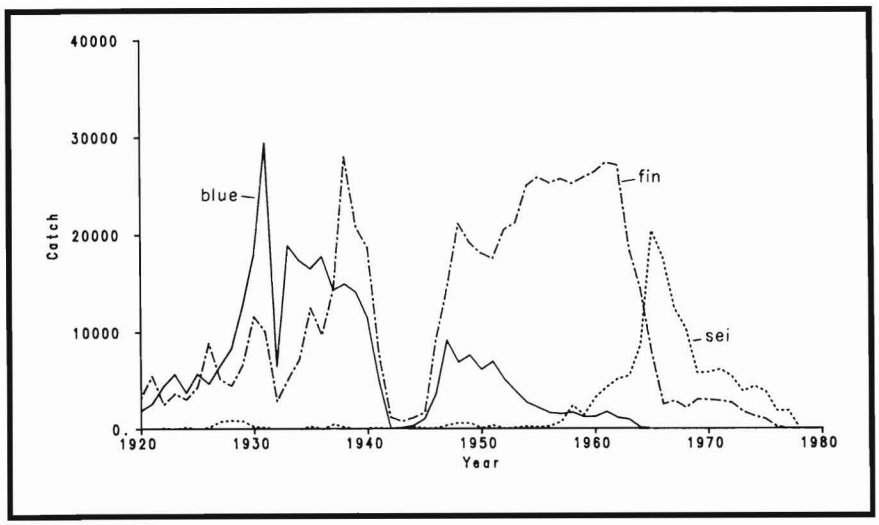


Figure 2.—Catch of sei, fin, and blue whales in the Antarctic, 1920-75 (from the Bureau of International Whaling Statistics).

which the catch dropped to 14 by 1968. Catch of sei whales in this region stopped entirely after 1971.

North Atlantic

When modern whaling began in Norway in the late 1800's, blue whales and then fin whales were the preferred species, although a few sei whales were taken late each season after the larger rorquals had migrated out of the area. As blue and fin whale stocks declined, however, sei whale catches gained in importance. In the early years, most sei whale catches occurred in waters off Norway and Iceland, although substantial catches were taken off Nova Scotia from 1967 to 1972. Currently, the Icelandic stock is the only one harvested in the North Atlantic.

Southern Hemisphere

Antarctic exploitation began in 1904, but in the early years whalers preferred humpback, blue, and fin whales. As stocks of these other whales declined, catches of sei whales began to increase, rising rapidly in the late 1950's and early 1960's (Fig. 2). Sei whale catches peaked at over 20,000 in 1964, declining rapidly to under 2,000 by 1976, and stopping entirely after sei whales were protected in 1977.

Current and Pre-exploitation Stock Sizes

North Pacific

Ohsumi and Fukuda (1975) estimated that the pre-exploitation population of sei whales in the North Pacific was about 45,000 whales, with a current (1967) range of from 22,000 to 37,000.

North Atlantic

Mitchell (1974) estimated the current (1966) population of sei whales to be 1,856 off Nova Scotia and 828 in the Labrador Sea. According to the Cetacean and Turtle Assessment Program[1], there may be as many as 2,273 sei whales in U.S. Atlantic coastal waters.

Southern Hemisphere

Estimates of early and current sei whale population sizes (Table 1) were reported at the IWC Special Meeting on Southern Hemisphere Sei Whales (IWC, 1980).

Management

Sei whales have been especially difficult to assess as evidenced by the number of special meetings on Southern Hemisphere sei whales held by the IWC since the early 1970's. During the 1960's and early 1970's, it was thought that Southern Hemisphere sei whales were at or near their unexploited levels during the late 1950's. Later evidence suggested that sei

Table 1.—Estimates of early and current sei whale population sizes by IWC statistical area in the Antarctic.

Area	Population est. 1930	Population est. 1979
I	6,900	1,600
II		
III	22,400	1,100-1,200
IV	14,700	5,700
V	11,200-12,300	1,100-2,900
VI	7,900-8,100	300-360

[1]Cetacean and Turtle Assessment Program. 1982. A characterization of marine mammals and turtles in the mid- and north Atlantic areas of the U.S. outer continental shelf. Unpubl. manuscr., 450 p. Graduate School Oceanogr., Univ. Rhode Isl., Kingston, RI 02881. (Prep. for U.S. Dep. Int., Bur. Land Manage. under Contr. AA551-CT8-48.)

whales were increasing prior to the 1950's, and that they were at their "initial" size early in this century. However, this later evidence has also been questioned so that the true situation is unclear. The basic indices of abundance used to assess sei whales have been sightings per unit of effort and catch per unit of effort. Often, these two indices have resulted in substantially different estimates for the same stock area. In the Southern Hemisphere, sei whale catches peaked during the mid-1960's as preference shifted from fin to sei whales and then dropped to low levels during the 1970's. In the North Pacific, there have been no sei whale catches since 1976; Iceland, however, still takes some sei whales in the North Atlantic.

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The Humpback Whale, *Megaptera novaeangliae*

JAMES H. JOHNSON and ALLEN A. WOLMAN

Introduction

The humpback whale, *Megaptera novaeangliae* (Borowski, 1781), is a medium-sized baleen whale of the Balaenopteridae family, which includes all the rorquals and is found in all oceans of the world (Fig. 1). At maturity, the humpback reaches a length of about 15.6 m (51 feet) and weighs about 34 metric tons (t). The body is relatively short and rotund and is characterized by exceptionally long flippers. The flippers, which are one-fourth to one-third the total body length, are knobbed on the anterior edges. The span of its symmetrical flukes is one-third the total body length.

Although generally recognized by a pear-shaped blow about 1.8 m (6 feet) high, it is most specifically identified as it breaches, displaying its unique body contours. The whale may occasionally leap clear of the water and spin partially as it falls with a resounding smack. Sometimes it rolls on the surface, slapping the water with its flukes or flippers. Occasionally it holds one flipper in the air while lying on one side or both.

The humpback has a rich, varied vocabulary and a wide range through the tonal scale. Its "song," a long series of varied phrases repeated in sequence over intervals of more than a half hour, is varied slightly from year to year, and may be identified in a group over a number of years. Different stocks of whales have regional "dialects."

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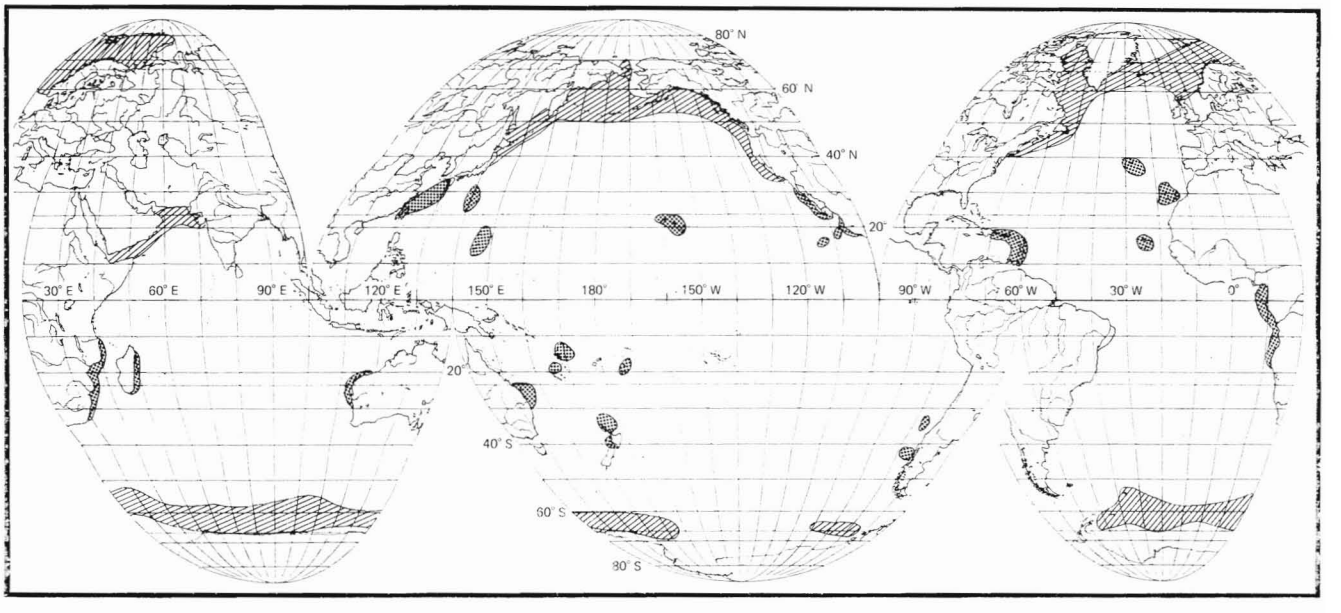

Figure 1.—Geographical distribution of the humpback whale. Simple hatching indicates the summer feeding grounds. Stippling indicates the winter grounds. Migration routes between summer and winter grounds are not shown because they are poorly known.

Like most species of baleen whales, the humpback spends the summer on high-latitude feeding grounds and migrates long distances to low-latitude winter grounds (Fig. 1) where mating and calving take place. Since the reproductive cycles of the Northern and Southern Hemisphere stocks are 6 months out of phase, whales from the two hemispheres do not interbreed. The species is divided into three reproductively and geographically isolated populations, one each in the North Pacific, the North Atlantic, and the Southern Ocean.

During the winter, the humpback is mostly confined to shallow waters along coasts and around oceanic islands. This restriction further divides each of the three major populations into several largely discrete breeding stocks which may broadly overlap on their summer grounds, except for the western North Atlantic, where the situation is opposite. Its coastal habitat has made the humpback whale one of the most vulnerable species to modern whaling methods. The history of humpback whaling worldwide has been one of repeated episodes of overexploitation which result in depletion of the local stocks.

Although humpbacks are now protected from commercial whaling by the International Whaling Commission (IWC), the wintering grounds of some stocks lie within the territorial waters of nonmember nations. A few animals are taken each year in aboriginal hunting. Further, as a coastal species they are increasingly subject to nearshore pollution, boat traffic, mineral and industrial development, and other human activity.

Distribution and Migration

Humpback whales are found in all seas between the Arctic and Antarctic, with local changes in distribution according to fairly distinct migration patterns. The Northern and Southern Hemisphere populations are regarded as separate. They do not go into the polar pack ice zones (Chittleborough, 1965; Dawbin, 1966).

The first documented information on migratory movement of humpback whales came from recovery of whales marked with discovery-type marks. Migration information on humpbacks and other cetaceans is now coming from photographic identification techniques that use distinctive scars, fin shapes, external growths, and patterns of pigmentation (Glockner-Ferrari, 1982; Katona et al., 1982; Payne, 1972; Bigg et al.[1]; Jurasz and Jurasz[2])

North Pacific

Humpback whales range widely across the North Pacific during the summer. On the Asian side they range south to the Sanriku coast of Honshu Island, Japan, and on the U.S. side they range south to about Point Conception, Calif. They range north through most of the Bering Sea, and a few enter the Chukchi Sea.

There are three major wintering areas for humpbacks in the North Pacific:

1) The Mexican stock ranges along the west coast of Baja California, chiefly from Isla Cedros south to Cabo San Lucas, and around the cape at least as far north as Isla San Jose in the Gulf of California; along the mainland coast from southern Sonora to Jalisco; and around the far offshore Islas Revillagigedo (Rice[3]).

A humpback whale on its wintering grounds near Maui, Hawaii. Note the extremely long flippers. Photo by J. Hudnall.

[1]Bigg, M. A., I. B. MacAskie, and G. Ellis. 1976. Abundance and movements of killer whales off Vancouver Island with comments on management. Unpubl. manuscr., 19 p. Arct. Biol. Sta., Dep. Fish. Oceans, 555 St. Pierre Blvd., Ste. Anne de Bellevue, Quebec, H9X 3L6, Can.

[2]Jurasz, C. M., and V. Jurasz. 1977. Censusing of humpback whales, *Megaptera novaeangliae*, by body characteristics. (Abstr.) *In* Proceedings of the 2nd Conference on the Biology of Marine Mammals, San Diego, California, 12-15 December 1977, p. 54. (Avail. from first author, Sea Search, P.O. Box 93, Auke Bay, AK 99821.)

[3]Rice, D. W. 1966. Status of humpback whales on their wintering grounds in the southeastern North Pacific. Unpubl. manuscr., 11 p. Natl. Mar. Mammal Lab., Northwest Alaska Fish. Cent., NMFS, NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115.

2) The Hawaiian stock ranges around all the main Hawaiian Islands from Kauai to Hawaii (Wolman and Jurasz, 1977; Baker and Herman, 1981).

3) The Asian stock ranges around the Mariana Islands, the Bonin Islands, the Ryukyu Islands, and Taiwan (Nishiwaki, 1959; Townsend, 1935).

Recovery of discovery-type marks prior to protection of humpbacks from commercial whaling demonstrated migratory movement in the western North Pacific as follows (Ivashin and Rovnin, 1967; Ohsumi and Masaki, 1975):

Winter ground	*Summer ground*	*Number of recoveries*
Ryukyu Islands	E. Bering Sea	5
Ryukyu Islands	S. of E. Aleutians	1
Bonin Islands	N.E. Honshu	1
Bonin Islands	E. Bering Sea	2

In the eastern North Pacific, a number of linkages have been made of individual whales between summer feeding grounds and winter calving and breeding grounds, based on photograph matches (Baker et al.[4]). The picture emerging appears to be one of discrete regional feeding grounds off Alaska, with thus far no detectable exchange between regions, but a general mixing together on the winter grounds of animals from different feeding areas. In addition, a small degree of yearly exchange between Hawaii and Baja California winter grounds has been noted (Darling and Jurasz, 1983). While humpbacks may range widely within a given feeding region, e.g., southeast Alaska (Baker et al.[5]), site fidelity is evidenced by individual whales that returned to southeastern Alaska's Glacier Bay for at least 12 years (Jurasz and Palmer[6]).

North Atlantic

In the eastern North Atlantic, humpbacks are found in the summer from Iceland, Scotland, Spitsbergen, and Norway, to Novaya Zemlya in the Barents Sea. These animals winter as far south as the Cape Verde Islands, off west Africa (Kellogg, 1929).

In the western North Atlantic, summer feeding grounds of humpbacks are found in the Denmark Strait west of Iceland, off southwestern Greenland, southern Labrador, eastern Newfoundland, in the Gulf of St. Lawrence, and in the Gulf of Maine/Nova Scotia.

During winter, humpbacks inhabit the relatively shallow waters of islands and offshore banks along the Antillean chain in the West Indies, with large concentrations on Silver and Navidad Banks, north of the Dominican Republic, and along the coast of Puerto Rico (Balcomb and Nichols, 1982; Whitehead et al., 1982).

As in the North Pacific, humpbacks tend to return each year to the same summer feeding grounds (Katona et al., 1982; Mitchell, 1974; Whitehead, 1982; Cetacean and Turtle Assessment Program[7]; Perkins et al.[8]). Recently, humpbacks from both the Gulf of Maine and Newfoundland have been found in the Gulf of St. Lawrence (Whitehead[9]). Also analogous to North Pacific migratory patterns, animals from feeding grounds off New England, Canada, west Greenland, and Iceland all intermingle in winter on breeding/calving grounds in the West Indies (Katona et al., 1982; Martin et al.[10]).

The only recent sightings in the Gulf of Mexico are two in the north central area in 1952 and 1957, and one off Tampa Bay in 1962 (Schmidley, 1981).

Northern Indian Ocean

In the northern part of the Arabian Sea, humpbacks in numbers from tens to hundreds were reported by Slijper et al. (1964) during both winter and summer months. It is most likely a separate stock.

Southern Hemisphere

In the Southern Hemisphere, humpbacks concentrate every winter in six distinct breeding grounds: Along the tropical western sides of each continent, to a lesser extent along eastern coastlines, and around island groups. In spring, the whales move more or less directly south from the breeding grounds, resulting in six general feeding areas in the Antarctic. Summer concentrations occur around South Georgia and the South Shetland Islands, and south of the west and east coasts of Africa, Australia, and South America (Dawbin, 1966). Reports of a number of mark recoveries (Brown, 1957; Dawbin, 1956, 1966) indicate that there is at least some intermingling on the feeding grounds of animals from different breeding areas.

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[4]Baker, C. S., L. M. Herman, B. G. Bays, and W. F. Stifel. 1982. The impact of vessel traffic on the behavior of humpback whales in southeast Alaska. Unpubl. manuscr., 78 p. Kewalo Basin Mar. Mammal Lab., Univ. Hawaii, 1129 Ala Moana, Honolulu, HI 96814. Prep. for Nat. Mar. Mammal Lab., NMFS, NOAA, Seattle, WA 98115, under Contr. 81-ABC-00114.

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[7]Cetacean and Turtle Assessment Program. 1982. A characterization of marine mammals and turtles in the mid- and North Atlantic areas of the U.S. outer continental shelf. Unpubl. manuscr., 450 p. Graduate School Oceanogr., Univ. Rhode Island, Kingston, RI 02881. (Prep. for U.S. Dep. Inter., Bur. Land Manage., under Contr. AA551-CT8-48.)

[8]Perkins, J. S., K. C. Balcomb, III, and G. Nichols, Jr. 1983. West Greenland humpbacks, update to 1983. (Abstr.) *In* Proceedings of the 5th Biennial Conference on the Biology of Marine Mammal, November 27-December 1, 1983, Boston, Massachusetts, p. 80. (Avail. from first author, Ocean Res. Educ. Soc., 19 Harbor Loop, Gloucester, MA 01930.)

[9]H. Whitehead, Newfoundland Inst. for Cold Ocean Science, Mem. Univ. Newfoundland, St. John's A1B 3X7. Pers. commun.

[10]Martin, A. R., S. Katona, D. Mattila, D. Hembree, and T. Waters. 1984. Humpback whales from eastern and western North Atlantic feeding grounds share a common breeding area. Unpubl. manusc. Avail. from S. Katona, Coll. Atl., Bar Harbor, ME 04609.

A group of eight humpback whales engage in coordinated feeding behavior in Frederick Sound, southeastern Alaska. Photo by C. D'Vincent.

Life History and Ecology

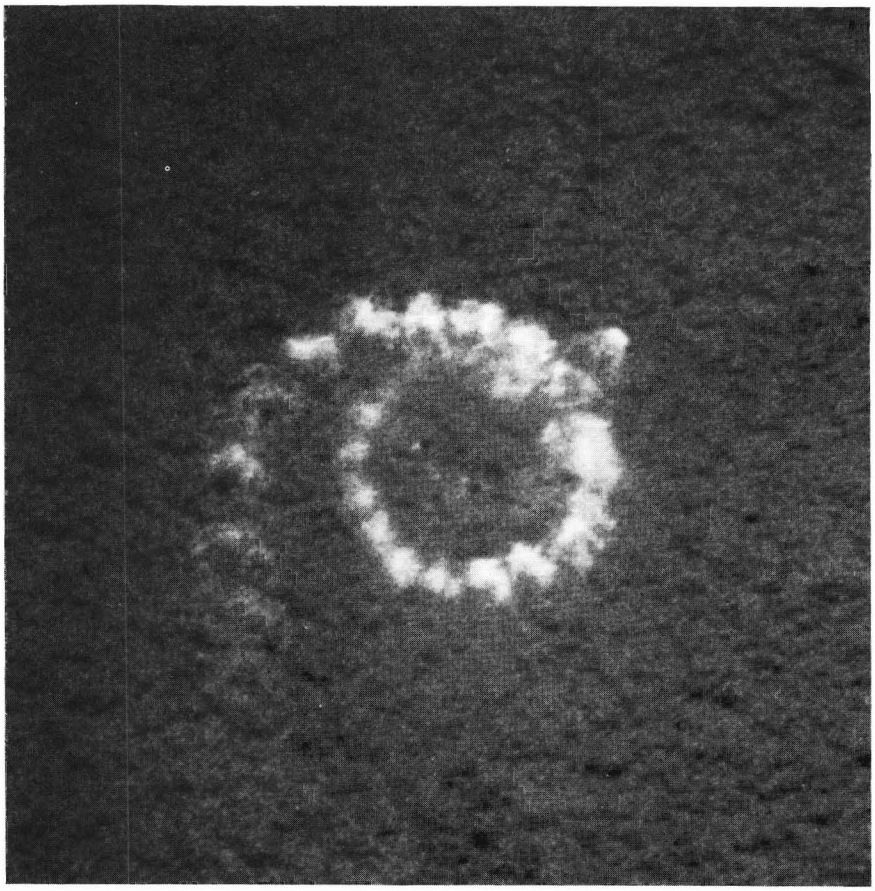
Feeding

The diet of humpbacks in the Northern Hemisphere consists of both benthic and pelagic-layer organisms of the coastal zone (Tomilin, 1957). These include krill (euphausiids), copepods and other crustacean zooplankton; herring, Clupeidae; sand lance, *Ammodytes* sp.; capelin, *Mallotus villosus*; juvenile salmonids, *Oncorhynchus* spp.; Arctic cod, *Boreogadus saida*; walleye pollock, *Theragra chalcogramma*; pollock, *Pollachius virens*; and pteropod and some cephalopod mollusks. In the Antarctic the diet is restricted almost exclusively to krill (Nemoto, 1959; Gaskin, 1972).

Humpback distributions are heavily clumped in areas of food abundance. On the Newfoundland coast, for example, spawning capelin coincide with the humpback migratory return, while off New England and west Greenland, sand lance and capelin are the major prey items, with krill and other plankton playing a minor part (Kapel, 1979; Perkins et al., footnote 7). In Alaskan waters, the main prey appear to be krill, herring, and capelin (Bryant et al., 1981; Dolphin and McSweeney, 1983).

Humpbacks feed either at or below the surface. Subsurface feeding (although probably more often employed than surface feeding, at least in the Northern Hemisphere) is unobservable after the whale dives and thus has not been described. Surface feeding, on the other hand, is observable and exciting to behold. The techniques are numerous, and most may be used by a single whale or by a number of animals feeding together. Techniques by which the whale remains largely at the surface include horizontal lunging, circular swimming, and thrashing (Edel and Winn, 1978; Watkins and Schevill, 1979), "flick feeding," in which the fluke is used to stun or concentrate prey (Jurasz and Jurasz, 1979), and a similar technique, termed "inside loop," also using fluke slaps (Hain et al., 1982). The humpback varies these techniques as it disappears for brief periods beneath the surface and probably does not dive very deep.

Bubble feeding is generally considered the most intriguing feeding behavior of all, and was first described by Ingebrigtsen (1929). The submerged whale releases a single large bubble or clouds of bubbles, or bubbles in patterns ranging from a



Aerial view of a bubble-net blown by a feeding humpback whale in Stephens Passage, southeastern Alaska. The whale is beginning to surface just outside the upper right edge of the spiral. Photo by J. M. Olsen.

line to partial or complete circles, with or without "tails." In each case the whale comes up open-mouthed through the circle or clouds of bubbles, which apparently concentrate or corral schools of zooplankton or small fishes. Presumably, the feeding technique or variation used is dictated by the available prey species and density. D'Vincent et al.[11] noted evidence for coordinated feeding behavior.

Like other rorquals, humpbacks fast mainly, if not entirely, during the winter and feed during the summer. A few spend the winter in Alaskan waters and presumably continue feeding. According to Chittleborough (1965), from four to five times more oil was recovered from northbound humpbacks in the southern ocean than from those on their way south.

Reproduction and Recruitment

Both male and female humpbacks begin to mature sexually at about 9 years of age. Chittleborough (1965), Nishiwaki (1959), and others placed sexual maturity at only 5 years, but their determinations erroneously assumed the laying down of two laminae per year in the ear plug, instead of only one (Roe, 1967).

Births occur between January and March in the Northern Hemisphere. Gestation lasts about 12 months, and lactation close to a year (Rice, 1967). Chittleborough (1958) reported that, while 8.5 percent of the sexually mature female humpbacks he examined were both pregnant and lactating and so must have mated soon after giving birth, most wait 1 or more years between giving birth and becoming pregnant again. Glockner-Ferrari[12] reported three females with newborn calves in consecutive years; one was seen with a new calf 4 years in a row. However, the usual reproductive cycle for humpbacks appears to be 2 or more years.

Rate of recruitment to maturity may range from 3.9 to 11.8 percent for the western North Atlantic stock (Whitehead, 1982), and from 10.3 to 13.1 percent for the Antarctic Group IV population (Chittleborough, 1965), although Chittleborough's figures are uncorrected for the aging problem.

Natural Mortality

Sharks and killer whales, *Orcinus orca*, may be the greatest causes of natural mortality among calves (Gaskin, 1972). Gilmore (1959) reported seeing a humpback missing one fluke but which swam normally. The killer whale is the only known marine predator which could inflict such damage, and probably only to a young humpback.

Dead humpbacks are occasionally beached, and because they are highly eurythermal animals and may frequent the edge of ice fields, one is sometimes trapped in the ice (Tomilin, 1957). Various parasites and commensals infest humpback

[11]D'Vincent, C. G., R. M. Nilson, and R. E. Hanna. 1984. Vocalization and coordinated feeding behavior of the humpback whale (*Megaptera novaeangliae*) in southeastern Alaska. Unpubl. manuscr. Ocean Res. Under Sail, P.O. Box 1167, Monterey, CA 93942.

[12]D. A. Glockner-Ferrari, P.O. Box 1539, Lahaina, Maui, Hawaii 96767-1539. Pers. commun.

whales, but they rarely appear to have a pathologically debilitating effect on the hosts (Matthews, 1978; Tomilin, 1957).

Humpbacks are subject to skin damage caused by lampreys and by various species of the small tropical shark *Isistius* sp. (Jones, 1971). Competing male humpbacks on the breeding grounds also have been observed inflicting cutting wounds on one another, using their flukes.

Exploitation and Population Size

History of Exploitation

Eastern North Atlantic

Modern whaling began in Norway in the 1860's, spread to Iceland, the Faroe Islands and Spitsbergen, and reached the British Isles in 1903. From 1868 to 1955, at least 1,579 humpbacks were taken in the eastern North Atlantic and Arctic. An unknown number were taken in the Faroe Islands between 1894 and 1909. Commercial whaling for humpbacks in this area ended when the IWC, with no objections, listed the stock as protected in 1955. From 1955 to 1967, 11 animals were taken for local consumption in Norway, the Faroe Islands, and Madiera (Brown, 1976; Committee for Whaling Statistics, 1930-80). No data are available from Spain or Portugal.

Western North Atlantic

From 1886 to 1976, 522 humpbacks were taken off west Greenland (Kapel, 1979), and 1,397 were caught in Nova Scotia, Newfoundland, and Labrador waters from 1903 to 1970 (Mitchell, 1974). In addition, about 170 were taken in the West Indies in 1925 and 1926 (Committee for Whaling Statistics, 1930-80) and about 53 from the Bequia area in the Windward Islands between 1950 and 1982 (Price, In press). A subsistence catch exceeding the IWC-recommended 10 per year (10 in 1977; 21 in 1978; 14 in 1979; 13 in 1980; 11 in 1981; 12 in 1982) has been taken in Greenland in recent years (IWC, 1980; In press).

North Pacific

Aboriginal whaling and early commercial hunting on the high seas, using hand harpoons, took an unknown number of humpbacks prior to 1900. From 1905 to 1960, about 23,000 humpbacks were killed in modern-style whaling, which began in 1889 in the western Pacific and in 1905 in the eastern Pacific. From 1960 to 1965, over 5,000 were killed, reducing the population to about 1,000 (Rice, 1978).

Southern Hemisphere

Before becoming one of the mainstays of the modern whaling industry, a large population of humpbacks inhabited the Southern Hemisphere. Between 1904 and 1966, when commercial humpback whaling was banned, over 68,000 animals were killed in the Antarctic (Bonner, 1982). Chittleborough (1965) reported 18,180 captures between 1949 and 1962. In 1978, the last year of aboriginal whaling in Tonga (western South Pacific), 12 animals, including 3 calves, were taken.

Current and Initial Stock Sizes

From a pre-expoitation world population of over 120,000, only about 10,000 remain.

Eastern North Atlantic

Although population data are lacking, the eastern North Atlantic humpback population is probably no larger than a few hundred whales.

Western North Atlantic

The current estimate of the western North Atlantic population is 5,773 ± 516 (IWC, In press). Whitehead (1982) estimates between 1,535 and 2,720 humpbacks summering in the area of northeast Newfoundland and southern Labrador; Perkins et al. (footnote 7) estimate a present west Greenland stock of 282 animals, based on photoidentification of 143 individuals.

Mitchell and Reeves (1983) recalculated catch figures for the region and now estimate an original population size of at least 4,400 whales in 1865, and an even larger one before whaling began in the West Indies and Gulf of St. Lawrence during the second half of the 18th century.

North Pacific

The pre-1905 humpback population of the North Pacific was probably about 15,000 (Rice, 1978), and is now about 1,200. Of these, Rice and Wolman[13] estimate that 550-790 winter in Hawaiian waters. Most of the remainder winter off Mexico since probably fewer than 100 humpbacks now migrate to the Asian winter grounds.

Southern Hemisphere

In the Southern Hemisphere, the humpback has gone from a pre-exploitation population of about 100,000 to recent estimates ranging from about 2,500 (Masaki[14]) to 3,000 (Gambell, 1976).

Management

The IWC declared a ban on commercial killing of humpback whales in the North Atlantic in 1955, the North Pacific in 1965, and in the Southern Hemisphere in 1966. An annual aboriginal subsistence harvest is allowed in Greenland, as noted. Otherwise, protection of the species is nearly total.

Because the humpback whale inhabits shallow coastal areas, it is increasingly exposed to human activity. Environmental problems for coastal-dwelling whales either already exist or can be expected to result from offshore petroleum exploration and production, ocean dumping, coastal logging, mining and manufacturing, fishing, resort development, and increasing pleasure boat and cruise ship

[13]Rice, D. W., and A. A. Wolman. 1984. Census of humpback whales wintering around the Hawaiian Islands, 1976-1979. Unpubl. manuscr. 22 p. Nat. Mar. Mammal Lab., Northwest Alaska Fish. Cent., NMFS NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115.

[14]Masaki, Y. 1975. Japanese pelagic whaling and sighting in the Antarctic 1974/75. Unpubl. manuscr., Nansei Reg. Fish. Res. Lab., Fish. Agency Jpn., Ohno-cho, Saeki-gun, Hiroshima-ken, 739-04, Jpn.

traffic. Each activity has potential for either direct, confrontational disturbance of whales or an indirect affect through damage to habitat or, in some cases, both.

Paradoxically, the need for such protection of whales in the United States grew partly out of increased public interest in and concern for marine mammals and the desire to see them in the wild. To protect the humpback whale from a growing harassment problem in Hawaiian waters—a problem mainly related to whale watching, though not limited to it—the National Marine Fisheries Service (NMFS) in 1979 augmented its enforcement efforts in that area and also successfully increased public awareness of the consequences of disturbance. A National Oceanic and Atmospheric Administration (NOAA) proposal to establish a humpback whale sanctuary in Hawaii is currently under study by the various State and Federal agencies and public interest groups that would be involved or affected by its establishment.

Environmentalists have urged establishment of another such sanctuary in Alaska waters, which they maintain would provide additional needed protection to a major portion of the North Pacific humpback population on both its winter and summer grounds. Opponents of the proposals in both states argue that the Marine Mammal Protection Act and the Endangered Species Act provide adequate protection for the humpback whale, and that sanctuaries would only impose additional and unnecessarily burdensome regulations on fishermen and other local interest groups.

In Glacier Bay National Park in southeast Alaska, the number of vessel entries, their date of entry, and length of stay are all regulated, except for commercial fishing boats, under a National Park Service permit system to achieve compatibility between the humpback whales that feed there and tourism. The system, which includes enforcement of vessel traffic regulations, was established following a dramatic drop in 1978 in the number of whales occupying Glacier Bay.

In the West Indies, the Dominican Republic is considering the establishment of a humpback whale sanctuary on Silver Bank, although territorial rights to the bank itself are in dispute. No similar protective proposals for humpbacks are known to be under consideration in the Southern Hemisphere.

The current world population of humpback whales, about 10,000 animals, is probably only about 8 percent of its estimated pre-exploitation size. The Southern Hemisphere population, at an estimated 3.7 percent of its former size, is the most depleted. The North Pacific population is currently estimated to be 8 percent of its former size, and the North Atlantic population at about 50 percent of its former size. Stocks closest to extinction are those in the eastern North Atlantic and western North Pacific. Due to uncertainties of population sizes at the time commercial whaling of humpbacks ended, plus questionable validity of past census techniques, it cannot yet be shown with certainty that humpback populations are recovering. Although recovery probably is taking place, it is doing so at a rate slower than expected.

Habitat Protection

Degradation of coastal habitat results from numerous human activities, including landfill, dredging, construction, drilling, mining, logging, and from toxic chemical pollution, the last being generally viewed as one of the most widespread and potentially serious threats faced by coastal whales and their would-be protectors. Since whales are long-lived and at or near the top of the food chain, questions arise about cumulative effects and what constitutes threatening levels of toxic contamination (DeLong et al., 1973; Gaskin, 1982; Sergeant[15]). To date, most of those questions remain unanswered. Regulatory protection of coastal waters in the United States is provided under the Federal Marine Protection, Research and Sanctuaries Act; National Environmental Policy Act, Clean Water Act, and River and Harbor Act, among others, and their state counterparts. Government agencies regularly involved in regulation of activities affecting coastal habitat include the U.S. Army Corps of Engineers, Environmental Protection Agency, Forest Service, Coast Guard, and advisory agencies such as the NMFS, U.S. Fish and Wildlife Service, and their state counterparts.

Accidental Mortality

Humpback whales are sometimes wounded and killed by being hit by ships, but this happens so seldom as not to be considered a serious problem. More serious is the frequency with which they become entangled in commercial fishing nets, particularly on the east coast of Canada and, to a lesser extent, the United States. Coincident with the near collapse of the offshore capelin stocks in that area in the late 1970's, humpbacks moved closer inshore and the number of entanglements increased alarmingly (Lien and McLeod[16]). Of 64 humpbacks entangled in 1979, at least 24 died (Mitchell, 1979). Since then, as the fishery has recovered, entanglements have fallen off sharply, but it remains a problem which could reescalate at any time.

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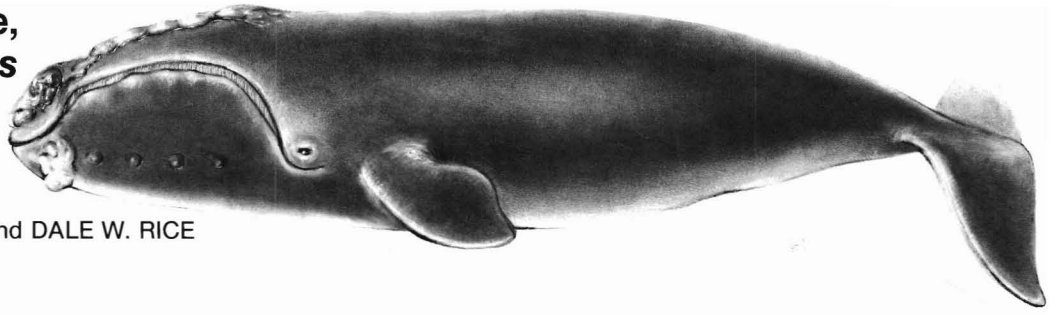
The Right Whale, *Balaena glacialis*



HOWARD W. BRAHAM and DALE W. RICE

Introduction

The right whale, *Balaena glacialis* Muller, 1776[1], also known as the black right whale, resembles the bowhead, *B. mysticetus*, in its robust build, narrow arched rostrum, and lack of a dorsal fin, but is readily recognized by the callosities on its rostrum and its scalloped lower lips. The right whale occurs in all the world's oceans from temperate to subarctic waters (Fig. 1). Seasonally, it is a coastal species; however, important feeding aggregations are reported well out to sea, especially in the North Pacific and South Atlantic. Like most other baleen whales, they spend the summer on high-latitude feeding grounds and migrate to more temperate waters during the winter calving and mating seasons.

The species was overexploited principally by European and Yankee whalers, but very little is known about the impact of whaling on the number and location of populations around the world. Nevertheless, several discrete breeding populations are hypothesized. The reproductive cycles of animals in the Northern and Southern Hemispheres are 6 months out of phase, and right whales from these regions, therefore, do not interbreed. This divides the species into at least three reproductively isolated populations, one each in the North Pacific, the North Atlantic, and the Southern Hemisphere; other stocks

[1]Some authors place the species *glacialis* in a separate genus, *Eubalaena* Gray, 1864 (e.g., Rep. Int. Whaling Comm., Spec. Issue 9).

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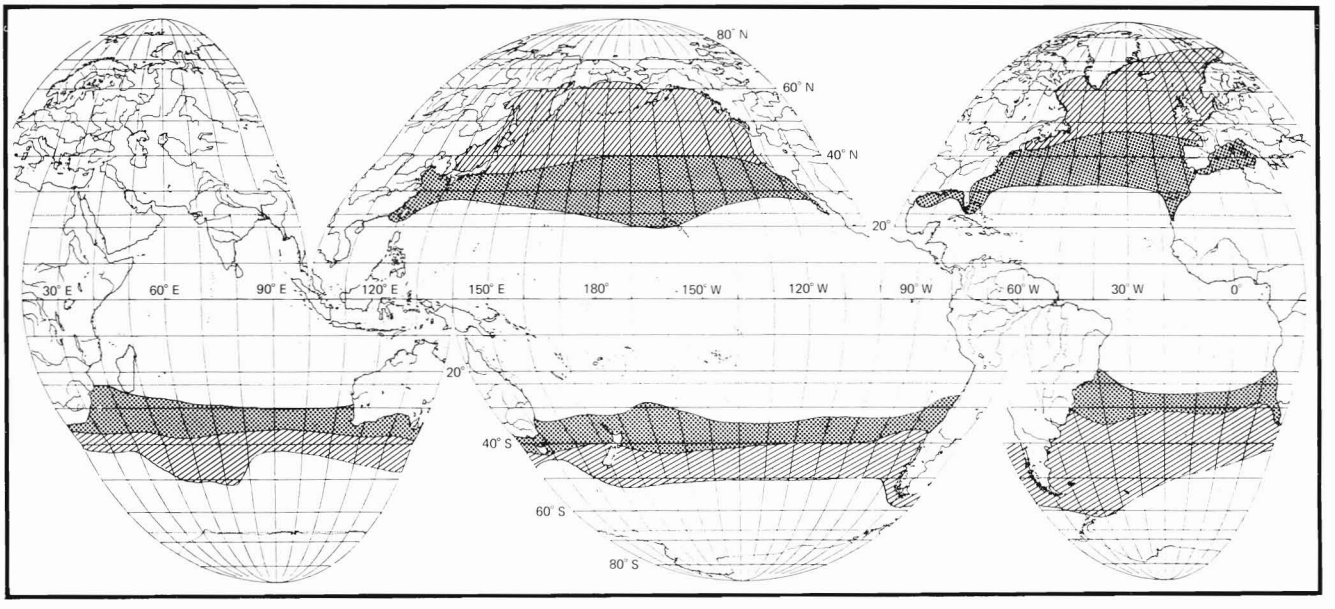


Figure 1.—Geographical distribution of the right whale. Simple hatching indicates the summer feeding grounds. Stippling indicates distribution during autumn, winter, and spring; records are scarce during these seasons, and the distribution is to a large extent speculative.

within these regions are presumed. These stocks may not interbreed, but some overlap on their summer feeding grounds.

Although the right whale has been protected from whaling under international agreement since 1931, there is little evidence of recovery in most areas, unlike other baleen whales so protected. This suggests that it might be the most vulnerable to human intervention of all great whales. For example, their behavior of moving into coastal habitats during the sensitive calving season probably makes them particularly vulnerable to nearshore development.

Distribution and Migration

Right whales are found in temperate waters above lat. 25° during the late autumn to early spring calving and mating season, and in higher latitudes, usually above lat. 40° during the spring to autumn feeding season. No overlap in distribution occurs between Northern and Southern Hemisphere populations in tropical waters; hence the stocks are geographically isolated. Right whales rarely occur in the polar pack ice.

North Atlantic

The International Whaling Commission (IWC, In press, a) currently recognizes three stock areas for right whales in the North Atlantic: One each on either side of the 30°W meridian from the southern tip of Greenland (Cape Farewell) south, and the third area within lat. 60-62°N, long. 33-35°W from Greenland to Iceland. Some question remains as to whether this third unit might be confused with a bowhead whale stock area, since the data are primarily from the early whale fishery for bowheads.

Current data support the hypothesis that right whales in the western North Atlantic principally occur in coastal waters from Florida to Labrador. A few sightings have been made in the Gulf of Mexico (Moore and Clark, 1963) and Bermuda to the south, and from early whaling records they once occurred as far north as south Davis Strait, Canada (IWC, In press, a). Right whales apparently spend the winter months (January-March) along the southeast coast of the United States from Florida to North Carolina, most beyond sight of land. They then move into coastal waters of Massachusetts, Maine, southeast Nova Scotia, and Labrador, traveling north from spring to early autumn (Winn and Price, In press).

Calving appears to occur in late winter. On the basis of the size of calves seen in the Bay of Fundy, Kraus and Prescott[2] estimate that calving occurs from February to April. The peak numbers of right whales seen in spring are off Cape Cod in April, but few are seen there in summer (Schevill, et al., In press). Most summer sightings are from southeast Canadian waters (Reeves et al., 1978); many likely occur well offshore during summer and autumn based on 19th-century whaling records (IWC, In press, a).

The southward autumn migration (from about October through December) presumably occurs farther offshore than in spring, and the period of migration is shorter (Winn and Price, In press). This is consistent with reports of the movement of right whales off South Africa (Best, 1981). However, definitive information on the movements is generally lacking and the available information is based on scattered historical whaling and sightings records reviewed by Schevill et al. (In press), and Winn and Price (In press).

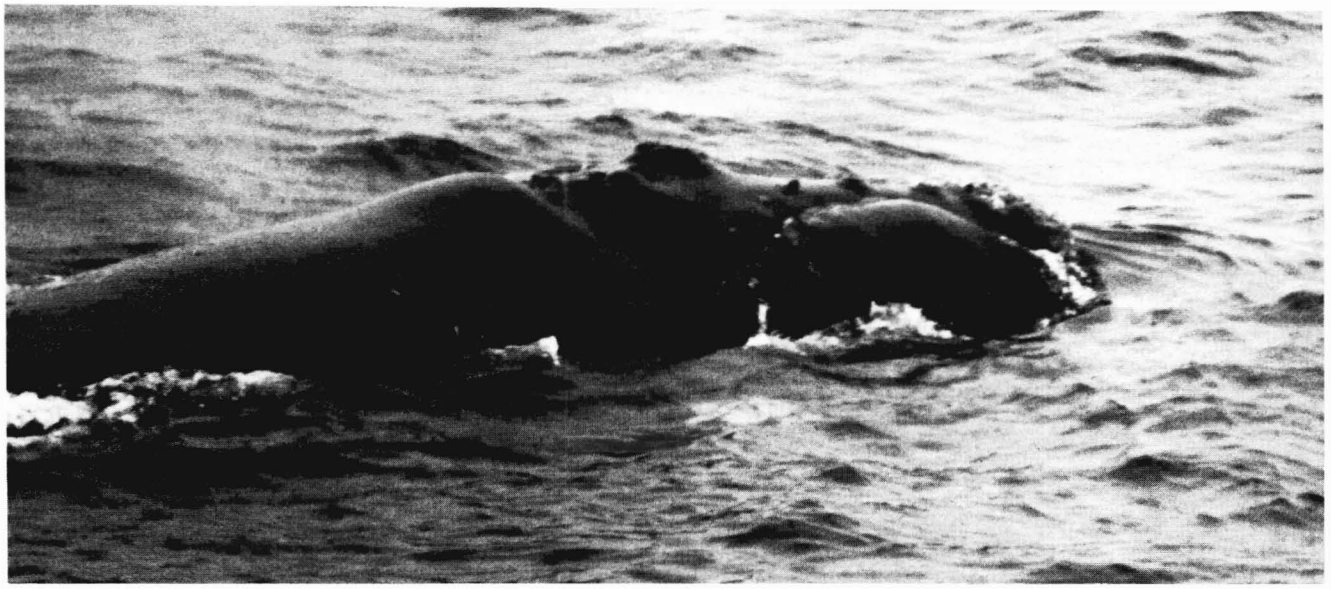
Current records of right whales in the eastern North Atlantic are far fewer, and their seasonal movements are not known. Whaling records back to the 16th century indicate that right whales were taken from off Cape Farewell to Iceland (although this may have been more a bowhead fishery); off North Cape, Norway; and off the British Isles. Important winter hunting grounds, and thus presumed calving areas, were in the Bay of Biscay of northwest Spain and western France, and Cintra Bay (lat. 23°N, long. 16°15′W) off northwest Africa.

North Pacific

Wintering areas for right whales in the North Pacific are unknown. Migration patterns are also largely unknown, except that northward movements from temperate and subarctic waters occur in spring, with the species occurring on summer feeding grounds generally between lat. 50°N and 63°N (Omura, 1958). Some early whaling records reported by Maury (1852) and Townsend (1935), as well as Japanese sighting data during the 1960's and 1970's, support the hypothesis that right whales are distributed all across the North Pacific north of lat. 35°N, with important concentrations in the Gulf of Alaska, eastern Aleutian Islands-southcentral Bering Sea, Okhotsk Sea, and coastal Japan. Although the evidence is certainly not definitive, the IWC (In press, a) has tentatively divided the North Pacific into two stock areas for purposes of reporting statistics.

Right whales in the western North Pacific occur from waters off Japan north into the Okhotsk Sea and western Bering Sea. There is no clear data to support the idea that more than one stock occurs in this area, or whether there is a continuum into the eastern North Pacific, but right whales were formerly abundant from Japan and the east China Sea to the Okhotsk Sea from late winter to summer (Klumov, 1962; Omura, 1958). The likely calving/mating area was south and west of Japan and in the east China Sea and Formosa Strait, predominantly from December to March (Omura, 1958). Right whales were taken off the Bonin Islands at lat. 27°N, long. 137°W (about 300

[2]Kraus, S. D., and J. H. Prescott. 1982. The North Atlantic right whale (*Eubalaena glacialis*) in the Bay of Fundy, 1981, with notes on distribution, abundance, biology and behavior. Unpubl. manuscr., 105 p. New England Aquarium, Central Wharf, Boston, MA 02110. (Prepared for the World Wildlife Fund, Washington, D.C., and the Northeast Fisheries Center, National Marine Fisheries Service, NOAA, Woods Hole, Mass., under Contract NA-81-FA-C-00030.)



A right whale surfacing showing the arched lower lip and the rough, horny callosities on the head. Photo by G. Joyce.

miles (500 km) southeast of Japan) in February (Rowntree et al., 1980). This may be the southern extent of their distribution; the northern recent record (two animals) occurred in summer 1982 at about lat. 60°48′N, long. 175°18′W (Brueggeman[3], U.S. Department of the Interior[4]).

The most important whaling ground for right whales in the eastern North Pacific was off Kodiak Island in the Gulf of Alaska. Right whales were also taken in the eastern Aleutians Islands area and off the coast of Canada and southeast Alaska, principally in summer. Evidence of large calves seen in the Gulf of Alaska in summer supports the notion that parturition occurs in late winter-early spring, presumably further south. There is no evidence to date that right whales either gave birth in or occupied coastal waters of the eastern North Pacific. Although coastal whaling for the gray whale, *Eschrichtius robustus*, and humpback whale, *Megaptera novaeangliae*, was extensive along the west coast of North America, only about 45 records of right whales exist below lat. 50°N (Scarff, In press), lending support to the hypothesis that right whales found on summer grounds in the eastern North Pacific may either 1) migrate from the western North Pacific or 2) winter in pelagic waters of the east and central North Pacific (Maury (1852) showed right whales well out to sea above lat. 35°N and east of long. 180° in February and March). The southern record for right whales along the North American Pacific coast is off Baja California at lat. 26°39′N, long. 113°40′W where two whales were seen about 8 km (5 miles) offshore on 11 March 1965 (Rice and Fiscus, 1968).

Southern Hemisphere

Right whales range throughout the southern oceans, particularly off South Africa, the southeast coast of South America, New Zealand, Australia, and in the south Indian Ocean. Specific migration patterns are not well understood, but the whales move north in late autumn along coastal routes and south to pelagic feeding areas in spring. The movements of offshore groups of whales are also unknown, but based upon limited historical whaling records, they are likely similar to those of coastal animals: Seasonal north-south movements. A survey of the current understanding of stock identity is reviewed by the IWC (In press, a).

Right whales occur seasonally in pelagic waters of the southwest Atlantic Ocean along the southeast coast of South America from Brazil (e.g., False and Brazil Banks) to southern Argentina, and east to the Falkland Islands. This latter area was referred to as the Tristan and Pigeon grounds (long. 10°W-30°W) by early whalers. The whales' distribution continues east to the southern coast of Africa where a distinct stock from those west of long. 20°E occurs. The area west of long. 20°E is tentatively called the Greenwich Stock area; that east of long. 20°E is called southeast African Stock area.

Right whales concentrate along the southeast coast of Argentina (about lat. 43°S at Peninsula Valdes) in

[3]J. J. Brueggeman, Envirosphere Company, 400 - 112th N.E., Bellevue, WA 98004, pers. commun.

[4]U.S. Department of the Interior. 1983. Navarin Basin lease offering (March 1984). Final Environmental Impact Statement. Unpubl. manuscr., Minerals Management Service, Alaska Outer Continental Shelf Region, U.S. Department of the Interior, P.O. Box 101159, Anchorage, AK 99510.

September and October (calving season), but are seen as early as June and as late as February. During this northward movement or migration, some individuals apparently continue north into Brazilian waters (Payne[5]). These animals are closely associated with coastal areas, such as bays and estuaries, as are those located off South Africa. The southward spring migration probably begins in about November, off Brazil and Argentina.

Along the south coast of South Africa (at about lat. 34°S), right whales occur primarily between June and November, having moved north from presumably subantarctic feeding areas, but are greatest in number during August and September (Best, 1981; Rice et al., In press). This inshore component may represent only one segment of the population, principally cows with calves and unaccompanied adults (Best, In press). As with the South American coast, right whales are essentially absent during the summer months when they are thought to be feeding in subantarctic waters. Based on 13 records, Japanese sighting surveys report right whales in Antarctic waters between lat. 60°S-65°S in January (Kasamatsu, In press).

There are at least five putative stock areas in the South Pacific and Indian Ocean: Off Chile, New Zealand, Campbell Island, Australia (southwest and southeast possible subdivisions), and central Indian Ocean-southeast Africa (possibly 2-3 subdivisions) (IWC, In press, a). The Chilean stock is considered provisional as there is a lack of sightings between New Zealand and Chile between long. 90°W and 130°W. Based on separate catch histories and the distribution of right whales at about the same time of year (mid-May to September), right whales off the east coast of New Zealand (Cawthorn, In press) and around Campbell Island (about 300-500 n.mi. south of New Zealand) are tentatively considered separate stocks. Right whales occur throughout waters of south Australia, especially in southeast and southwest Australia and Tasmania, principally from midwinter (July) to early spring (September) (Bannister, In press). It is thought that they migrate to the north from Antarctic waters, with the south coast of Australia being the north end of their range. Based on early whaling records, the western extent of this right whale stock area designation is about long. 90°E in the Indian Ocean. The stock areas and movements of right whales in the southern Indian Ocean (Central Indian group(s)) are known only from early whaling records. These suggest that perhaps up to three possible stocks occur within the area bounded by lat. 50°S-40°S and long. 50°E-80°E, near the Crozet, Kerguelen, and Amsterdam island groups.

Life History and Ecology

Feeding

During the summer, right whales inhabit cool temperate waters where they feed primarily on calanoid copepods, called "brit" by whalers. Right whales are specialized as "skimmers" that feed by swimming slowly with their mouths wide open through the swarms of copepods. They usually feed below the surface, but sometimes feed at the surface, raising their rostrum above water (Watkins and Schevill, 1976). The main species of copepods on which they feed are *Calanus cristatus* and *C. plumchrus* in the North Pacific, and *C. finmarchicus* in the North Atlantic (Collett, 1909; Klumov, 1962; Omura et al., 1969). Food habits have been little studied in the Southern Hemisphere, but in addition to species of *Calanus* they sometimes consume "lobster-krill," the pelagic postlarval stage of the crustacean *Munida gregaria* (Matthews, 1932). Euphausiids, or "krill," are also eaten sometimes, including *Euphausia pacifica* in the North Pacific, *Thysanoessa inermis* in the North Atlantic, and *E. superba* in the Southern Hemisphere.

Reproduction

Few data are available on reproduction in right whales (Best, 1981; Klumov, 1962; Matthews, 1938; Omura et al., 1969; Whitehead and Payne, 1981). As with other baleen whales, their reproductive cycle is synchronized with their feeding cycle and annual migration.

The gestation period is probably about 1 year. Females enter shallow coastal bays to give birth to their single calves. The calving season is during the winter—January to April in the Northern Hemisphere and July to October in the Southern Hemisphere. Calves average 5.5-6.0 m (18-20 feet) long at birth. They are probably weaned by the time they are 12 months old, when they are about 8.0 m (26 feet) long, but may remain with their mother through the winter following their year of birth. Right whales apparently do not attain sexual maturity until they are at least 8 years old. Body length of females at sexual maturity is 12.5-15.5 m (41-51 feet), and that of males is probably about 1 m less (there may be geographical variation in this feature). Mature females usually bear a calf only once every 3 years (IWC, In press, a).

Best (1981) and R. S. Payne (footnote 5) state that based on some 10 years of study of right whales off South Africa and Argentina, respectively, these right whale stocks appear to be growing at a rate of about 7 percent per year. This suggests a high rate of reproduction, with the ratio of calves to adults in the neighborhood of 15-25 percent. However, as Best and Payne point out (IWC, In press, a), few juveniles are seen, indicating that they are studying only a portion of the population. In addition, most mature females (as well as adult males) are not seen every year, but may return with a calf every 2 or 3 years. As the reproductive cycle between presumed successive births is at least 3 years (estimated to average 3.26 years, (IWC, In press, a)), the net recruitment is probably much lower than 7 percent.

The IWC (In press, a) attempted to resolve this issue, and through a series

[5]R. S. Payne, Center for Long Term Studies, Weston Road, Lincoln, MA 01773, pers. commun.

The whaling station which operated at Kyuquot, Vancouver Island, from 1919 until World War II. Source: Historical Photography Collection, University of Washington Libraries, Seattle.

of modeling exercises at the special workshop on right whales, concluded that to achieve population growth rates greater than 5 percent, survivorship would have to be much higher than thought by the scientists present. This exercise pointed out that while there are many inconsistencies in the available data, as well as in using certain assumed but contested parameters (e.g., survivorship and annual calf proportion), recruitment rates in right whales are probably lower than suggested by the apparent growth of the South African and Argentine populations, and that indeed net recruitment is likely among the lowest of the large baleen whales. Empirically, this seems to be supported by the apparent low rate of recovery of all right whales (including bowheads) in this century.

Natural Mortality

Important natural mortality factors are unknown. Barnacles and three species of cyamids or "whale-lice" often grow on the skin, and three kinds of parasitic worms have been found in the intestines (Delyamure, 1955), but all of these appear to be nonpathogenic. Predation on right whales by killer whales, *Orcinus orca*, appears to be quite rare.

Natural mortality rates have been estimated to be about 4.0 percent per year in adults, and are probably greater in immature animals. However, current estimates of mortality rates in large baleen whales are in question (IWC, In press, b).

Exploitation and Population Size

History of Exploitation

Right whales are large and slow-swimming, often congregate in nearshore waters, have a thick layer of blubber, and float when killed. These attributes make them easy and profitable prey for whalers (hence their name, the "right" whale). Thus they were the first species of great whale to become the object of a commercial fishery.

The Basques living on the shores of the Bay of Biscay in northern Spain and southwestern France began a right whale fishery as early as the year 1059. This fishery flourished until the early 1600's. The Basque whalers subsequently ventured farther afield, and after 1528 they regularly voyaged to the Grand Banks off Newfoundland, and later, the Gulf of Saint Lawrence, Canada (Jenkins, 1921).

American colonists began shore-based whaling for right whales in the early 1600's at many places along the Atlantic seaboard—notably in the vicinity of Massachusetts and Long Island. This fishery persisted until the early years of the 20th century.

In the early 1600's, commercial whale fisheries were also instituted in Japan. Right whales were an important component of their catches. This shore fishery has persisted to the present day, although right whales are no longer killed.

The American high-seas whale fishery was inaugurated in 1712 (Starbuck, 1878). This fishery was directed primarily toward sperm whales, *Physeter macrocephalus*, but right whales were also an important species. At first the fishery was confined to the Atlantic Ocean, and voyages usually lasted only a few months. Following the American Revolution, the high-seas whale fishery expanded rapidly. U.S. vessels began regular voyages to the Pacific Ocean in 1791, and to the Indian Ocean in 1830. These voyages routinely lasted 3 or 4 years. Several other nations—notably France and England—also engaged in the high-seas whale fishery, but to a lesser extent than the United States. Between 1804 and 1876, U.S. whalers killed an estimated 193,522 right whales worldwide (this figure includes an unknown, but small, proportion of bowhead whales). U.S. whaling reached its zenith in 1840, when 735 vessels were engaged in the fishery. The highest annual catch of right whales was reported in 1846, when U.S. vessels delivered to port the oil of an estimated 6,134 animals. During the latter half of the 19th century, the pelagic whale fishery rapidly declined owing to the severe depletion of right whale populations and to the substitution of petroleum for sperm oil.

During the heyday of the pelagic fishery, numerous shore whaling stations were established in Australia, New Zealand, and South Africa, and their prime target was the right whale.

By the time the modern whale fishery with its harpoon cannons and steam-powered catcher boats com-

A large right whale (lying on its back) on the flensing platform of the former whaling station at Akutan in the Aleutian Islands. Some of the 8-foot long baleen plates are protruding from the left side of the mouth. Source: Historical Photography Collection, University of Washington Libraries, Seattle.

menced in the late 1800's, right whales were so rare worldwide that they were almost never encountered. The modern fishery concentrated on blue, *Balaenoptera musculus*; fin, *B. physalus*; and humpback, *Megaptera novaeangliae*, whales which the old-style hand-harpoon fishery had largely ignored.

Current and Initial Stock Sizes

No one has attempted to estimate original population sizes, and there are perhaps too few data to do this with any precision. Based on the recorded catch figures for right whales, and on original population density estimates of other baleen whales, we suggest that the original population size of the right whale was on the order of 100,000 to 300,000, of which about two-thirds were in the Southern Hemisphere, and the remainder in the North Atlantic and North Pacific.

Current population size is also poorly known. There are roughly 3,000 right whales left in the Southern Hemisphere, 100-200 in the North Pacific, and a few hundred in the North Atlantic, for a world total of perhaps 3,000 to 4,000 (Gambell, 1976). The world population of right whales appears to have been reduced by at least 95 percent, and perhaps by as much as 99 percent during the first several centuries of exploitation. There are indications that some local stocks are beginning to increase slightly (see the section on Reproduction), but even with complete protection, recovery (if any) has been exceedingly slow and may take at least a century.

Management

The chief management problem is the usurpation of the right whales' nearshore calving grounds by coastal development and concomitant vessel traffic, pollution, and oil spills. The most significant present concern is for habitat protection and the potential problems associated with oil and gas development on the outer continental shelf along the east coast of the United States (Cetacean and Turtle Assessment Program[6]), in particular

[6]Cetacean and Turtle Assessment Program. 1982. A characterization of marine mammals and turtles in the mid- and north Atlantic areas of the U.S. outer continental shelf. Unpubl. manuscr., 450 p. plus appendices. Graduate School of Oceanography, University of Rhode Island, Kingston, RI 02881. (Prepared for the U.S. Department of the Interior's Bureau of Land Management under Contract AA551-CT8-48.)

Georges Bank, and along the west coast of the United States where right whales are likely to occur in or adjacent to at least six petroleum lease areas, primarily in Alaska (Braham et al., 1982; Morris et al., 1983; U.S. Department of the Interior, footnotes 4 and 7).

Because of their low population numbers, their habit of using coastal waters, and apparent low reproduction, right whales are likely the most vulnerable of all the great whales to habitat incursion and deterioration. Removal (death resulting from collision with tankers, oil spills, etc.) of just a few individuals from depressed populations would have a significant effect on recovery. Concern for other results of coastal developmental activities, such as pollution, is justified as well, since right whales migrate into coastal waters at least in the western Atlantic to feed on abundant prey, often nearshore (e.g., Cape Cod and Bay of Fundy).

Conclusions

It is clear that all stocks of the right whale were severely depleted as a result of commercial whaling. Some, like the northeast Pacific stock, if an identifiable breeding unit, have not recovered and may be nearing extinction, similar to that of the fate of the western Pacific gray whale and the Spitsbergen stock of bowhead whales. Other populations, such as those off Argentina and South Africa, have recently increased. But generally, insufficient data exist to give a precise determination of future growth for any stock. In addition, this species' penchant for coastal habitats, such as the eastern seaboard of the United States, where industrial and other nearshore development activities occur, could create potential obstacles to recovery.

[7]U.S. Department of the Interior. 1982. St. George Basin. Final Environmental Impact Statement. Unpubl. manuscr., Minerals Management Service, Alaska Outer Continental Shelf Region, U.S. Department of the Interior, P.O. Box 101159, Anchorage, AK 99510.

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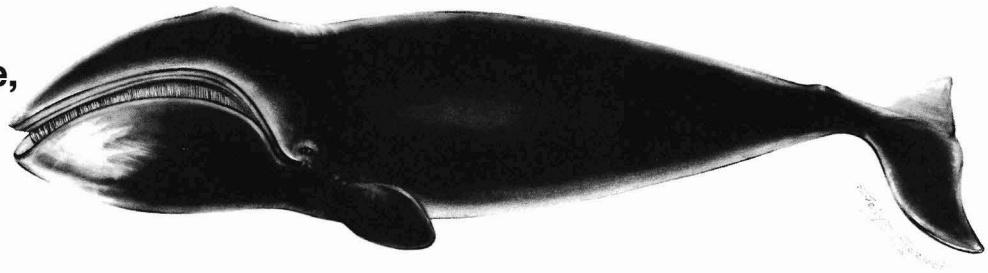
The Bowhead Whale, *Balaena mysticetus*



HOWARD W. BRAHAM

Introduction

The bowhead whale, *Balaena mysticetus* (Linnaeus 1758), also called the Greenland right whale, is the only baleen whale which spends its life in and around Arctic waters. It is also one of the rarest of all cetaceans. Heavily exploited for its whalebone (baleen) and oil-producing blubber, the species became seriously depleted throughout its range before the 20th century. As a result, the species was almost eliminated before quantitative biological data could be collected.

Some descriptive information on the bowhead's natural history was recorded by astute whalers (Scoresby, 1820; Scammon, 1874; Gray, 1894; Cook, 1926; Bodfish, 1936; Brower, 1942), early scientists (Eschricht and Reinhardt, 1866; Gray, 1886; Southwell, 1898; Allen, 1908; Gray, 1929a, b), and others (e.g., Zordrager, 1720; Lubbock, 1937). Intensive research on the bowhead did not begin until the mid-1970's, but has developed so rapidly that much of the information published as recently as 1980 already is now either outdated or greatly refined. Much recent work is still unpublished or based on such small sample sizes that it is difficult to assess the status of most bowhead stocks.

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Distribution and Migration

Four or five stocks of bowhead whales are recognized: East Greenland-Spitsbergen and Davis Strait/Hudson Bay stock(s) in the eastern and western North Atlantic, respectively; the western Arctic stock in the Bering, Chukchi, and Beaufort Seas; and the Sea of Okhotsk stock. A putative fifth stock may occur in Hudson Bay; however, the evidence is not definitive (Reeves et al., 1983), and it will be considered separately for this review.

The current hypothesis is that populations within and between the North Pacific and North Atlantic Oceans are geographically and thus reproductively isolated from each other. Some historical evidence suggests interchange may have occurred during periods of exceptionally favorable ice conditions in the Northwest Passage of North America and across the eastern Arctic of Europe and Asia.

Eskimos flense a large bowhead whale hauled out on the ice at Point Hope, Alaska. Photo by W. Marquette.

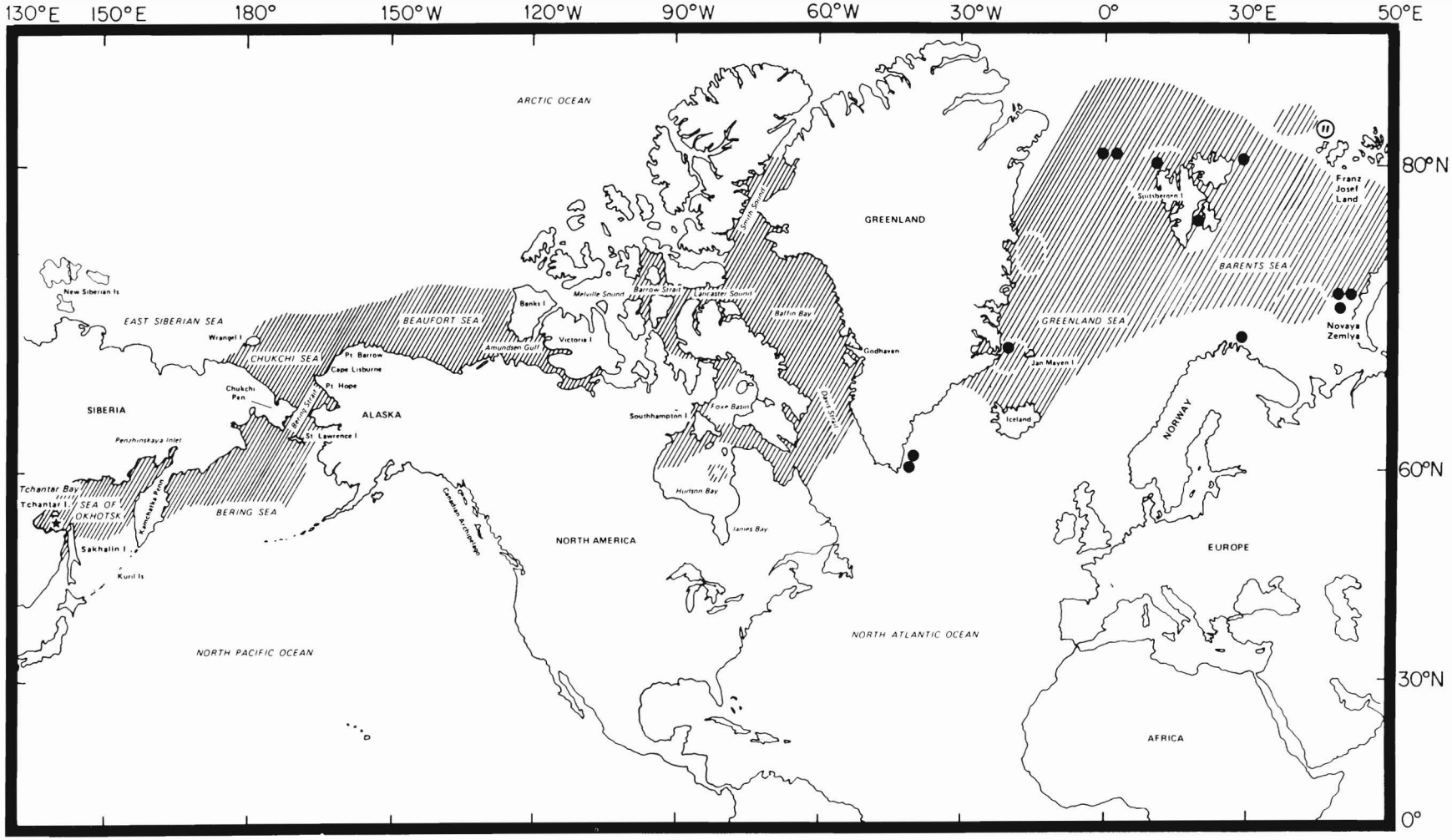


Figure 1.—Approximate world distribution of bowhead whales prior to commercial whaling. Current range of each stock may not be the same. Recent (1958-82) sightings in the eastern North Atlantic of single whales (dots) are from Jonsgård (1981) and of 11 whales sighted in May 1981 north of Franz Josef Land (circle) are from A. Yablokov (text footnote two). Sightings of bowheads in Academy Bay, Sea of Okhotsk (star) of 54 (1967), 35 (1974), and 55 (1979) are from Berzin and Doroshenko (1981). Recent sightings in the Bering, Chukchi and Beaufort Seas, and eastern North American Arctic are too numerous to plot here. The two sightings near the southern tip of Greenland are thought to be right whales (Reeves, R., Arctic Biological Station, Ste. Anne de Bellevue, Quebec, during a conversation at the IWC Scientific Committee meeting, 6 June 1984, Eastbourne, Engl.)

North Atlantic

East Greenland-Spitsbergen Stock

Bowhead whales in the eastern North Atlantic apparently wintered in the area between East Greenland, Iceland, and Spitsbergen Island (Fig. 1). (Spitsbergen is one of several islands collectively called Svalbard.) Their northeasterly movements in spring were correlated with the recession of the ice front, with some whales arriving at Spitsbergen in April (Scoresby, 1820; for a review see de Jong, 1983). In summer, most of the population was found from east Greenland and Novaya Zemlya to north of lat. 80°N (Eschricht and Reinhardt, 1866; Vibe, 1967).

Jonsgård (1981) reported that only 23 individual bowheads (including two dead) were seen in this area from 1945 to 1980. In 1980 and 1982, July to September, no bowheads were observed during continuous 24-hour-a-day observations from an ice reinforced vessel surveying the Barents Sea (between Svalbard and Franz Josef Land) and the ice front to lat. 83°N (Larsen[1]). Haug (1980) reported that one bowhead was seen by Norwegian whalers on 21 and 25 May 1980 at about lat. 71°00′N, long. 28°51′E along the coast of Finnmark, north Norway. A. Yablokov[2] reported that in May 1981, 11 bowheads were seen in one group about 100-150 km northwest of Franz Josef Land in a pack ice lead. Tomilin (1957) and Vasilchuk and Yablokov (1981) reported evidence of bowhead strandings along Soviet shores during this century, especially from the Kara Sea and Novaya Zemlya.

Davis Strait and Hudson Bay Stock(s)

Bowhead whales in the western North Atlantic range from southern Davis Strait and Hudson Strait, Canada, to Godhavn, West Greenland, in winter, and north to the Canadian High Arctic and northern Hudson Bay (including Foxe Basin), in summer (Fig. 1). Reeves et al. (1983) report that the bowhead's distribution and migration today is probably the same as it was prior to commercial whaling. Summering areas and migration routes include Hudson Strait (lat. 62°N, long. 72°W) into northwest Hudson Bay, Repulse Bay (lat. 66°N, long. 85°W) and Foxe Basin, Baffin Bay, Smith Sound, Lancaster Sound, Price Regent Inlet (lat. 73°N, long. 90°W) and Admiralty Inlet (69°N, long. 101°W), and waters between the islands of the Canadian High Arctic west to Barrow Strait. Sightings during the spring and autumn migrations over the past decade have been made primarily along the northeast end of Baffin Island (West Baffin Bay) (Davis and Koski, 1980), and a few more recently in spring near Godhavn, West Greenland, (Born and Heide-Jorgensen, 1983). Gray (1886) and Southwell (1898) reported that adult males occurred in open water in summer and autumn, while females and young were associated with the pack-ice front.

On the basis of different catch histories, apparent migration patterns, and separate areas of seasonal abundance, Mitchell and Reeves (1981) and Reeves et al. (1983) suggested that two stocks occur in the eastern North American Arctic: The "Davis Strait Stock" and the "Hudson Bay Stock." However, as Reeves et al. (1983) pointed out, "The separate identity of these two putative stocks needs confirmation through direct evidence."

A bowhead whale rests at the surface in June, late in spring migration. Graying patches of skin along the head, back, and edges of fluke are thought to be areas of molting. Photo by B. Krogman.

North Pacific

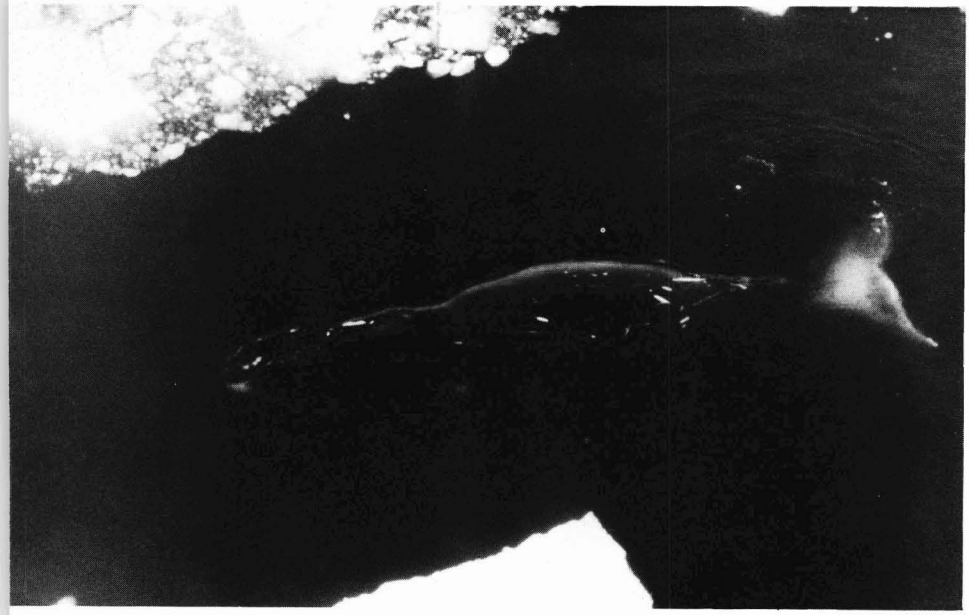
Western Arctic Stock

Bowhead whales in the western Arctic of North America during the 19th century ranged from the southwestern Bering Sea into the Chukchi and Beaufort Seas (Townsend, 1935; Bockstoce and Botkin, 1983) (Fig. 1). Their range today is virtually the same, although they are probably absent from the southeastern Bering Sea except during years of very heavy ice (Braham et al., 1980b; Dahlheim et al., 1980). Plots of seasonal catches, adapted from Townsend (1935), replotted by month, and reported in Dahlheim et al. (1980) and Braham et al. (1984), suggest that the distribution of bowheads during open-water periods in the mid-19th century was from the Bering Sea to the eastern Beaufort Sea. This implies that their summer distribution included, essentially, their entire range.

Catch data early in the Yankee whaling fishery in the western Bering Sea in July show that some component of the population did not migrate north of lat. 64°N. Anecdotal comments by Cook (1926) further suggest that by the end of the 19th century, bowheads were not found in

[1]Thor Larsen, Norwegian Polar Research Institute, Oslo, Norway. Pers. commun., 24 February 1983.

[2]Alexey Yablokov, Academy of Sciences of the U.S.S.R., Moscow. Pers. commun., 27 April 1983 during a U.S.-U.S.S.R. bilateral meeting in Santa Cruz, Calif. Subsequently, Randall Reeves passed to me a letter from Yablokov written to Reeves on 1 July 1981 in which Yablokov provides some details.



Adult bowhead whale resting at the surface among spring ice floes. The light coloration of the inner surface of the flukes is caused by natural markings, while the small white marks on the animal's back and rostrum are perhaps healed wounds in the skin (from unknown causes) inflicted throughout the animal's life.

summer and autumn (July-August) in the Bering Sea. Rather, they were encountered there only near the ice front in spring and early summer. Today bowhead whales are found in abundance in summer (July-August) only in the Beaufort Sea. I conclude from this that the current southern limit of their summer distribution is several hundred miles further north than it was in the 19th century.

Currently, bowhead whales in the western Arctic spend the winter months from December to March in and near the pack ice of the western Bering Sea from St. Lawrence Island south to St. Matthew Island and west to the U.S.S.R. coast (Braham et al., 1980a, b; Bogoslovskaya et al., 1982; Brueggeman, 1982). The spring northward migration usually occurs from April through June in the western Bering and eastern Chukchi Seas, and offshore in the Beaufort Sea (Braham et al., 1980a). The whales follow cracks in the pack ice, called "leads," which are openings in the fracture zone of ice formed when the pack ice moves away from shore during spring breakup as a result of wind, currents, and melting ice. The eastern or Canadian Beaufort Sea serves as the bowheads' primary feeding ground from June to September (Cook, 1926; Fraker and Bockstoce, 1980). During this period, they occur principally from Amundsen Gulf to Demarcation Bay (lat. 69°40′N, long. 141°20′W), Alaska (Mansfield, 1971; Fraker et al., 1978; Fraker and Bockstoce, 1980; Davis et al.[3]).

The autumn migration westward through the western Beaufort Sea begins in August and September, and occasionally a few whales are seen as late as early November. Most autumn sightings (September and October) in U.S. waters have been of whales near the 20-100 m depth contour between Demarcation Bay and Point Barrow (Braham et al., 1977, 1984; Ljungblad et al., 1980, 1982; Ljungblad, 1981). From Point Barrow, the animals move west across the Chukchi Sea toward Herald and Wrangel Islands (Cook, 1926) and then south and east along the north coast of the Chukchi Peninsula to their winter grounds in the Bering Sea (Johnson et al., 1981; Bogoslovskaya et al., 1982; Marquette et al., 1982). A few recent sightings have been made along the northwest coast of Alaska in the Chukchi Sea during the autumn migration (Ljungblad et al., 1982; In press).

Sea of Okhotsk Stock

Bowheads were formerly found in the northern and western Sea of Okhotsk during spring and summer, occurring as far north as Penzhinskaya Inlet (northern Sea of Okhotsk) and as far southwest as Shantar Bay (also spelled Tchantar Bay) (Fig. 1). Today their seasonal movements are unknown. Three vessel and aerial surveys of the Sea of Okhotsk resulted in sightings of 54 (June-July 1967), 35 (August 1974), and 55 (August 1979) bowheads in and adjacent to Academy Bay (lat. 54°N, long. 138°E) northwest of Sakhalin Island (Berzin and Doroshenko, 1981). On 23 June 1969, a 6.3 m bowhead was taken by Japanese fishermen in Osaka Bay, Japan (Nishiwaki and Kasuya, 1970). This was a very rare event, since central Japan is almost a thousand miles south of the bowheads' historical range in the Sea of Okhotsk.

Life History and Ecology

Feeding

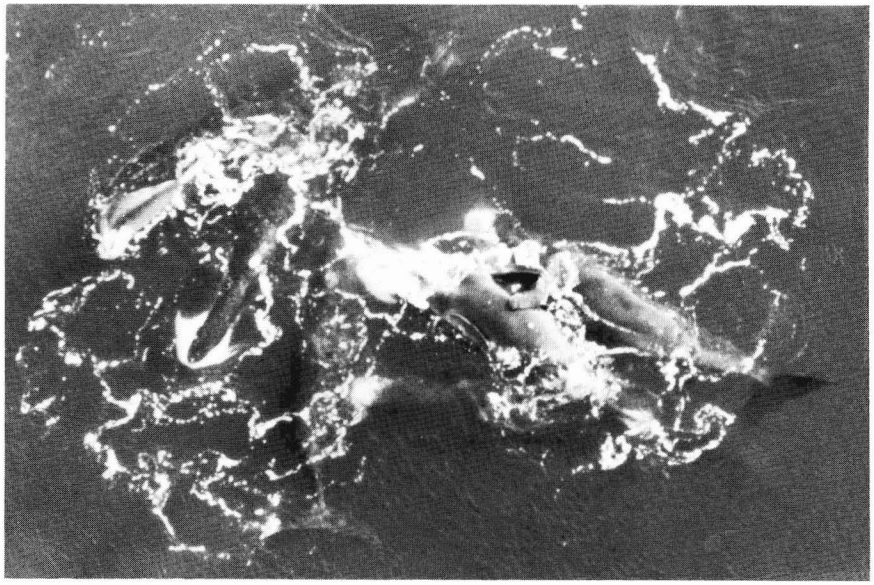
Euphausiids (*Thysanoessa raschii*) and copepods (*Calanus* sp.) are the principal prey of bowhead whales, at least in the western Arctic (Lowry et al., 1978; Lowry and Burns, 1980). Bowheads feed while in the eastern Beaufort Sea during the summer and autumn (about June to October), but the percent of time spent feeding, especially at other times of the year, is unknown. Frost and Lowry[4] (summarized in Marquette et al., 1982) estimated that bowheads consume about 3 percent of their body weight per day. The predominant prey taken are, by volume, euphausiids (65 percent), copepods (30 percent), hyperiid

[3]Davis, R., W. Koski, and G. Miller. 1983. Preliminary assessment of the length-frequency distribution and gross annual reproductive rate of the Western Arctic bowhead whale as determined with low-level aerial photography, with comments on life history. Final rep., 91 p. LGL Ltd., 44 Eglinton Ave. W., Toronto, Ontario, M4R 1A1, Can. (Prep. for Natl. Mar. Mammal Lab., NMFS, NOAA, Seattle, WA 98115.

[4]Frost, K., and L. Lowry. 1981. Feeding and trophic relationship of bowhead whales and other vertebrate consumers in the Beaufort Sea. Final report, 106 p. Alaska Dep. Fish Game, 1300 College Road, Fairbanks, AK 99701. (Prep. for Natl. Mar. Mammal Lab., NMFS, NOAA, Seattle, WA 98115.)

amphipods (1 percent), and other species (4 percent).

Based on a 1-year study of predator interactions in the eastern U.S. Beaufort Sea, Frost and Lowry (footnote 4) concluded that competition for food among predators such as Arctic cod, *Boreogadus saida*; ringed seals, *Phoca hispida*; and seabirds during summer and autumn might adversely affect the feeding and population growth of bowheads in some years if food is limited. Further calculations by Lowry and Frost (1984) suggest that prey density in the Beaufort Sea supplies sufficient energy needs for bowheads during an estimated 130-day feeding season.



Group mating behavior of bowhead whales among the spring ice near Barrow, Alaska. Photo by B. Krogman.

Reproduction

Estimates of vital rates and other life history information on bowhead whales come mainly from the western Arctic (Nerini et al., 1984). Conception is believed to occur primarily in March, although mating behavior has been observed from March to August. Gestation lasts for perhaps 13 months. Calves are apparently born from March into July, but the peak of parturition is during the spring migration, from April to June, with most calves thought to be born in May. Gray (1894) (from de Jong, 1983) also reported seeing "very young" animals (presumably calves) from early May to July in Davis Strait. Biological data from whales landed by Alaskan Eskimos suggest that the pregnancy rate is from 0.15 to 0.33 and that adult females produce a calf once each 3-6 years. Age at sexual maturity and other age-related parameters cannot be estimated at present because methods of ageing bowheads have not been successful (Nerini, 1983). Length estimates at various stages of growth are 4-4.5 m at birth, 8-8.5 m at one year, 13.5-14 m at (female) sexual maturity, and 18-20 m maximum length.

Estimates of the gross annual reproductive rate (i.e., the number of calves in proportion to all other animals counted) ranged from 3.6 to 12.4 percent (Cubbage and Rugh, 1982; Marquette et al., 1982; Nerini et al., 1984; Davis et al., footnote 3). After reviewing all estimates, Nerini et al. (1984) concluded that the probable value is less than 11.6 percent, but certainly more than 3.6 percent. Braham (In press) and Chapman (In press) suggest that the estimate lies between 5 and 10 percent. The bowheads' closest living northern relative, the right whale, *Baleana* (or *Eubalaena*) *glacialis*, is reported to have an estimated gross reproductive rate of 4.4-6.9 percent (IWC, 1984), but this is based upon a small sample.

Natural Mortality

The rate of natural mortality has not been estimated for bowhead whales. The Alaskan Eskimo harvest of about 20 per year is the only mortality factor that can be directly measured. Predation by killer whales, *Orcinus orca*, could, along with Eskimo hunting and ice entrapment, be mortality factors (Mitchell and Reeves, 1982). Mass mortality as a result of ice entrapment does occur, although with unknown frequency (Tomilin, 1957; Mitchell and Reeves, 1982; Nerini et al., 1984).

Exploitation and Population Size

History of Exploitation

Commercial whaling on the East Greenland-Spitsbergen stock began near Spitsbergen in about 1610, and by the late 1600's the Arctic coastal fishery had been exhausted (Zorgdrager, 1720; de Jong, 1978, 1983). This was the first bowhead fishery, dominated initially by land-based European whalers, such as the British, Dutch, Basques, and Germans, and later by pelagic whalers from other nations as well. The early fishery was the "east-ice" fishery from Spitsbergen to the Barents Sea, and then from 1642 to 1688 the "west-ice" pelagic fishery was active off eastern Greenland. Pelagic whaling allowed the whalers to follow the bowheads farther from land, into northern waters, and later in the year. Although bowheads were taken into the early 20th century, the fishery probably reached a low point during the early 18th century (Reeves, 1980; de Jong, 1983).

Soon after the turn of the 18th century, European whalers sailed into Davis Strait and found bowheads to be abundant. Between 1729 and 1738,

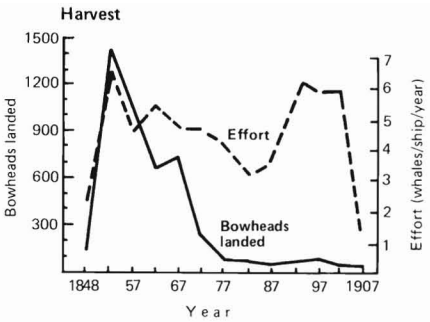


Figure 2—Most bowhead whales in the western Arctic stock were removed between 1850 and 1870, although whaling effort remained high into the 20th century (Braham et al., 1977).

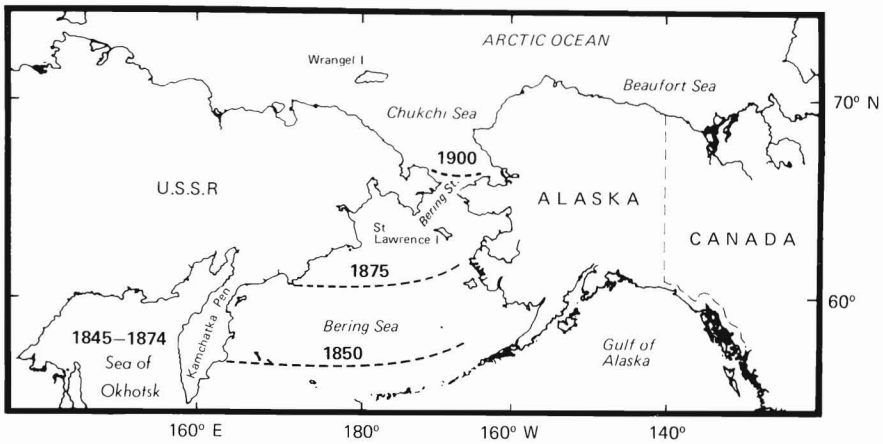


Figure 3.—Commercial bowhead whaling principally occurred in the Sea of Okhotsk from 1845 to 1874, and in the Bering Sea from 1848 to 1917. Within 20 years of the start of the fishery, the stocks were depleted, and no bowheads were taken south of the dashed lines after the dates indicated. Data from Townsend (1935) and Bockstoce and Botkin (1983).

4,000 were taken (Ross, 1979). By the mid-1700's, bowheads in Davis Strait were thought to be depleted, but large catches continued farther north in Baffin Bay into the 20th century (Reeves et al., 1983; Ross and McIver[5]). For 8 years (1765-72), the Hudson's Bay Company conducted bowhead whaling in Hudson Bay, but commercial whaling did not begin there until 1860 when about 1,000 animals were taken over a 40-year period (Ross, 1974; Mitchell and Reeves, 1982). Important reviews of whaling in the western North Atlantic have been published by Ross (1974, 1979), Mitchell and Reeves (1982), Reeves et al. (1983), and Ross and McIver (footnote 5).

In the North Pacific, commercial whaling for bowhead whales first began in the Sea of Okhotsk in 1845 and in the Bering Sea (western Arctic stock) in 1848 (Scammon, 1874). The Sea of Okhotsk fishery shifted principally to the Bering Sea between 1849 and 1852 after Captain Roys "discovered" bowheads in the Bering Strait region in 1848. In 1849, Yankee crews from 154 ships killed over 1,500 bowheads in the Bering Sea (Bockstoce and Botkin, 1983). By 1852, apparently so few bowheads were found in open water south of the Bering Strait and weather conditions were so poor that the whalers returned to the northern Sea of Okhotsk where they intensively pursued bowheads until 1857 (Kugler and Henderson, In press). In 1858, Yankee whalers in the Sea of Okhotsk once again sailed back through the Bering Strait and intensified the fishery in the Chukchi Sea and Arctic Ocean. Although the Sea of Okhotsk fishery continued into the early 20th century, it had essentially failed by 1874 (Kugler and Henderson, In press).

Within the first two decades of the fishery in the Bering, Chukchi, and Beaufort seas (1850-70), over 60 percent of the stock was removed (Fig. 2), and over the 65- to 70-year history of this fishery, some 18,650 bowheads were killed (Bockstoce and Botkin, 1983). By 1900, pelagic whalers had great difficulty finding bowheads south of Bering Strait from June to October (Fig. 3). A shore-based fishery operated from several U.S. and Soviet Eskimo villages on the Bering and Chukchi Seas from the 1880's to about 1909 (Marquette and Bockstoce, 1980). The low point of the bowhead population probably occurred near the end of the pelagic fishery (about 1914), but the recovery rate during this century is unknown (Fig. 4). Breiwick et al. (1984), in

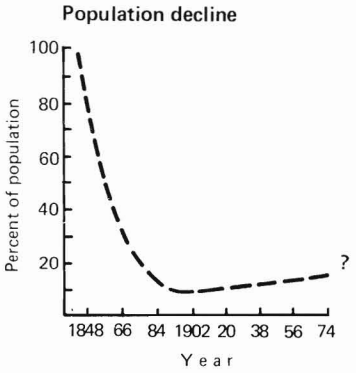


Figure 4.—The population decline and possible increase of the western Arctic stock since the end of commercial whaling is the author's approximated projection using information from Townsend (1935), Eberhardt and Breiwick (1980), Breiwick et al. (1981, 1984), and Bockstoce and Botkin (1983).

[5]Ross, W. G., and A. McIver. 1982. Distribution of the kills of bowhead whales and other sea mammals by Davis Strait whalers, 1829-1910. Unpubl. manuscr., 75 p. Arct. Pilot Proj., Petro Can., 550-6th Ave., S.W. Calgary, Alberta, T2P-144, Can.

modelling the population life history parameters, predicted that recovery has been very slow, if at all, in the face of a continued small harvest by Alaskan Eskimos.

Pre-exploitation and Current Stock Sizes

A summary of estimates of abundance for bowhead whales is provided in Table 1. The East Greenland-Spitsbergen stock is thought to have been the largest of all the stocks, perhaps numbering 25,000 in 1679, about 70 years after the beginning of the fishery (IWC, 1978; Mitchell[6]). The current population size is unknown, but probably is very small, as fewer than 20 live individuals have been seen since World War II. Jonsgård (1981) stated his belief that this stock is nearing extinction.

Mitchell and Reeves (1981) estimated that there were at least 11,000 bowheads in the Davis Strait stock in 1825, and 680 in the putative Hudson Bay stock in 1859. Although several field surveys and literature review studies have been conducted since 1971, there is no quantitative estimate of the current stock size in the western North Atlantic. Reeves et al. (1983) stated that the population probably "numbers only a few hundred."

The size of the western Arctic stock in 1848 is thought to have been about 18,000 (IWC, 1983), although other estimates range from 8,000 to 40,000 (Breiwick et al., 1981; Bockstoce and Botkin, 1983; Breiwick and Mitchell, 1983; Tillman et al., 1983). The minimum estimate of current abundance, based on visual census studies conducted since 1978 near Point Barrow, Alaska, is 3,871 with a standard error of 254 (IWC, 1984). These estimates of current population size are about 20 percent of the population size prior to the beginning of commercial whaling in 1848.

Table 1.—Estimates of abundance for the world's stocks of bowhead whales.

	Population size estimates			
	Early whaling period		Current	
Stocks	Year	Estimate	Year	Estimate
North Atlantic				
E. Greenland-Spitsbergen	1679	[1]25,000	1980	Nearing extinction[2]
Davis Strait	1825	[3]11,000	1983	Unknown[3]
Hudson Bay	1859	[3]680	1983	Unknown[3]
North Pacific				
W. Arctic	1848	[4]18,000	1983	[5]3,871
Sea of Okhotsk	1845	Unknown[6]	1981	Unknown[7]

[1]International Whaling Commission (1978), Jong (1978), and Mitchell (text footnote six).
[2]Jonsgård (1981) believes they are nearing extinction, whereas International Whaling Commission (1978) and Reeves (1980) believe it to be "at a very low level."
[3]Mitchell and Reeves (1981) and Reeves et al. (1983) report these estimates based upon a literature survey and some whalers logbooks and records for the two putative stocks: "Davis Strait Stock" and "Hudson Bay Stock"; the current population size for the eastern North American Arctic may be a few hundred, although this is not based upon quantitative census studies.
[4]The precommercial whaling population size has been variously estimated at no lower than 8,000 (Breiwick et al, 1981) to a high of 40,000 (Bockstoce and Botkin, 1983). Further assessment of the problem resulted in a "best estimate" of 18,000 (International Whaling Commission, 1983).
[5]International Whaling Commission (1983), based upon an evaluation of spring census counts made since 1978, considered this a minimum estimate with a standard error of 254.
[6]Two estimates have been reported: 6,500 by Berzin and Doroshenko (1981), who cite "(U.K., 1979)" but do not list this reference within the literature cited, and about 10,000 by Ivashin (text footnote 7). But no data and no methods of estimation were provided; hence, these estimates cannot be considered acceptable. David Henderson (New Bedford Whaling Museum, New Bedford, MA 02740, during a conversation at the IWC special meeting on right whales, 13 June 1983, Boston, Mass.) reported working on the 19th century Yankee logbooks and whaling records for the Sea of Okhotsk, and I expect a reliable estimate of initial abundance is forthcoming (e.g., Kugler and Henderson, In press).
[7]On the basis of three vessel and aerial surveys in 1967, 1974, and 1979, Berzin and Vladimirov (1981) and Ivashin (text footnote 7) concluded that the population was perhaps a few hundred.

No satisfactory estimate of abundance is available for any period for bowheads in the Sea of Okhotsk. Ivashin[7] estimated that the population was at least 10,000 when commercial whaling began (about 1845). An estimate of 6,500 in the IWC literature (IWC, 1983) cannot be verified. None of these estimates seem to be based on comprehensive analayses of available data, such as from whaler's logbooks, journals, or notes, and there is conjecture as to whether right whales and bowheads were separated in the catch data used to make the estimates (IWC, 1983). No estimate of current abundance has been made; Soviet scientists at IWC Scientific Committee meetings have stated since 1981 that there are at least a few hundred. They base this on the three surveys (discussed earlier) in the southwestern Sea of Okhotsk (Berzin and Doroshenko, 1981).

Management

Two highly visible problems facing management are the American Eskimo subsistence hunt and oil and gas development activities in the Arctic. The Alaskan Eskimo harvest of about 20-25 whales per year is currently under IWC quota: The 1984-85 quota is 43 strikes, with no more than 27 strikes allowed for 1984. It remains unclear if this level of removal will ensure growth in the population but projections using life history and harvest data (including struck and lost mortality estimates) suggest that it may (Breiwick et al., 1984). An Alaskan Eskimo take of bowheads is permitted by exemptions in the Marine Mammal Protection Act of 1972, Endangered Species Act of 1973, and by the current IWC schedule on aboriginal/subsistence whaling. If the number of bowheads in the other stocks is as low as suspected, then certainly no harvest is warranted.

Oil and gas development activities have been underway in the Canadian Beaufort Sea since the early 1970's, and is beginning in Alaskan waters throughout much of the bowhead's range. Those areas of particular concern are 1) the southern Beaufort Sea, which serves as the major feeding

[6]Mitchell, E. D. 1977. Initial population size of bowhead whale (*Balaena mysticetus*) stocks: Cumulative catch estimates. Unpubl. manuscr. Arc. Biol. Sta., 555 St. Pierre Blvd., Ste. Anne de Bellevue, Quebec, H9X 3L6, Can. (Submitted to IWC Sci. Comm., Canberra, Aust., June 1977, as SC/29/Doc. 33.)

[7]Ivashin, M. 1982. Russian hunting for right whales in the Sea of Okhotsk (18th-19th centuries). Unpubl. manuscr. All-Union Sci. Res. Inst. Mar. Fish. Oceanogr. (VNIRO), Moscow. (Submitted to IWC Sci. Comm., Cambridge, Engl., June 1982, as SC/34/PS21.)

Alaskan Arctic spring ice conditions; a bowhead whale surfaces in the near shore lead. Only a small part of the animal's back is visible to the Eskimo whalers. Photo by G. Carroll.

ground for summering bowheads, in particular from southern Amundsen Gulf, Canada, to Point Barrow, Alaska; 2) the northwest Bering Sea and eastern Chukchi Sea, where bowheads spend the months of March to June migrating, calving, and mating and, September to December, migrating and perhaps feeding; 3) the Bering Strait, an important constriction in their spring and autumn migration; and 4) the central Bering Sea, where bowheads winter and perhaps mate (March). To provide meaningful management advice, greater information is needed on specific migration patterns, behavior (e.g., habitat use), and population production, particularly for the eastern North American Arctic stock(s), as less work has been conducted there in relation to future exploratory activities than in the western North American Arctic.

Conclusions

All stocks of bowhead whales were severely depleted during the commercial whaling era prior to the 20th century. The western Arctic stock is the least depleted of all stocks, with about 20 percent of the 1848 population remaining today. When commercial whaling came to a halt between 1911 and 1917, the western Arctic stock was probably not less than 1,000 animals (Eberhardt and Breiwick, 1980) and, given the current population size estimate of about 4,000, it seems reasonable that it was larger than 1,000 in 1917 (Breiwick et al., 1984). However, because of the uncertainties in the 1917 population size, and the difficulty of estimating or measuring certain life history parameters (e.g., natural mortality), the rate of recovery cannot be precisely determined.

Reliable estimates of the current population sizes for the other three or four stocks of bowheads are not available, but they probably number no more than a few hundred individuals each. If so, then all stocks of bowheads, with the exception of those in the western North American Arctic, are no greater than 5 percent of their initial population size.

Because of their low population numbers, their habit of frequenting coastal waters during vulnerable periods of their annual cycle (i.e., calving and feeding), and apparent low reproductive rate, bowheads may be particularly vulnerable to the development activities of humans. With some stocks, removal of a few individuals could be significant. A rigorous policy of habitat conservation and research is needed throughout the Arctic.

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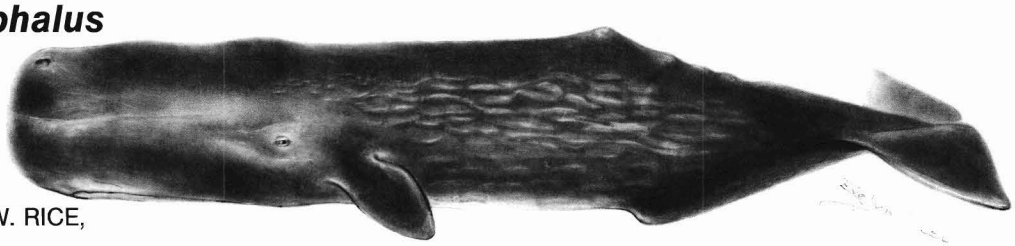
The Sperm Whale, *Physeter macrocephalus*



MERRILL E. GOSHO, DALE W. RICE, and JEFFREY M. BREIWICK

Introduction

The sperm whale *Physeter macrocephalus* Linnaeus, 1758[1], is the largest of the toothed whales (Odontoceti). In the past, males as large as 20 m (65 feet) in length have been recorded; today, however, males larger than 18 m (60 feet) are rare. The maximum length of female sperm whales is 12 m (40 feet) (Berzin, 1971). The average size of a calf at birth is 4 m (13 feet) (Ohsumi, 1965). Gaskin (1972) reported that sperm whales can reach a maximum age of 50 years.

The sperm whale is distinguished by an unusually large head that is from about one-fourth to one-third of its total body length. It is the only living cetacean that has a single blow hole asymmetrically situated on the left side of the head near the tip. The Y-shaped lower jaw on the underside of the head contains two rows of 20-30 erupted teeth.

The interior of the mouth and the surrounding area are often white, in contrast to the rest of the dark body, which has been variously described as black, dark bluish-gray, slate gray, iron gray, purplish brown, grayish-brown, or blackish-brown. The sperm whale has no dorsal fin; however, a hump or a series of humps are present along the dorsal surface of the tail-stock. The skin of the trunk is corrugated into many series of longitudinal ripples.

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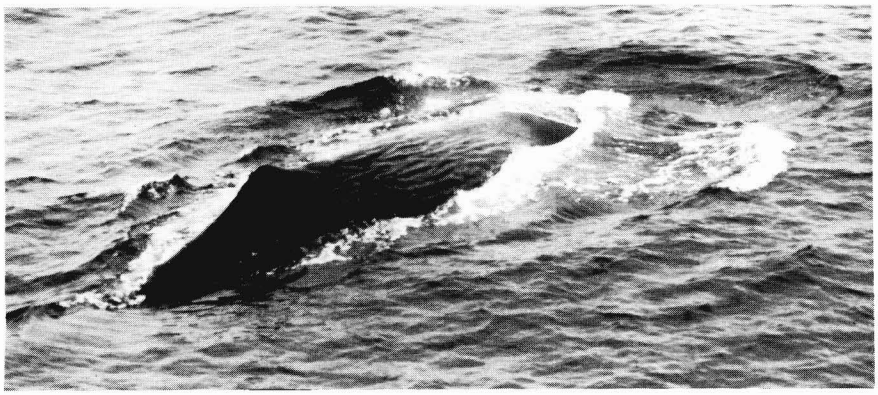
[1]This name is used instead of *Physeter catodon* according to Husson and Holthius, 1974.



A sperm whale surfaces in the Southern Ocean. Note the characteristic wrinkled appearance of the body surface and the obtusely rounded dorsal hump. Photo by G. Joyce.

Sperm whales have a strong schooling instinct, forming schools of females and young, young males, and mixed ages and sexes. The older adult males are often solitary and tend to migrate to higher latitudes than do the females and younger animals.

Sperm whales are noted for their ability to make prolonged deep dives. Large adult males can remain submerged for over an hour, while females and younger animals usually surface after 15-20 minutes (Rice, 1978). Clarke (1976) observed two large adult male sperm whales diving off Durban, South Africa, in water over 3,193 m (10,476 feet) deep. The whales made dives lasting 82 and 83 minutes; when captured later their stomachs contained bottom-dwelling sharks.

The head of the sperm whale contains the spermaceti organ, which is a large reservoir for spermaceti oil. Sperm whales are hunted for this oil as well as for the lower grade oil contained in the blubber. The remainder of the whale is processed into animal feed, fertilizer, and, to a limited extent, human food and pharmaceuticals.

Distribution and Migration

Habitat

Sperm whales inhabit all oceans of the world. Their distribution is dependent on their food source and suitable conditions for breeding, and varies with the sex and age composition of the groups.

These whales usually inhabit the offshore waters. Berzin (1971) reported that sperm whales are restricted to waters deeper than 300 m (1,000 feet), while Watkins (1977) reported that they are usually not found in waters less than 1,000 m (3,300 feet) deep. When found close to land, the sperm whale concentrations are usually associated with a sharp drop in depth of the bottom where upwelling occurs. In these areas, organic production is high, implying the presence of a good food supply (Clarke, 1956; Berzin and Rovnin, 1966).

Deep-water cephalopods (squids) are the major food of sperm whales. Global cephalopod distribution is influenced by such factors as their inability to withstand salinities below 30 ‰ and a temperature requirement of 10°-20°C which is necessary for their eggs to develop (Akimushkin, 1963). Berzin (1971) reported that the occurrence of sperm whales is rare in the Yellow and East China Seas, the Sea of Japan, and the Baltic Sea; these seas are relatively shallow and have a low salinity.

During the summer, sperm whales migrate to higher latitudes; the mature males migrate much farther poleward than do the females and younger males. The females and younger animals may be restricted in their migrations by an intolerance to low water temperatures. Nishiwaki (1967) reported that female sperm whales in the North Pacific do not migrate into waters having a temperature lower than 10°C. Gilmore (1959) reported that harem herds with mixed sexes and ages are restricted by the 20°C isotherm, although Gaskin (1972) observed nursery schools with very small calves in waters to the east of New Zealand with a temperature of 14°-16°C. Because breeding herds are confined almost exclusively to the warmer waters, many of the larger male sperm whales return in the winter to the lower latitudes to breed.

In the Northern Hemisphere, sperm whale stocks are believed to be segregated units. However, in the Southern Hemisphere (Fig. 1a, b), there could be a gradual mixing of both male and female sperm whales around the southern coasts of Africa and Australia, and of males south of Cape Horn (Mackintosh, 1965). It is not clear if the mature males which migrate to higher latitudes always return to the same breeding herds (Gaskin, 1972).

Pacific Ocean

During the summer, sperm whales are widely distributed throughout the entire Pacific Ocean. The females and young sperm whales usually remain in tropical and temperate waters between lat. 45°N and lat. 45°S (Rice, 1978), while the males continue north to the Gulf of Alaska, Aleutian Islands, and Bering Sea, and south to the Antarctic. The northernmost boundary for male sperm whales is from Cape Navarin (lat. 62°N) to the Pribilof Islands (Omura, 1955). Sperm whales are usually distributed below lat. 40°N during the winter.

In the spring, sperm whales in the western North Pacific begin to migrate from the Philippines to the southern coast of Japan, along the

An immature male sperm whale lies on the slipway of the former whaling station at Coal Harbour, Vancouver Island, B.C. Note the large barrel-like head and the long, narrow lower jaw. Photo by D. W. Rice.

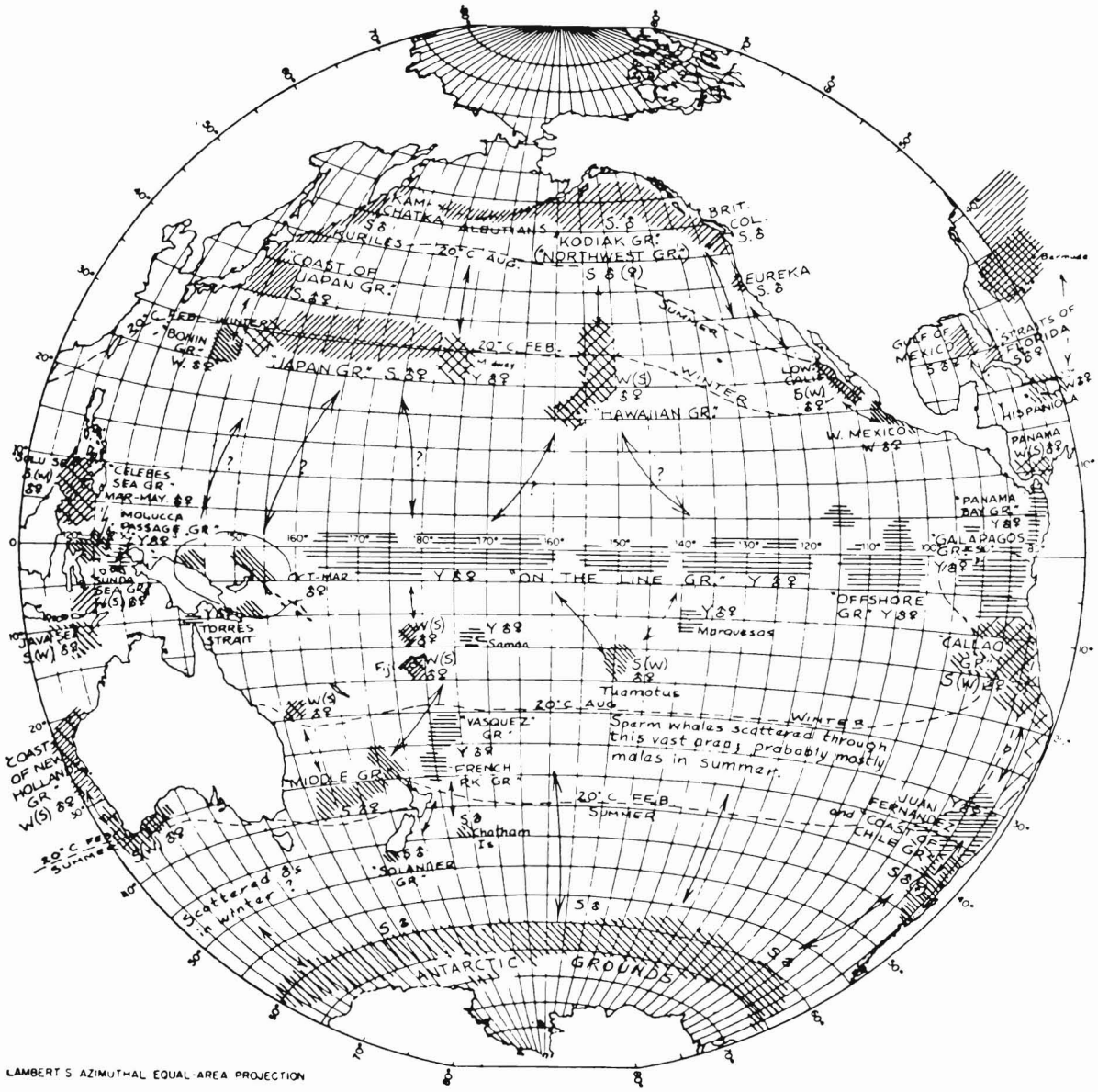


Figure 1a.—Pacific Ocean distribution of sperm whales based on past commercial catches (Gilmore, 1959).

Japan coast to the Kurile Islands, and up to Kamchatka (Berzin, 1971). Many of the mature males leave their herds to continue northward to the Aleutian Islands, Bering Sea, and the Gulf of Alaska (Ohsumi, 1966; Ohsumi and Masaki, 1977).

In the eastern North Pacific, sperm whales are commonly found off central California, although very few are present in midsummer. Two annual peaks of abundance occur off central California in mid-May and mid-September, which suggest a northward migration in the spring and a southward migration in the fall. During the winter, breeding schools of sperm whales are frequently sighted over the continental slope off California from lat. 33°N to lat. 38°N from November to April (Rice, 1974). During the summer, sperm whales are found in the Gulf of Alaska, Aleutian Islands, and southeastern Bering Sea.

Sperm whaling grounds in the Pacific south of lat. 40°N (Fig. 1a) were historically located around the Hawaiian Islands, from the Bonin Islands to Midway Island, from the Philippines and Borneo along the

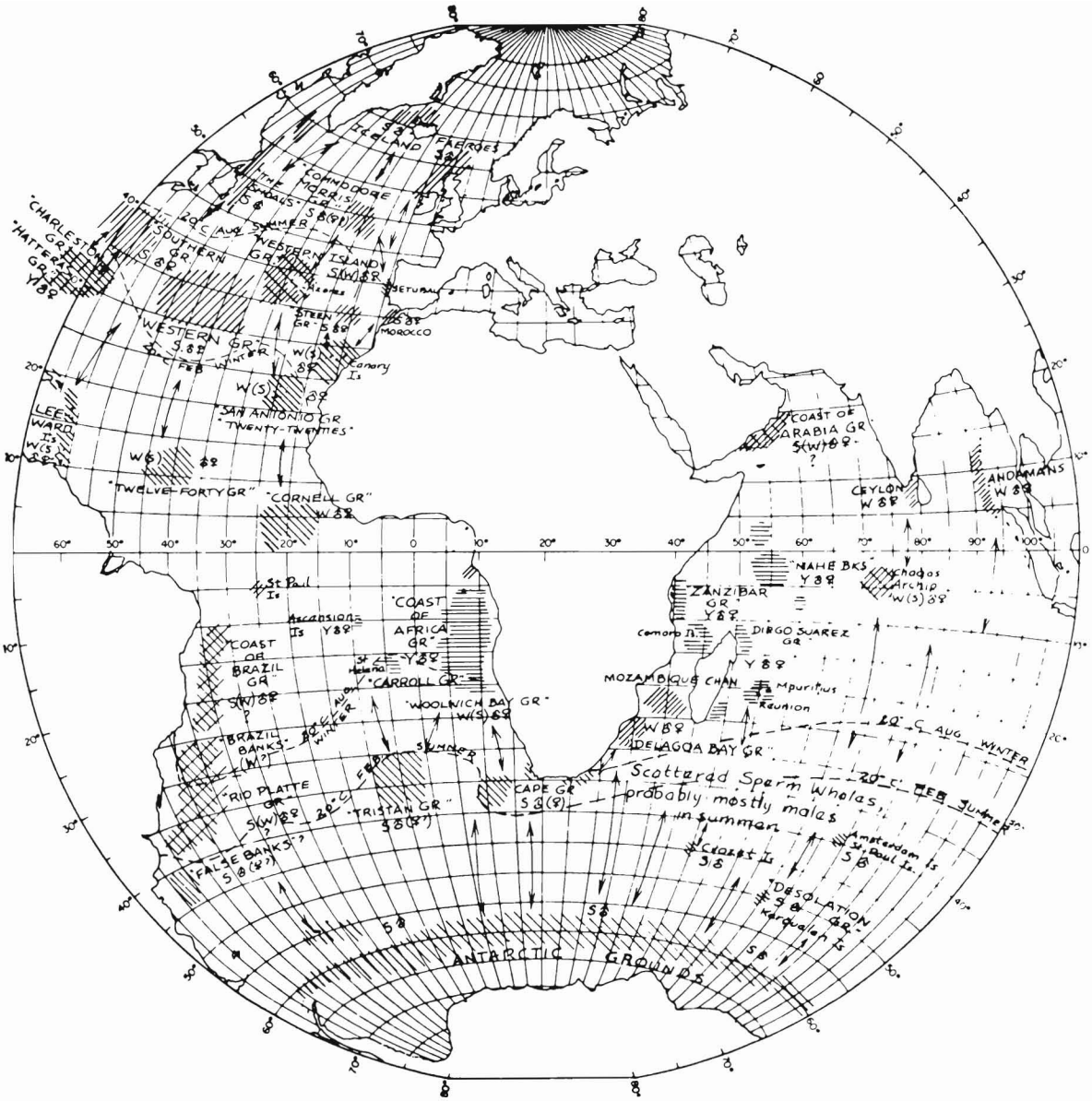


Figure 1b. – Atlantic and Indian Ocean distribution of sperm whales based on past commercial catches (Gilmore, 1959).

Equator to South America, along the western coast of South America, and around the Society Islands, the Marquesas, Fiji, Samoa, New Zealand, and in the Tasman Sea (Townsend, 1935).

Atlantic and Arctic Oceans

The northernmost limit of male sperm whales is approximately lat. 70°-75°N in the Arctic Ocean (Berzin, 1971). Sperm whales have been reported as far north as Spitsbergen, west of Jan Mayen Island, the southeastern Barents Sea off the Murman Coast, and the Kanin Peninsula. Female sperm whale sightings have occurred as far north as lat. 54°N in the North Atlantic, although female and young sperm whales are generally restricted to latitudes less than lat. 40°N (Slijper, 1962).

Past sperm whaling grounds in the Gulf of Mexico, Caribbean Sea, and off the southeastern United States are shown in Figure 1a, while those in the rest of the Atlantic Ocean are shown in Figure 1b. In addition, small numbers of sperm whales were taken during the summer in Davis Strait, off

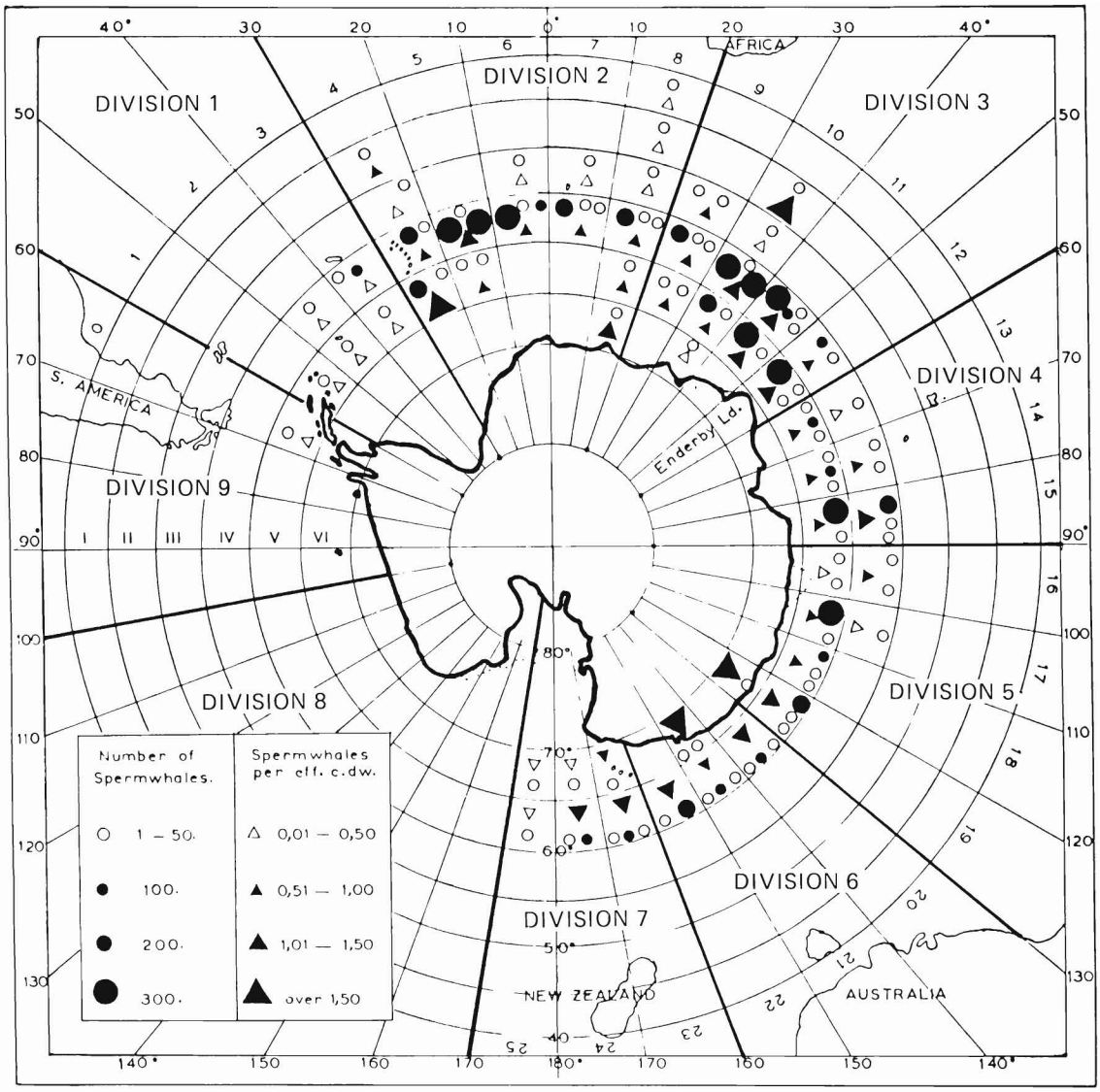


Figure 2.—Total catch of sperm whales in the Antarctic and average yield of sperm whales per effective catcher's day's work (c.d.w.) for seasons 1950-51, 1951-52, 1954-55, and 1955-56 apportioned between squares of 5 degrees latitude and 10 degrees longitude (Holm and Jonsgård, 1959).

Labrador, Newfoundland, Greenland, Iceland, Norway, and around the Faroe and Shetland Islands; they frequently appear off the coasts of Scotland, England, Ireland, and the Netherlands, and strandings often occur there. Sperm whales also occur in the Bay of Biscay, off the west coasts of Spain and Portugal, and in the Mediterranean Sea (Berzin, 1971).

Tomilin (1957) believed that sperm whales followed the warm Gulf Stream and West Greenland currents along the North American coast as far as Davis Strait in the summer and returned to the Gulf of Mexico, Antilles, and Bermuda in the winter to breed. However, Mitchell (1975) reported that a male sperm whale, tagged in 1966 off Nova Scotia, was captured over 7 years later off Spain in August 1973.

Tomilin (1957) also believed that in the eastern North Atlantic sperm whales would summer in the northern areas and winter around the Azores, Madeira, Canary, and Cape Verde Islands. Martin (1982) reported that a 14 m (46-foot) male sperm whale captured off Iceland in August 1981 had previously been harpooned in the Azores in August 1980.

Sperm whales occur year-round off the coasts of southern Africa and South America (Berzin, 1971). The southernmost boundary of harem

animals in the South Atlantic appears to be around lat. 50°-54°S.

Indian Ocean

In the 18th and 19th centuries, sperm whaling in the Indian Ocean was conducted in all seasons. However, most whaling (Fig. 1b) occurred in the western half of the Indian Ocean (Townsend, 1935).

Gambell (1967, 1972) reported that sperm whales in the region around Durban were present year-round, moving into and out of the area at different times of the year; there was a net northward movement up the coast in the early part of the year. Bannister and Gambell (1965) believed that schools of sperm whales drifted south in the austral spring. In the central Indian Ocean, Soviet surveys found large concentrations of sperm whales to the north of St. Paul and Amsterdam Islands in December and January (Berzin, 1971).

Bannister (1969) reported that, in the summer, sperm whales follow the coastlines of Australia, moving southward along the western coast and westward or southwestward along the southern coast. Bannister (1969) also hypothesized that three stocks inhabited the Indian Ocean: One off the southeast coast of Africa, an oceanic stock around Amsterdam and St. Paul Islands, and an eastern stock off western Australia.

Antarctic

Male sperm whales travel up to the ice edge in the Antarctic (Berzin, 1971). Sperm whales are more evenly distributed in the Antarctic than at lower latitudes and travel from one region to another around the Antarctic in search of food (Kirpichnikov, 1950). Holm and Jonsgård (1959) reported that sperm whales were particularly abundant from long. 70°W eastward to long. 170°W (Fig. 2).

Because female sperm whales do not enter Antarctic waters, the 20th-century fishery there was exclusively for males. Sperm whaling in the Antarctic took place mainly during the austral summer (December to March). After summering in the Antarctic, the males travel to their wintering grounds. Best (1969) reported the presence of a skin-film containing Antarctic diatoms on male sperm whales taken off the southwest coast of South Africa in April and May. This diatom is rarely present in warmer waters and indicates that these animals had recently arrived from the Antarctic. This skin film of Antarctic diatoms was also found on sperm whales in Albany (southwest Australia) and New Zealand by Bannister (1968; 1969) and in South Georgia by Matthews (1938).

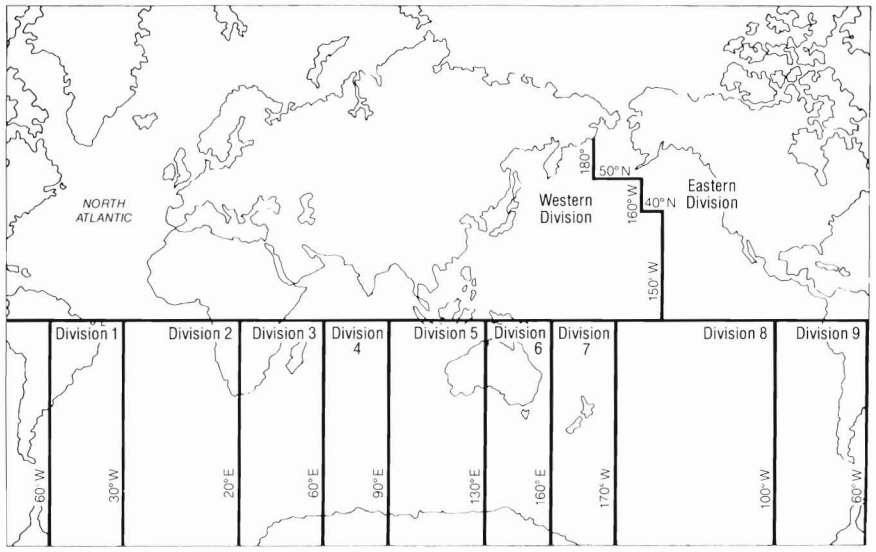


Figure 3.—Sperm whale stock divisions of the International Whaling Commission.

IWC Sperm Whale Stocks and Divisions

To make population assessments and manage the world sperm whale stocks, the International Whaling Commission (IWC) has divided the world oceans into the following areas: North Pacific, North Atlantic, Indian Ocean, and Southern Hemisphere (Fig. 3).

The IWC reported the possibility that more than two stocks of sperm whales may inhabit the North Pacific; however, because of a lack of data precisely delineating the geographical boundaries, and because the mature males from these different stocks may intermingle in the Bering Sea, the North Pacific Ocean was divided only into Eastern and Western Divisions (Fig. 3) (Allen, 1980; IWC, 1980a).

In the North Atlantic Ocean, there is no indication that more than one sperm whale stock exists. For this reason, the IWC treats sperm whales in the North Atlantic as a single stock for management purposes (IWC, 1981).

At present, there is no clear-cut evidence that sperm whales in the Indian Ocean north of the Equator are from the same stocks as those south of the Equator (IWC, 1980b). The latter are treated as Southern Hemisphere sperm whale stocks for management purposes. Southern Hemisphere sperm whales are separated into nine divisions extending from the Antarctic ice edge to the Equator and between the meridians of longitude shown in Figure 3.

Life History and Ecology

Feeding

Sperm whales feed mainly on medium- to large-sized mesopelagic squids, including the giant squids *Architeuthis* and *Moroteuthis*; adult males generally take larger squids than do the females and immature males. Sperm whales—especially mature males in higher latitude

waters—also take a significant quantity of large demersal and mesopelagic sharks, skates, and fishes (Berzin, 1971; Clarke, 1980).

Reproduction

Sperm whale populations are organized into two types of groupings (Best 1979): 1) Breeding schools (also called harem schools or mixed schools) and 2) bachelor schools. Older males are often solitary.

Breeding schools consist of females of all ages and juvenile males, and usually contain about 20-40 individuals (larger groups of up to several hundred appear to be assemblages of two or more schools). The mature females ovulate in spring and early summer—April through August in the Northern Hemisphere and October through February in the Southern Hemisphere (the breeding season of equatorial populations is not known). During this season, one or more large mature bulls temporarily join each breeding school.

The calves, which average about 4 m (13 feet) long at birth, are born after a gestation period of about 15 months. The lactation period lasts 1-2 years, but the calves probably begin taking solid food long before weaning. Females attain sexual maturity at a mean age of 9 years, when they average 9 m (30 feet) long. They remain in the breeding schools and produce a calf every 3-6 years. In males, puberty is prolonged; beginning at about 9 years of age and a body length of 9 m (30 feet), it reaches completion when the testes are fully spermatogenic at about 20 years of age and a body length of 12 m (39 feet).

Bachelor schools consist entirely of males, which, as they approach physiological sexual maturity, leave the breeding schools and aggregate in loose groups of up to about 40 animals. Males continue to grow long after sexual maturity. As they grow older, they become less gregarious, and by the time they are about 30 years old and 13 m (43 feet) long, they remain solitary most of the year; at this age, they have attained "social" maturity and consort with the breeding schools only during the mating season.

Natural Mortality

Important natural mortality factors are unknown. Although the sperm whale is renowned for occasional mass strandings of entire schools, this factor is insignificant in terms of overall mortality. Estimates of total natural mortality rates in different areas range from 0.05 to 0.09 per year (IWC, 1971).

Exploitation and Population Size

History of Exploitation

The abundance of whales along the eastern coast of America was one of the main reasons for the early settlement of Cape Cod by the English. During the 17th century, the animals were hunted close to shore and catches consisted primarily of humpback, *Megaptera novaeangliae*, and right, *Balaena glacialis*, whales. Sperm whaling began on the New England coast around 1712 (Harmer, 1928; Starbuck, 1878).

Humpback, right, and sperm whales are relatively slow-swimming whales and were accessible to early whalers using open boats. Furthermore, these whales floated after death. During the 17th and first half of the 18th centuries, the whales were killed and towed back to shore stations for processing. The whale oil which was produced by this process was used for lighting, lubrication, and softer kinds of soap (Tønnessen and Johnsen, 1982).

The on-board tryworks and the spermaceti candle were developed about 1750. The on-board tryworks enabled the whaling ships to process the whales on the whaling grounds without having to return to port with each catch. The spermaceti candle was a smokeless candle which increased the market for spermaceti oil (Kugler, 1981).

In 1762, about 78 U.S. vessels were engaged in whaling; this number increased to 125 by 1770 (Scammon, 1874). Searching for whales, these vessels visited various parts of the Atlantic (off Newfoundland, Cape Verde, Brazil, and the Falkland Islands), the Caribbean Sea (off the West Indies), and the Gulf of Mexico (Harmer, 1928; Scammon, 1874).

England began sperm whaling in 1785; France followed in 1790. Although France had 40 vessels engaged in sperm whaling, the French Revolution forced an end to its whaling (Harmer, 1928). By the end of the 18th century, Portugal had also begun sperm whaling (Slijper, 1962).

Between 1787 and 1791, some ships began venturing around Cape Horn to the Pacific Ocean, while others moved into the Indian Ocean. Around 1800, U.S. whalers were operating off Peru, Chile, and the Galapagos Islands. In 1802, they traveled to New Zealand and the Molucca Islands. In 1822, more than 30 ships were hunting for sperm whales off the coast of Japan; this number increased to 100 by 1835 (Harmer, 1928; Scammon, 1874). Harmer (1928) reported that by 1842 there were 594 U.S. whaling vessels and 230 from other nations.

By 1846, Hawaii had become an important whaling center, harboring more than 600 ships. In addition, numerous whale oil merchants and ship's chandlers had moved their businesses there (Slijper, 1962). However, from 1846 Yankee whaling began to decline.

The number of U.S. vessels engaged in all whaling had increased from 500 in 1835 to 736 in 1846 (Table 1). However, the number of U.S. whaling vessels had dropped to 514 by 1861 and to 124 by 1886. Furthermore, not all of these vessels were engaged solely in sperm whaling. Harmer (1928) reported that the sperm whaling fleet consisted of 315 U.S. vessels in 1844, 231 vessels in 1870, and dropped to 134 vessels in 1875.

The estimated annual sperm whale catch also declined during this period, fluctuating between 6,000 and 8,000 sperm whales from 1835 to 1845 and between 3,000 and 5,000 sperm whales from 1846 to 1861. By 1886,

Table 1.—Number of U.S. whaling vessels, barrels of sperm oil, and estimated sperm whale catch[1], (1835-72 data from Scammon, 1874; 1877-86 data from Clark, 1887).

Year	U.S. whaling vessels[2]	Barrels of sperm oil	Est. sperm whale catch	Year	U.S. whaling vessels[2]	Barrels of sperm oil	Est. sperm whale catch
1835	500	172,683	7,598	1859	625	91,408	4,022
1836	507	132,130	5,814	1860	569	73,708	3,243
1837	509	181,724	7,996	1861	514	68,932	3,033
1838	550	131,856	5,801	1862	423	55,641	2,449
1839	676	150,000	6,600	1863	353	65,055	2,862
1840	559	157,791	6,943	1864	307	64,372	2,833
1841	585	159,304	7,009	1865	276	33,242	1,463
1842	594	165,637	7,288	1866	263	36,663	1,614
1843	627	166,985	7,347	1867	312	43,433	1,911
1844	647	139,594	6,142	1868	329	47,174	2,076
1845	696	157,917	6,949	1869	336	47,936	2,109
1846	736	95,217	4,190	1870	321	55,183	2,428
1847	723	120,753	5,313	1871	288	41,534	1,827
1848	659	107,976	4,751	1872	218	44,881	1,975
1849	614	100,944	4,442				
1850	543	92,892	4,088	1877	163	41,119	1,810
1851	553	99,591	4,382	1878	179	43,508	1,914
1852	620	78,872	3,471	1879	178	41,308	1,817
				1880	173	37,614	1,656
1853	661	103,077	4,535				
1854	668	73,696	3,243	1881	177	30,600	1,346
1855	638	72,649	3,197	1882	161	29,884	1,315
1856	635	80,941	3,562	1883	147	24,595	1,082
1857	655	78,440	3,452	1884	144	22,670	998
1858	654	81,941	3,606	1885	133	24,203	1,065
				1886	124	23,312	1,025

[1]Sperm whale catch estimated using 25 barrels per sperm whale plus 10 percent for mortally wounded and lost whales not landed.
[2]All U.S. whaling vessels, not solely sperm whaling vessels.

Table 2.—Estimated catch[1] and effort for sperm whaling, 1800-1909 (IWC, 1969).

	U.S. sperm whaling						Worldwide		
Decade	Yearly barrels of oil	Gross tonnage of registered whalers	Barrels per ton of boat	Avg. no. of whales per vessel per year[2]	Avg. voyage length (yr)[2]	Average barrels per whale[1]	Yearly total catch in barrels	Avg. no. of whales per year	Add 15 percent wounded + ship-wreck
1800-09	11,910	5,810	2.05	37.0	1.0	(24.0)est.	19,850	827	951
1810-19	14,726	6,127	2.40	19.7	1.2	(24.0)est.	22,655	944	1,201
1820-29	64,951	35,896	1.81	30.6	2.0	24.0	92,787	3,866	4,446
1830-39	126,334	88,039	1.43	23.3	2.0	33.0	147,414	4,467	5,137
1840-49	130,628	145,557	0.90	15.6	2.2	36.2	145,790	4,027	4,631
1850-59	85,333	145,726	0.59	10.7	2.2	37.3	94,814	2,542	2,923
1860-69	53,616	90,903	0.59	10.5	2.1	32.9	59,573	1,811	2,083
1870-79	42,454	46,258	0.92	11.4	2.4	32.1	47,171	1,470	1,692
1880-89	24,617	25,744[3]	0.96	13.5	2.2	(30.2)net	27,352	906	1,042
1890-99	14,321	9,781[3]	1.46	24.0	2.0	(28.3)net	15,912	562	646
1900-09	16,382	5,711[3]	2.87	38.4	1.6	26.4	18,202	689	792
1910-19				42.5	1.5				
1920-29				24.3	1.0				

[1]The total catches, in numbers, were estimated from the U.S. production of oil, divided by the average production per whale, increased by the proportion of foreign vessels in the fishery, and by 15 percent to allow for whales wounded and dying, but not processed, and whales caught by vessels wrecked before returning to home port.
[2]Data from Townsend (1935).
[3]For these years, tonnage of steam whalers (introduced in 1881 and specializing in Arctic whaling) subtracted from total.

the estimated catch had dropped to 1,025 sperm whales.

Many factors contributed to the decline of the U.S. sperm whale fishery. Starbuck (1878) reported that whaling as a business declined because of the scarcity and shyness of whales, requiring longer and more expensive voyages. The catch per unit of effort (CPUE) (measured as the sperm oil production per ton of boat, or per vessel per year) for the 19th century (Table 2) shows a marked decline from the early years to a minimum in the 1850's and 1860's. This would be consistent with a decline in abundance of sperm whales as a result of heavy exploitation. An apparent recovery during and after the 1870's occurred when the effort decreased after the 1860's (IWC 1969).

Labor also became a problem for the U.S. whaling industry. In the middle of the 19th century, labor and capital were shifted away from whaling and shipping and into agricultural and mineral development, where greater profits existed. A skilled worker could earn two or three times as much onshore as he could in whaling (Tønnessen and Johnsen, 1982). Manpower was lost to the developing cotton industry (1846) and to the California gold rush (1849) (Slijper, 1962). Whaling crews were initially composed almost entirely of Americans, but were later recruited from foreign countries (Starbuck, 1878).

The American Civil War (1861-65) not only further reduced the labor force, but also destroyed a considerable portion of the whaling fleet. Confederate raider ships, such as the *Alabama* (McClung, 1978) and the *Shenandoah* (Starbuck, 1878) captured and sank many Yankee whaling ships.

During this period, sperm oil was receiving increasing competition from other means of illumination, notably from natural gas but also from vegetable oils, animal fats, baleen whale oil, and ultimately from petroleum (Kugler, 1981).

The sperm whale catch and effort continued to decline in the early part of the 20th century. In 1925, when the whaling vessel *John R. Manta* returned to New Bedford for the last time, the era of Yankee sperm whale hunting was over (Hegarty, 1959).

Modern mechanized whaling developed in Norway in the latter half of the 19th century and was initially used to exploit the faster swimming rorquals (blue, fin, sei, and Bryde's whales). The techniques of modern whaling involved the use of steam-driven (later, diesel-driven) whaling vessels, harpoons fired from cannons, and grenades, attached to the harpoon, which exploded in the whale. In 1863, the first steam-powered whaling vessel which had separate guns for

harpoon shots and grenade shots was introduced. In 1868, Sven Foyn perfected a cannon which combined the harpoon and grenade into one instrument (Tønnessen and Johnsen, 1982). In 1903, the first modern factory ship was used (Slijper, 1962).

Although some attempts were made to modernize American whaling methods, these were largely unsuccessful. The United States was never a major participant in modern mechanized whaling.

Table 3.—World catch of sperm whales (catch data for 1910-37 from Clarke, 1954; for 1938-82 from Committee for Whaling Statistics, 1959-1983).

Year[1]	Catch	Year[1]	Catch	Year[1]	Catch
1910	155	1935	2,481	1960	20,344
1911	302	1936	5,068	1961	21,130
1912	619	1937	7,392	1962	23,316
1913	465	1938	3,763	1963	27,858
1914	757	1939	5,511	1964	29,255
1915	861	1940	4,671	1965	25,548
1916	1,083	1941	5,641	1966	27,378
1917	513	1942	4,957	1967	26,424
1918	1,092	1943	5,503	1968	24,080
1919	1,219	1944	2,614	1969	23,929
1920	873	1945	1,669	1970	25,521
1921	796	1946	3,461	1971	22,642
1922	912	1947	7,546	1972	18,895
1923	740	1948	9,850	1973	22,305
1924	950	1949	9,016	1974	21,217
1925	1,475	1950	8,219	1975	21,045
1926	1,775	1951	18,281	1976	17,134
1927	1,441	1952	11,558	1977	12,279
1928	1,989	1953	9,577	1978	11,065
1929	2,074	1954	13,543	1979	8,536
1930	1,311	1955	15,593	1980	2,091
1931	597	1956	18,590	1981	1,456
1932	811	1957	19,156	1982	526
1933	1,423	1958	21,846		
1934	1,999	1959	21,298		

[1]Calendar years for all areas outside Antarctic. Antarctic seasons are 1909-1910, etc.

Table 4.—Estimates of initial (1910) and current (1982) sperm whale stock size for the North Pacific Ocean.

Area	Reference year	Sex and age	Exploitation population size
Western North Pacific[1]	Initial (1910)	Males (age 11+)	128,500
		Females (age 10+)	180,900
	Current (1982)	Males (age 11+)	61,000
		Females (age 10+)	137,100
Eastern North Pacific[2]	Initial (1910)	Males (age 13+)[3]	142,700
		Females (mature)	168,300
	Current (1982)	Males (age 13+)	111,400
		Females (mature)	162,600

[1]Data from IWC (1983). Based on length-specific model.
[2]Data from IWC (1979). Based on catch and effort data.
[3]Average age at recruitment.

From 1883 to 1924, the average annual worldwide catch was less than 1,000 sperm whales (Tables 2 and 3). After 1924, the annual catch increased, but until 1951 did not exceed 10,000 sperm whales. However, as the abundance of the larger rorquals decreased, greater attention was paid to the smaller rorquals and the sperm whales. Furthermore, following World War II, sperm whale oil once again came into demand as an extreme pressure lubricant and industrial wax (Frost, 1978). The catch of sperm whales reached 29,000 in 1964; the average annual catch worldwide between 1956 and 1976 was over 20,000 sperm whales.

In recent years, the catch of sperm whales has been reduced drastically as a result of the imposition of catch quotas. The sperm whale catch was 2,091 in 1980 and 1,456 in 1981. In 1982, only 526 sperm whales were taken worldwide.

Current and Initial Stock Sizes

Catch and effort statistics are used to assess the status of large cetacean stocks with varying degrees of success. The assumption is that CPUE, where effort is usually defined as the number of boat-days spent whaling or the number of hours spent searching, is proportional to population abundance. A major problem in assessing whale stocks using a time series of catch and effort data is standardizing effort so that units of effort in each year are equivalent. Factors such as vessel size, horsepower, captain and gunner experience, and technical advances are important considerations in standardizing effort.

The most important technical advance has been the introduction of echo-locating equipment such as ASDIC (Anti-Submarine Detection Investigation Committee), a type of sonar. In the baleen whale fishery the use of ASDIC tends to frighten whales, causing them to remain on the surface and thus become easier to catch. In catching sperm whales, ASDIC has been used to track whales underwater, so that the catcher boat could determine where the whale was likely to surface. Other factors which make standardization of effort difficult are captain and gunner skill. Comparison of CPUE series between vessels from different countries operating in the same fishery often show major differences due to these and other factors (Allen, 1980).

Another useful index of abundance is the number of whales sighted per unit of effort. More sophisticated techniques include cohort analysis (analysis of data by age groups over time) (Allen and Kirkwood, 1977) and a length-specific model which is based on the length composition of sperm whale catches (Beddington and Cooke, 1981). Models incorporating biological parameters such as changes in survival and pregnancy rate, harem size, and age at sexual and social maturity are also used in assessing sperm whale stocks. Tables 4-6 give

Table 5.—Estimates of initial (1905) and current (1981) sperm whale stock size (in thousands) for the North Atlantic Ocean.[1]

Population component	Reference year	Sex	Iceland	Azores	Spain[2] A	Spain[2] B
Exploitable	Initial (1905)	Males	28.6	13.6	12.6	12.9
		Females	NA[3]	30.2	28.0	28.6
	Current (1981)	Males	19.1	3.8	2.3	2.7
		Females	NA	18.5	15.2	15.9
Mature	Initial (1905)	Females	43.0	35.7	33.1	33.7
	Current (1981)	Females	38.9	19.7	15.7	16.7

[1]Data from IWC (1982). Separate estimates of the North Atlantic stock using a variant of the length-specific method.
[2]Two series of Spanish catch and effort data have been used.
[3]NA = no data available.

the most recent pre-exploitation and current stock size estimates for sperm whales in the North Pacific, and North Atlantic, and in the Southern Hemisphere.

Caution must be used in interpreting the population estimates in Tables 4-6. Although they are the most current estimates available, new analyses, using different data sets and biological parameters, may produce much different estimates. The estimates in Table 5 (North Atlantic) may be especially unreliable due to concern about the validity of certain assumptions of the estimation technique. There is also uncertainty in the assumption of a single stock. The estimates do suggest, however, that there has been a decline in abundance, more so in males than females.

Management

Sperm whale populations or stocks have been difficult to assess because of the number of factors required by the assessment models. These factors include: Effort, effort modifiers, pregnancy rates, natural mortality rate, age at recruitment, reserve male ratio, and a density-dependent exponent. Most relevant data required by the models are lacking or are not well understood. The length-specific model of Beddington and Cooke (1981) requires knowledge of the growth curve as well as other parameters and assumptions. The CPUE data are confounded by geographical variations in density of whales, problems in interpretation (with possibly two or more "real" populations being fished as one), seasonal and annual changes in availability, and the shifting of whaling operations with time.

Additionally, there are inconsistencies in the available population estimates (e.g., as reported by the Scientific Committee of the IWC) as well as difficulties in establishing stock identity. Inconsistencies between population estimates result from using different population models, each requiring different types of data and often different assumptions. There is also a lack of data for the more recent years, and, because of the IWC whaling moratorium, future data will probably be minimal.

At present there are zero quotas (no catch allowed) for sperm whales in the Southern Hemisphere, North Atlantic, and northern Indian Ocean. In the Western division of the North Pacific, the catch limits for the 1982 and 1983 coastal seasons (taken by Japan) are 450 and 400 whales, respectively (including an 11.5 percent bycatch of females).

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Table 6.—Estimates of stock size for Southern Hemisphere sperm whales.

Sex	Stock Division	Initial (1946) stock size A[1]	Initial (1946) stock size B[2]	Current stock size 1977[1]	Current stock size 1979[2]
Males	1	12,400		4,600	
	2	33,000	23,000	16,400	10,600
	3	38,400	25,700	13,700	6,600
	4	23,100	15,800	12,100	7,600
	5	21,900	15,800	7,400	4,200
	6	11,300		5,100	
	7	15,900		4,900	
	8	37,700		33,600	
	9	36,200	48,400	12,800	16,300
	Total	229,900		111,300	
Females	1	20,300		17,800	
	2	54,100	49,100	50,800	41,100
	3	63,000	55,000	52,600	42,900
	4	37,900	33,900	21,600	32,300
	5	35,900	33,800	34,100	30,800
	6	18,500		17,300	
	7	26,100		21,000	
	8	58,500		57,400	
	9	46,400		25,700	
	Total	360,700		299,400	

[1]Data from IWC (1978). Males 20+ years old (15+ years old for Div. 9); Females 10+ years old.
[2]Data from IWC (1980b).

A sperm whale surfaces off California. Note the single, open blowhole on the left side of the snout. Photo by D. W. Rice.

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U.S. Tuna Trade Summary, 1983

SAMUEL F. HERRICK, Jr. and STEVEN KOPLIN

Introduction

The year 1983 showed some signs of a turnaround for the U.S. tuna industry, which experienced a substantial decline in canned tuna sales, cannery receipts[1] of domestically caught and imported raw tuna, and domestic production activity during most of 1982. By the end of 1983, there was overall improvement in U.S. canned tuna sales, deliveries of raw tuna to U.S. canneries, and domestic processing activity.

Buoyed by a recovering U.S. economy and declining shelf prices, overall volume of canned tuna sales at the retail level was reported to have increased 7 percent for all of 1983. Improved retail sales acted to reduce the buildup of canned inventories that plagued the industry in 1982, and stimulated the flow of raw tuna through U.S. canneries. Cannery receipts of imported and domestically caught albacore, *Thunnus alalunga*, and tropical tunas (skipjack tuna, *Euthynnus pelamis*; yellowfin tuna, *T. albacares*; blackfin tuna, *T. atlanticus*; bluefin tuna, *T. thynnus*; and bigeye tuna, *T. obesus*) were up 6 percent from 1982, but were still 11 percent below the 5-year (1978-82) average volume of annual cannery receipts (Table 1). Despite fierce competition from foreign processors and record levels of canned tuna imports, overall canned tuna production rose 5 percent during 1983, though it was still 9 percent below the 1978-82 annual average (Table 1). These improvements in overall performance accompanied significant changes in the structures and operations of the U.S. tuna industry. These changes gained attention in 1982 and were heightened during 1983.

Due in part to the adverse effects of El Niño on tuna resources in the eastern Pacific Ocean[2] and continuing problems of access to traditional fishing grounds in this area, as well as the attraction of potentially more abundant tuna resources in the western Pacific Ocean, the movement of U.S. tuna purse seiners to the western Pacific accelerated during 1983. At least 60 of the 127 seiners comprising the U.S. tuna purse seine fleet operated in the western Pacific during 1983. U.S. seiners fishing in this area were quite successful, with regard to volume of catch, and for the first time, cannery receipts of domestically caught tuna from this area accounted for the greatest share of domestically caught cannery receipts by oceanic area: 171,153 short tons (tons), 60 percent of total domestically caught cannery receipts for 1983 (Table 2). Nevertheless, a significant portion of the U.S. tuna fleet—about 25 percent—was inactive all or part of 1983 for economical reasons. U.S. canneries continued to sell, or attempted to sell, interests they held in tuna purse seiners, reflecting the likelihood that tuna fishing under current conditions is more efficient or cost-effective when undertaken by independent vessels.

Table 1.—U.S. tuna cannery receipts and U.S. cannery production, 1982-83.

	Domestically caught			Imports			Total			Average	
Item	1982	1983	% Chg.	1982	1983	% chg.	1982	1983	% Chg.	1978-82	% Chg.
Cannery receipts[1]	228,156	285,554	+25	272,490	246,495	−9	500,646	532,049	+6	600,307	−11
Total pack[2]							27,088	28,382	+5	31,278	−9

[1]In short tons: Includes imports and domestically caught tuna.
[2]Thousands of standard cases. A standard case consists of 48 6.5-ounce cans of light meat tuna and 48 7-ounce cans of albacore or white meat tuna.
Source: Statistics and Market News, Southwest Region, NMFS, NOAA.

[1]Cannery receipts include only tuna destined for U.S. canneries. They exclude U.S.-caught tuna landed at foreign sites or U.S.-caught tuna landed at U.S. sites that is destined for foreign canneries, U.S.-caught tuna destined for the fresh-fish market; they also exclude tuna imported as flakes, imported tuna not fit for human consumption, and imported "sushi" grade tuna.

[2]The eastern and western Pacific are distinguished at long. 150° W.

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Table 2.—U.S. tuna cannery receipts (short tons) by receiving site and ocean of origin, 1982-83.

Item	Domestically caught 1982	Domestically caught 1983	% Chg.	Imports 1982	Imports 1983	% Chg.	Total 1982	Total 1983	% Chg.
Site									
California	140,850	134,658	− 4	56,397	51,481	− 9	197,247	186,139	− 6
Am. Samoa/Hi	42,388	79,240	+ 87	41,180	35,983	− 13	83,568	115,223	+ 38
Puerto Rico	44,918	71,656	+ 60	174,913	159,031	− 9	219,831	230,687	+ 5
Total	228,156	285,554	+ 25	272,490	246,495	− 10	500,646	532,049	+ 6
Ocean									
Eastern Atlantic		21	+ 100	78,552	55,911	− 29	78,552	55,932	− 29
Western Atlantic	115	77	− 33	41,306	40,643	− 2	41,421	40,720	− 2
Eastern Pacific	159,618	115,303	− 28	31,164	12,237	− 61	190,782	127,540	− 33
Western Pacific	68,423	170,153	+ 149	102,086	118,663	+ 16	170,509	288,816	+ 69
Indian				19,382	19,041	− 2	19,382	19,041	− 2
Total	228,156	285,554	+ 25	272,490	246,495	− 10	500,646	532,049	+ 6

Source: Statistics and Market News, Southwest Region, NMFS, NOAA.

Table 3.—U.S. albacore cannery receipts and U.S. white meat cannery production, 1982-83.

Item	1982	1983	% Chg.	1978-82	% Chg.
Total cannery receipts[1]	101,564	83,325	− 18	103,815	− 20
Total pack[2]	6,021	5,105	− 15	6,056	− 16

[1]In short tons: Includes imports and domestically caught tuna.
[2]Thousands of standard cases. A standard case consists of 48 7-ounce cans of white meat tuna.
Source: Statistics and Market News, Southwest Region, NMFS, NOAA.

More than 75 percent of the domestically caught tuna from the western Pacific was delivered or transshipped to offshore canneries located in American Somoa, Hawaii, and Puerto Rico in 1983. That offshore processing sites are becoming more dominant in terms of U.S. tuna production is also reflected in the fact that in 1983, about 63 percent of the total U.S. pack of canned tuna was processed at offshore facilities. This compares with 61 percent of total production at offshore sites in 1982 and 58 percent in 1981. As a result of this continuing shift in canned production to offshore sites, employment at California canneries, which fell sharply in 1982, is reported to have decreased further during 1983, by the equivalent of about 1,250 full-time jobs.

In the sections that follow, information pertaining to the production of raw and processed tuna by the U.S. tuna industry during 1983, and the consumption of tuna products by U.S. consumers is reviewed in more detail. In the last section, several issues and events are discussed that affected the industry's performance during 1983.

U.S. Production of Albacore (White Meat Tuna)

While overall improvement in the performance of the U.S. tuna industry was observed in 1983, this was not entirely the case when production and consumption are distinguished by fishery and product category. According to industry reports, consumption of canned white meat tuna, which is 100 percent albacore, increased almost 17 percent in 1983. On the other hand, total cannery receipts, 83,325 tons, and canned production of albacore, 5,105 thousand standard cases, were down 18 and 15 percent, respectively, for 1983 (Table 3). The fact that cannery deliveries and domestic production declined while sales showed an increase in 1983 probably reflects either a move to reduce canned white meat inventories on the part of processors or dominance of U.S. retail sales by imported canned white meat tuna, or both. In any case, retail sales were stimulated through significant albacore price adjustments at the ex-vessel, wholesale, and retail levels.

Table 4.—U.S. albacore cannery receipts (short tons) by receiving site, 1982-83.

Site	Domestically caught 1982	Domestically caught 1983	% Change	Imports 1982	Imports 1983	% Change	Total 1982	Total 1983	% Change
Continental	5,099	9,434	+ 85	11,115	5,616	− 49	16,214	15,050	− 7
Am. Samoa/HI	1,866	1,032	− 45	22,814	17,134	− 25	24,680	18,166	− 26
Puerto Rico	0	4	+ 100	60,670	50,105	− 17	60,670	50,109	− 17
Total	6,965	10,470	+ 50	94,599	72,855	− 23	101,564	83,325	− 18

Source: Statistics and Market News, Southwest Region, NMFS, NOAA.

U.S. 1983 Cannery Receipts of Domestically Caught Albacore

In recent years the U.S. albacore fishery has had upwards of 750 vessels participating on a regular basis. The majority of these vessels are in the 40-to 50-foot length range and use troll gear exclusively. There is also a number of larger baitboats that operate in the fishery, and more recently several vessels have started to fish albacore using drift gillnets. Many of the vessels are of a multipurpose design, capable of fishing albacore using a variety of gears, as well as operating in a number of alternative fisheries (e.g., ocean salmon, crab, tropical tuna).

The U.S. albacore fishery occurs almost entirely in the Pacific Ocean north of the Equator and seaward from the west coast to about long. 180°. In 1983 all cannery receipts of domestically caught tuna, 10,470 tons, came from this area with the exception of 4 tons which came from the Atlantic Ocean. Cannery receipts of domestically caught albacore for 1983 were up 50 percent from 1982 (Table 4). This significant increase can largely be attributed to a combination of environmental and economic factors.

Albacore ex-vessel prices, which fell sharply in 1982, continued to decline in 1983. Early in the season a two-tiered price system paid fishermen $1,250 per ton (not adjusted for fish quality) for albacore 9 pounds and over and $975 per ton for albacore less than 9 pounds, a decrease of 12 and 32 percent, respectively, from 1982. These price reductions meant that fishermen would have to experience substantially greater success on the fishing grounds if they were to improve their collective economic performance from 1982. Such was the case, for the unusual warming of nearshore waters brought about by El Niño increased the availability of albacore to U.S. fishermen operating along the west coast.

However, while the effects of El Niño benefited the coastal albacore fishery, they tended to have an unfavorable impact on the offshore and mid-Pacific albacore fisheries. This is partly revealed in the 33 percent decline in cannery receipts of domestically caught and imported albacore from the western Pacific during 1983 (Table 5). Because of these factors, there was a ready market for relatively less expensive U.S.-caught albacore in 1983 which generated $13 million in ex-vessel revenue, up 35 percent from 1982. Dividing 1983 albacore ex-vessel revenue by total cannery receipts yields a weighted ex-vessel price of $1,248 per ton, down 10 percent from 1982.

Table 5.—U.S. albacore cannery receipts (short tons) by ocean of origin, 1982-83.

	Domestically caught			Imports			Total		
Ocean	1982	1983	% Chg.	1982	1983	% Chg.	1982	1983	% Chg.
Eastern Atlantic	0	0	0	19,815	16,935	− 15	19,815	16,935	− 15
Western Atlantic	0	4	+ 100	21,129	16,127	− 24	21,129	16,131	− 24
Eastern Pacific	5,099	9,434	+ 85	48	243	+ 400	5,147	9,677	+ 88
Western Pacific	1,866	1,032	− 45	36,760	24,783	− 33	38,626	25,815	− 33
Indian	0	0	0	16,847	14,767	− 12	16,842	14,767	− 12
Total	6,965	10,470	+ 50	94,599	72,855	− 23	101,564	83,324	− 18

Source: Statistics and Market News, Southwest Region, NMFS, NOAA.

Table 6.—Preliminary U.S. Imports as received (short tons) of fresh, frozen, and partially processed whole tuna by exporting country for the 10 leading exporters during 1982-83.

	Albacore		Skipjack tuna		Yellowfin tuna[1]		Unident. tuna		Total		
Source	1982	1983	1982	1983	1982	1983	1982	1983	1982	1983	% Chg.
Panama			10,321	4,728	12,683	7,218	910	501	23,914	12,447	− 48
Venezuela			5,482	5,647	4,742	4,134	375	535	10,599	10,316	− 3
Brazil	609	619	14,539	13,996	416	293	3	4	15,567	14,912	− 4
France	2,738	794	18,784	13,365	4,570	4,133	166	59	26,258	18,621	− 29
Singapore	1,990	2,114	2,555	3,281	353	205	63		4,961	5,600	+ 13
Philipp.	360	50	5,436	5,140	2,077	1,579	2	1	7,875	6,770	− 14
Rep. Korea	1,905	2,705	3,709	8,802	884	2,067	643	207	7,141	13,781	+ 93
Taiwan	27,434	17,829	2,062	3,842	767	1,976	36	41	30,299	23,688	− 22
Japan	21,308	22,826	19,412	29,450	2,902	844	55	26	43,677	53,146	+ 22
Ghana			13,602	22,198	1,066	1,162	41	53	14,709	23,413	+ 59
"Other"	37,349	25,224	35,900	29,750	20,151	13,948	872	973	94,272	69,895	− 26
Total[2]	93,693	72,161	131,802	140,469	50,611	37,559	3,166	2,400	279,272	252,589	− 10

[1]Includes bigeye and bluefin tuna.
[2]Individual species totals may not agree with those reported elsewhere due to unidentified category. Overall totals may not agree with those reported elsewhere because they can include tuna not destined for U.S. canneries and exclude foreign transshipments.

U.S. 1983 Production of Canned White Meat Tuna

Albacore is consumed almost exclusively as canned white meat tuna by U.S. consumers. Traditionally, the most popular albacore product has been the 7-ounce (standard size) can of solid white meat tuna packed in water.

San Diego and San Pedro, Calif., Mayaguez and Ponce, Puerto Rico, Honolulu, Hawaii, and Pago Pago, American Samoa, are the major U.S. tuna receiving and processing sites. For reporting purposes, tuna receipts are combined for California and for American Samoa and Hawaii (American Samoa/Hawaii). Of the total 1983 raw (whole and other than whole) albacore cannery supply (83,325 tons), 60 percent was delivered to Puerto Rico, 22 percent to American Samoa/Hawaii, and the remaining 18 percent to California. All three areas showed declines in total albacore receipts, 17, 26, and 7 percent, respectively, from 1982 (Table 4).

Of the total 1983 domestically caught, raw albacore cannery receipts, 90 percent was received in California. Virtually all of the remainder was received at American Samoa/Hawaii sites except for 4 tons delivered to Puerto Rico. Domestically caught albacore delivered to California rose 85 percent from 1982 to 1983, while receipts at American Samoa/Hawaii sites decreased 45 percent. There was no domestically caught albacore tuna delivered to Puerto Rico in 1982 (Table 4).

U.S. cannery receipts of imported raw albacore totaled 72,855 tons in 1983, down 23 percent from 1982. Imports composed 87 percent of the total 1983 cannery supply of albacore compared with 93 percent in 1982. Puerto Rico was the major receiving site for U.S. imports of raw albacore during 1983, with 50,105 tons or 69 percent of the total. American Samoa/Hawaii followed with 24 percent of the 1983 total, and California accounted for the remaining 7 percent. Albacore imports received in Puerto Rico during 1983 decreased 17 percent from 1982, while imports received at American Samoa/Hawaii and California declined 25 and 49 percent, respectively, from 1982 (Table 4).

Japan was the leading exporter of raw albacore to U.S. canneries during 1983 with about 22,826 tons or 31 percent of the total raw albacore imports. Taiwan was next with 17,829 tons, 24 percent of the total (Table 6).

Table 7.—U.S. production of canned tuna (thousand standard cases) by processing site, 1982-83.

Site	White meat 1982	White meat 1983	White meat % Change	Light meat 1982	Light meat 1983	Light meat % Change	Total 1982	Total 1983	Total % Change
California	954.4	781.1	– 18	9,427.4	9,190.5	– 3	10,197.4	9,971.5	– 2
American Samoa/HI	1,537.2	911.9	– 41	3,004.2	5,482.3	+ 82	4,541.5	6,394.3	+ 41
Puerto Rico	3,529.1	3,412.2	– 3	8,635.1	8,604.1		12,164.2	12,016.3	– 1
Total	6,020.7	5,105.2	– 15	21,066.7	23,276.9	+ 11	27,087.4	28,382.1	+ 5

Source: Statistics and Market News, Southwest Region, NMFS, NOAA.

Table 8.—U.S. tropical tuna cannery receipts and U.S. light meat cannery production, 1982-83

Item	1982	1983	% Chg.	1978-82	% Chg.
Total cannery receipts[1]	399,082	448,724	+ 12	496,492	– 10
Total pack[2]	21,067	23,277	+ 10	25,222	– 7

[1]In short tons: Includes imports and domestically caught tuna.
[2]Thousands of standard cases. A standard case consists of 48 6.5-ounce cans of white meat tuna.
Source: Statistics and Market News, Southwest Region, NMFS, NOAA.

Raw albacore imports received at U.S. canneries in 1983 were valued at about $97 million, down almost 45 percent from 1982. Dividing this value by the corresponding volume results in a weighted average import price of $1,335 per ton for raw albacore in 1983, almost 28 percent below that for 1982.

In 1983, the Pacific Ocean provided 43 percent of the total U.S. cannery supply of albacore. The Atlantic and Indian Oceans followed with 40 and 17 percent, respectively, of the total supply, almost all imports. This pattern was unchanged from 1982. Because of the significant increase in domestically caught albacore cannery receipts, the eastern Pacific was the only oceanic area from which an increase in supply (88 percent) was reported in 1983 (Table 5).

Of the three major U.S. canned tuna production centers, Puerto Rico was the primary U.S. albacore processing site during 1983 with 3,412,000 standard cases, 67 percent of the total white meat pack for 1983. This is a 3 percent decrease from 1982. American Samoa/Hawaii followed with 912,000 standard cases, 18 percent of the total 1983 white meat pack, down 41 percent from 1982. Continental sites produced 781,000 standard cases of white meat tuna in 1983, 15 percent of the total, and an 18 percent decrease from 1982 (Table 7).

Wholesale list prices for U.S. produced, advertised white meat tuna ranged from $59.45 to $62.50 per standard case at the beginning of 1983 and fell to $53.17-60.63 per standard case by year's end, a decline of between 11 and 3 percent. Also, discounts further reduced the price to as low as $40.20 for a standard case. In terms of total value, U.S. production of canned white meat tuna—advertised and private brands—generated $196 million in 1983, down 29 percent from 1982. Based on total white meat volume, the weighted average price was $38.40 per standard case compared with $45.74 for 1982, a 16 percent decrease.

U.S. Production of Tropical Light Meat Tuna

U.S. tuna industry performance in terms of tropical or light meat tuna harvesting and production improved substantially in 1983. Consumption of canned light meat tuna reportedly rose 12 percent during 1983. There was a similar increase in total (U.S.-caught and imported) cannery receipts of tropical tunas, to 448,724 tons in 1983. However, the volume of 1983 tropical tuna cannery receipts was still 10 percent below the 1978-82, 5-year average (Table 8). Production of canned light meat tuna rose in 1983, to a total pack of 23,277,000 standard cases, which was up 10 percent from 1982 (Table 8). Declining prices at the ex-vessel, wholesale, and retail levels during 1982 and most of 1983 led to increased purchases of tropical tuna by both producers and consumers.

U.S. 1983 Cannery Receipts of Domestically Caught Tropical Tunas

In 1983, the U.S. tropical tuna fleet consisted of 146 vessels: 127 purse seiners and 19 bait boats (pole and line gear). This compares with a total fleet of 139 vessels in 1982: 127 purse seiners and 12 baitboats. Fleet carrying capacity was 129,126 tons in 1983, up 2 percent from 1982. However, by the end of 1983, there were about 30 inactive purse seiners in the U.S. tropical tuna fleet. Purse seiners account for by far the bulk of domestically caught tropical tuna cannery receipts, over 97 percent in 1983.

In 1983, domestically caught cannery receipts of tropical tunas were 275,084 tons, 24 percent above 1982 (Table 9). Practically all of this was taken from the Pacific Ocean. However, in 1983 more vessels, representing a disproportionately greater amount of carrying capacity, operated in the western Pacific than in the historically more popular eastern Pacific Ocean. U.S. vessels active in the western Pacific numbered 60 during 1983, an increase of 85 percent from 1982, while 57 vessels were active in the eastern Pacific, a 40 percent decrease from 1982. Carrying capacity of the vessels operating in the western Pacific was 73,395 tons in 1983, an average of 1,223 tons per vessel, compared with 30,986 tons, or an average of 544 tons per vessel, for the eastern Pacific. Fifty-nine of the vessels that operated in the western Pacific had carrying capacities of at least 1,000 tons as opposed to only 15 of the vessels operating in the eastern Pacific. Very little U.S. tropical tuna fishing occurred in the Atlantic Ocean during 1983.

Ex-vessel prices for domestically caught tropical tuna continued to fall

during 1983. At the close of 1983, the posted ex-vessel price (without quality adjustments) in effect for skipjack tuna in the 3.0-4.0 pound range was $640 per ton, down 9 percent from the close of 1982. The posted ex-vessel price for yellowfin tuna in the 7.5-20.0 pound range (without quality adjustments) at the end of 1983 was $990 per ton, 6 percent below that at the close of 1982. The full range of skipjack and yellowfin tuna ex-vessel prices for 1983 is shown in Table 10.

Domestically caught skipjack tuna cannery receipts totaled 155,040 tons for 1983, up significantly, 51 percent, from 1982 (Table 11). Domestically caught skipjack tuna receipts were valued at $124 million ex-vessel in 1983, a 26 percent increase over 1982. This yields a weighted ex-vessel skipjack tuna price of $800 per ton for 1983, down 16 percent from 1982. Cannery receipts of domestically caught yellowfin tuna (includes bigeye, bluefin, and blackfin tuna) totaled 120,044 tons in 1983, up slightly, 1 percent, from 1982 (Table 11). Domestic deliveries of yellowfin tuna generated about $124 million in ex-vessel revenues during 1983, 7 percent below 1982. The weighted ex-vessel price for yellowfin tuna in 1983 was $1,031 per ton, a decrease of 8 percent from 1982. Total ex-vessel revenues from domestically caught tropical tuna receipts were about $248 million in 1983. This is a 7 percent increase over 1982, indicating that U.S. tropical tuna fishermen more than offset the loss in per unit revenue through increased cannery deliveries.

U.S. Production of Canned Light Meat Tuna

Skipjack and yellowfin tuna are blended together and canned as light meat tuna, the most popular tuna product consumed in the United States. The 6.5-ounce (standard size) can of chunk style, light meat tuna in water led light meat tuna sales in 1983.

Table 9.—U.S. tropical tuna cannery receipts (short tons) by ocean of origin, 1982-83.

Ocean and Species	Domestically caught 1982	1983	% Chg.	Imports 1982	1983	% Chg.	Total supply 1982	1983	% Chg.
Skipjack tuna									
Eastern Atlantic		21	+ 100	49,417	34,358	− 30	49,417	34,379	− 30
Western Atlantic		3	+ 100	17,119	18,070	+ 6	17,119	18,073	+ 6
Eastern Pacific	59,925	40,103	− 33	11,916	4,502	− 62	71,841	44,605	− 38
Western Pacific	42,529	114,913	+ 182	46,892	75,066	+ 60	89,421	189,979	+ 112
Indian				1,763	3,312	+ 88	1,763	3,312	+ 88
Subtotal	102,454	155,040	+ 51	127,107	135,308	+ 6	229,561	290,348	+ 26
Yellowfin tuna[1]									
Eastern Atlantic				9,320	4,618	− 50	9,320	4,618	− 50
Western Atlantic	115	70	− 39	3,058	6,446	+ 111	3,173	6,516	+ 105
Eastern Pacific	94,594	65,766	− 30	19,200	7,492	− 61	113,794	73,258	− 36
Western Pacific	24,028	54,208	+ 126	18,434	18,814	+ 2	42,462	56,092	+ 32
Indian				772	962	+ 25	772	962	+ 25
Subtotal	118,737						69,521	158,376	− 7
Total tropical tuna									
Eastern Atlantic		21	+ 100	58,737	38,976	− 34	58,737	38,997	− 34
Western Atlantic	115	73	− 37	20,177	24,516	+ 22	20,292	24,584	+ 21
Eastern Pacific	154,519	105,869	− 31	31,116	11,994	− 61	185,635	117,863	− 37
Western Pacific	66,557	169,121	+ 154	65,326	93,880	+ 44	131,883	263,001	+ 99
Indian				2,535	4,274	+ 69	2,535	4,274	+ 69
Grand total	221,191	275,084	+ 24	177,891	173,640	− 2	399,082	448,724	+ 12

[1]Includes bigeye, bluefin, and blackfin tuna.
Source: Statistics and Market News, Southwest Region, NMFS, NOAA.

Table 10.—Posted ex-vessel prices ($/ton), without quality adjustments, for skipjack and yellowfin tuna (includes bigeye, bluefin, and blackfin tuna), 1982-83.

Size (lb)	Skipjack tuna 1982	1983	% chg.	Yellowfin tuna 1982	1983	% chg.
< 3.0	$500	$400-440	− 16	$890	$400	− 55
3.0-4.0	$700	$640	− 9	$890	$640	− 28
> 4.0, < = 7.5	$890	$800	− 10	$890	$800	− 10
> 7.5	$890	$900	+ 1			
> 7.5, < = 20.0				$1,050	$990	− 6
> 20.0				$1,170	$1,125	− 4

Source: Statistics and Market News, Southwest Region, NMFS, NOAA.

Table 11.—U.S. tropical tuna cannery receipts (short tons) by receiving site, 1982-83.

Species and site	Domestically caught 1982	1983	% Chg.	Imports 1982	1983	% Chg.	Total supply 1982	1983	% Chg.
Skipjack tuna									
California	56,167	58,521	+ 4	37,108	41,450	+ 12	93,275	99,971	+ 7
Am. Samoa/HI	26,598	54,911	+ 106	8,729	9,182	+ 5	35,327	64,093	+ 81
Puerto Rico	19,689	41,608	+ 111	81,270	84,676	+ 4	100,959	126,284	+ 25
Subtotal	102,454	155,040	+ 51	127,107	135,308	+ 6	229,561	290,348	+ 26
Yellowfin tuna[1]									
California	79,584	66,703	− 16	8,174	4,415	− 46	87,758	71,118	− 19
Am. Samoa/HI	13,924	23,297	+ 67	9,637	9,667		23,561	32,964	+ 40
Puerto Rico	25,229	30,044	+ 14	32,973	24,250	− 25	58,202	54,299	− 7
Subtotal	118,737	120,044	+ 1	50,784	38,332	− 25	169,521	158,376	− 7
Total tropical tuna									
California	135,751	125,224	− 8	45,282	45,865	+ 1	181,033	171,089	− 5
Am. Samoa/HI	40,522	78,208	+ 93	18,366	18,849	+ 3	58,888	97,057	+ 65
Puerto Rico	44,918	71,652	+ 60	114,243	108,926	− 5	159,161	180,551	+ 13
Grand total	221,191	275,084	+ 24	177,891	173,640	− 2	399,082	448,724	+ 12

[1]Includes bigeye, bluefin, and blackfin tuna.
Source: Statistics and Market News, Southwest Region, NMFS, NOAA.

The total supply of raw tropical tuna, 448,724 tons, was delivered to canneries in Puerto Rico, American Samoa and Hawaii, and California during 1983. Puerto Rico was the leading receiving site in 1983 with 180,551 tons, 40 percent of the total cannery supply. California canneries followed with 38 percent of the total supply and American Samoa/Hawaii sites received 22 percent of the total 1983 supply. Total tropical tuna receipts for Puerto Rico increased 13 percent from 1982, increased 65 percent for American Samoa/Hawaii, but fell 5 percent for California (Table 11).

Of the total domestically caught receipts of tropical tuna for 1983, 125,224 tons (46 percent) was received in California, 78,208 tons (28 percent) at American Samoa/Hawaii sites, and the remaining 71,652 tons (26 percent) in Puerto Rico. Domestically caught deliveries of tropical tuna to California fell 8 percent from 1982 but increased 93 percent in American Samoa/Hawaii and increased 60 percent in Puerto Rico. Skipjack tuna dominated domestically caught tropical tuna receipts, composing 56 percent of the total domestically caught tropical tuna receipts for 1983 (Table 11).

Imported tropical tuna receipts totaled 173,640 tons in 1983, 2 percent below 1982. Imports made up 39 percent of the total tropical tuna cannery supply in 1983 vs. 45 percent in 1982. Puerto Rico was the major receiving site for tropical tuna imports during 1983 with 108,926 tons, 63 percent of the total. California followed with 26 percent and American Samoa/Hawaii received the remaining 11 percent. Receipts of imported tropical tuna in Puerto Rico decreased 5 percent from 1982 and increased slightly for California and American Samoa/Hawaii sites (1 and 3 percent, respectively). Skipjack tuna was the major tropical tuna species imported during 1983, with 135,308 tons, comprising 78 percent of total tropical tuna imports. Yellowfin tuna contributed the balance. Overall skipjack tuna imports were up 6 percent from 1982, while yellowfin tuna imports fell 25 percent (Table 11).

The leading exporter of raw tropical tuna to the United States in 1983 was Japan, with approximately 30,320 tons or 12 percent of the 1983 total. Imports from Japan consisted of 97 percent skipjack tuna and the remainder yellowfin and unidentified tuna. Ghana followed with 23,413 tons, 9 percent of the total; of this 95 percent was skipjack tuna, and the rest was yellowfin and unidentified tuna (Table 6).

The total value of 1983 tropical tuna imports received at U.S. canneries was $138 million, down 21 percent from 1982. The value of skipjack tuna imports was approximately $100 million and the value of yellowfin tuna imports was about $38 million, decreases of 13 and 36 percent, respectively, from 1982. These values convert to weighted average prices of $742 per ton for skipjack tuna imports and $983 per ton for yellowfin tuna. This represents price decreases of 19 percent for skipjack tuna and 16 percent for yellowfin tuna from 1982.

The Pacific Ocean was the major source of U.S. tropical tuna cannery receipts. For all tropical tuna species combined, the Pacific provided 380,864 tons during 1983, 85 percent of the total supply. The Atlantic and Indian Oceans provided 14 and 1 percent, respectively, and virtually all were imports. On a regional basis, the western Pacific was the leading source of tropical tuna receipts contributing 263,001 tons, 59 percent of the total tropical tuna cannery supply in 1983. Total tropical tuna receipts from the western Pacific rose 99 percent from 1982. Of the total tropical tuna receipts originating in the western Pacific during 1983, 64 percent (169,121 tons), was domestically caught; the remainder (93,880 tons) consisted of imports. Domestically caught tropical tuna receipts from the western Pacific increased 154 percent from 1982 while imports increased 44 percent. Skipjack tuna dominated tropical tuna receipts from the western Pacific in 1983, contributing 72 percent of the total receipts from this oceanic area, and 42 percent of the total tropical tuna receipts from all areas. Other oceanic regions contributing to the 1983 U.S. cannery supply, in order of importance, were the eastern Pacific (primarily domestically caught yellowfin tuna), the eastern Atlantic (almost all skipjack tuna imports), and the western Atlantic (mainly skipjack tuna imports). A breakdown of the 1983 tropical tuna cannery supply by ocean of origin is presented in Table 9.

California was the leading U.S. production center for canned light meat tuna during 1983, with 9,190 thousand cases, 39 percent of the total light meat pack for 1983. Next was Puerto Rico with 8,604,000 standard cases, 37 percent of the total, followed by American Samoa/Hawaii with 5,482,000 standard cases, 24 percent of the 1983 total. Production of canned light meat tuna in California was down 3 percent from 1982, unchanged from 1982 in Puerto Rico, and up 82 percent from 1982 in American Samoa/Hawaii (Table 7).

The wholesale list price of U.S. produced advertised light meat tuna ranged from $43.00 to $46.65 a standard case, discounted to as low as $34.00 a standard case at the beginning of 1983. By the end of 1983 it had fallen to between $40.15 and $41.05 per standard case, a decrease of 7-12 percent. Total U.S. production of canned light meat tuna—both advertised and private label—in 1983 was valued at $625 million, down 3 percent from 1982. Dividing total value by total volume yields a weighted average price of $26.86 for a standard case of light meat tuna in 1983, down 12 percent from 1982.

Canned Tuna Imports

The United States imposes tariffs on canned tuna imports in two categories: Tuna in oil and tuna not in oil. The tariff schedules on imported canned tuna were originally established when light meat tuna packed in oil was much more popular among U.S. consumers than light meat not in oil. Since then, U.S. consumption has shifted significantly in favor of light meat tuna packed in water.

Canned tuna in oil is subject to a 35

Table 12.—Imports of canned tuna (in oil and not in oil) by exporting country and their corresponding value, 1978-83.

Source	Quantity (1,000 lb)						Value (1,000 dollars)					
	1978	1979	1980	1981	1982	1983	1978	1979	1980	1981	1982	1983
Japan	35,887	28,366	24,794	21,271	26,481	20,387	46,343	37,055	42,015	36,453	38,561	24,643
Philippines	3,374	6,998	13,777	21,451	27,631	32,018	3,536	7,319	20,043	30,504	31,085	32,291
Thailand	1,551	4,844	6,405	10,315	18,667	39,930	1,886	5,135	8,875	15,400	22,711	43,259
Taiwan	9,051	12,282	15,947	15,771	10,704	18,710	9,667	14,103	23,316	24,631	14,366	22,772
Australia	0	0	0	58	1,930	2,799				105	3,451	3,684
Malaysia	651	292	66	696	755	3,083	746	314	76	1,230	1,242	4,068
Indonesia	0	0	0	146	595	2,634				209	699	2,679
Maldives	0	62	600	592	327	0		67	825	874	379	
Spain	132	336	146	170	120	133	294	501	367	402	300	268
Singapore	0	0	28	65	120	329			38	91	141	386
All other	1,136	523	1,792	316	248	2,306	1,349	579	1,698	459	412	3,274
Total	51,781	53,704	63,553	70,852	87,579	122,329	63,822	65,071	97,254	110,358	113,347	137,324

Source: U.S. International Trade Commission, Publication 841, Summary of Trade and Tariff Information, July 1983, Bureau of Census.

percent ad valorem tariff and imports are negligible. Canned tuna imports not in oil are controlled under a tariff rate quota which allows imports up to 20 percent of the previous year's domestic production at one rate, with imports above this level subject to a higher rate. Prior to reaching the quota on canned tuna not in oil, imports of canned white meat tuna not in oil are distinguished from imports of canned light meat tuna not in oil. Once the quota is reached however, there is no distinction between light and white meat tuna.

In 1983 the tariff rate on tuna not in oil was 6 percent ad valorem below quota and 12.5 percent above quota. The 1983 quota on imports of canned tuna not in oil was 95,620,000 pounds or approximately 4,900,000 standard, light meat equivalent, cases. Total imports amounted to a record 122,329,000 pounds or almost 6,300,000 standard, light meat equivalent, cases, an increase of 40 percent from 1982. When the 1983 quota was reached, white meat comprised 16 percent of the canned imports not in oil, the remaining 84 percent was light meat tuna. U.S. imports of canned tuna in oil—virtually all light meat tuna—totaled 197,000 pounds in 1983 or about 10,102 standard cases, down 8 percent from 1982.

Thailand was the leading exporter of canned tuna to the United States in 1983 with 39,930,000 pounds of canned product or about 2,000,000 standard, light meat equivalent, cases. This was 33 percent of the total U.S. imports of canned tuna. The Philippines followed with 32,018,000 pounds, or about 1,600,000 standard, light meat equivalent, cases, representing 26 percent of the total 1983 canned imports.

The value of all imported canned tuna was approximately $137 million in 1983, an increase of 21 percent from 1982. This converts to a weighted average standard, light meat equivalent, case price of $21.89, which is 13 percent below that for 1982. Imports of canned tuna by exporting country and their corresponding value are shown in Table 12.

U.S. Consumption of Canned Tuna

U.S. civilian per capita consumption of canned tuna—both light and white meat—in 1983 was 3.0 pounds, 11 percent above 1982. Assuming that light meat comprises 80 percent of the total per capita consumption, and the remainder is white meat, domestic consumption is estimated to be 0.60 pounds of white meat tuna and 2.40 pounds of light meat tuna per capita for 1983, compared with 0.54 pounds and 2.16 pounds, respectively, for 1982. This is equivalent to 1.28 standard cans of white meat and 5.91 standard cans of light meat tuna per capita for 1983, and 1.15 standard cans of white meat and 5.32 standard cans of light meat tuna per capita for 1982. Based on the National Marine Fisheries Service's "Operation Price Watch," the 10-city average price for domestically produced canned tuna, U.S. consumers paid an average of $1.49 per can for white meat tuna and $0.87 per can for light meat tuna during 1983, a decrease of 3 percent and 9 percent, respectively, from 1982. This results in a slight increase in estimated per capita tuna expenditures: $7.05 for 1983 versus $6.88 for 1982. These estimates do not take into account domestic consumption of imported canned tuna.

Discussion

U.S. tuna industry performance during 1983 was highlighted by increased domestically caught cannery receipts of albacore and tropical tuna, an increase in the light meat tuna pack, and increased purchases of tuna products by U.S. consumers. However, marked improvement in these areas was not realized without some significant changes in the industry's structure and operations. Some of these changes can be traced back to the late 1970's and early 1980's when rising production costs, particularly for fuel, led to record high prices at the ex-vessel, wholesale, and retail levels. Higher prices increased consumer resistance to purchases of canned tuna resulting in an accumulation of canned tuna inventories. To stimulate consumption, the U.S. tuna industry initiated price reductions in mid-1981 and prices at all levels have declined since. This action, together with overall improvements in the U.S. economy during the past year, has enhanced canned tuna sales and done much toward restoring U.S. canned

tuna production to its historic average.

To accommodate wholesale price reductions and improve their inventory positions, U.S. processors sought to streamline cannery operations. Production at California canneries was cut back severely beginning in 1982 with the closure of one major cannery and significant contractions in the remaining operations. Processing in California declined further in 1983 as major U.S. canners shifted their operations to offshore sites (Puerto Rico, American Samoa/Hawaii) to take advantage of more favorable operating conditions.

Adverse conditions in the processing sector of the U.S. tuna industry at the end of 1981 filtered downward to U.S. tuna fishermen in the form of substantially lower ex-vessel tuna prices and difficulties and delays in selling their catches. Further, canneries were anxious to divest themselves of interests they held in tropical tuna vessels and to cut back their financial support to independently owned vessels. Under these circumstances many vessels were unable to participate in the fisheries. In addition to weakened ex-vessel markets, U.S. tropical tuna fishermen faced continued uncertainty in terms of access to traditional eastern Pacific fishing grounds, decreased availability of tropical tuna resources in the eastern Pacific attributed to El Niño, and increased competition from foreign fishermen. These factors, together with potentially more abundant tropical tuna resources to be found in the western Pacific Ocean, contributed to a reduction in the number of active U.S. tropical tuna vessels and a redeployment of most large U.S. purse seiners to the western Pacific in 1983. Whether this situation will persist is unclear in view of events over which the industry has little or no direct controls.

Of particular concern is the growing interest of resource adjacent nations to develop their own tuna fisheries, or otherwise benefit from readily accessible tuna resources. Whether the western Pacific will continue to account for the largest share of the U.S. tuna catch will depend on access and fishery development agreements that can be negotiated with the numerous island governments that exist in this region. In this regard, future stability in the exploitation of western Pacific tuna resources would seem contingent on the creation of a cohesive institutional arrangement that recognizes resource limitations as well as the particular interests of all parties involved. In addition, adequate industry infrastructure must be in place to support future growth. Similar concerns can be expressed over potential expansion of the U.S. tropical tuna fleet into the Atlantic and Indian Oceans. On the other hand, the eastern Pacific could regain its former harvesting stature once the effects of El Niño have completely abated and the pending international access licensing arrangement, the "Eastern Pacific Ocean Tuna Fishing Agreement," in this area is fully endorsed.

The U.S. industry has also expressed considerable alarm over the recent influx of canned tuna imports. Production of canned tuna outside the United States has grown steadily over the last decade. Most of this increase has been targeted for export to the United States, the major market for canned tuna, where the market share of imports has more than doubled in recent years from 6 percent in 1977 to 14 percent in 1982. In terms of total volume, U.S. imports of canned tuna increased 136 percent between 1978 and 1983 (72 percent from 1981 to 1983), an annual average rate of 19 percent. On the other hand, during this same period, imports of raw tuna decreased almost 43 percent, a significant shift in U.S. tuna imports from raw to finished product. Foreign producers thus gain the value added through processing. This implies a real cost-revenue squeeze for U.S. processors as they compete with foreign processors for inputs of raw tuna, driving up production costs and as they compete with foreign processors to maintain their share of domestic retail sales, putting downward pressure on prices they receive. Domestic wholesale prices fell to low levels in 1983, and discounts of up to $9.00 per case were also being offered; nonetheless, import prices were still from $3.00 to $5.00 per case below domestic prices. Lower production costs and a strong U.S. dollar abroad have made foreign produced canned tuna very attractive to U.S. importers since early 1982. Furthermore, since the ad valorem duties on canned tuna imports are determined by their price, the lower the price of imported canned tuna, the lower the customs duty. The current high value of the U.S. dollar acts to further reduce the effective tariff on imported canned tuna. Even if the dollar weakens against foreign currencies in the near term, U.S. producers will continue to face stiff competition from foreign processors.

A significant event affecting the tuna industry in 1983 was the exclusion of canned tuna not in oil packed in American Samoa from being counted against the quota on imports of canned tuna not in oil. It is estimated that one-third of the annual quota in recent years had been filled by canned tuna processed in American Samoa. In effect, the American Samoa exclusion allows foreign countries to export that much more canned tuna not in oil under the lower tariff duty rate. To a great extent this accounts for the large increase in foreign produced canned imports in 1983.

The U.S. tuna industry has brought attention to the import situation by seeking revisions to the tariff structure for tuna imports not in oil. It also successfully petitioned for a countervailing duty investigation on imported canned tuna from the Philippines. The investigation resulted in a countervailing duty of 0.72 percent being levied against Philippine exporters to offset production subsidies they received. This is the only case where the U.S. industry has obtained import relief, and it proved to be very minor, but as foreign competition grows more intense, it is likely that the U.S. industry will pursue other means available to protect itself as it adjusts to a new international order in tuna harvesting and processing.

Coral Reef Sanctuaries for Trochus Shells

GERALD A. HESLINGA, OBICHANG ORAK, and MARCUS NGIRAMENGIOR

Introduction

Economically, the coral reef snail *Trochus niloticus* (Fig. 1) is the most important gastropod mollusk in the tropical Indo-West Pacific (Heslinga and Hillmann, 1981; Heslinga, 1981a). Commercial trochus fisheries exist in New Caledonia, Indonesia, Papua New Guinea, Australia, Vanuatu, Fiji, French Polynesia, the Philippines, and in the Marshall, Mariana, Caroline, and Solomon Islands (Wells, 1981a). Subsistence fisheries for trochus shells and meat exist in many other island areas.

The meat is edible and is dried, cooked, or occasionally canned for local consumption. The aragonite shells, primary raw material for mother-of-pearl buttons, are exported to Asia and Europe. The annual world harvest is about 5,000 t (Heslinga and Hillmann, 1981) with a dockside value of about $4 million (at $0.88/kg, Palau's 1982 price). The retail value of the finished product is many times higher, since an individual trochus shell worth $0.15 ex-vessel will make 35 buttons worth about $0.30 each at retail (Udui and Van den Andel, 1981).

Contrary to popular opinion, the widespread use of plastic buttons and other fastening devices has not depressed the world trochus market. Annual demand has been estimated at 6,000 t worldwide (Bouchet and Bour, 1980), and the dockside price of trochus shell has increased 500 percent during the last decade (Heslinga and Hillmann, 1981). The Pacific Island trochus industry remains a principal source of foreign exchange for artisanal fishermen, particularly in

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ABSTRACT—Trochus niloticus *is exploited throughout the tropical Indo-West Pacific as a source of food and mother-of-pearl. In the Republic of Palau, trochus sanctuaries were established in 1960 to serve as centers of breeding and planktonic larval distribution. However, 1982 field surveys indicated that Koror State sanctuaries averaged only half as many trochus as adjacent exploited areas. In addition, sanctuaries were too numerous and widely scattered to be effectively patrolled. Recommendations to consolidate and relocate the sanctuaries in superior trochus habitats were approved and implemented by Koror State officials before the 1982 trochus season opened.*

We conclude that marine sanctuaries can contribute to trochus conservation efforts and are of potential economic benefit if properly sited and patrolled. Guidelines are suggested for sanctuary selection and assessment of trochus distribution and abundance. Population densities are shown to be influenced by reef orientation, degree of exposure to surf, substrate type, and water depth.

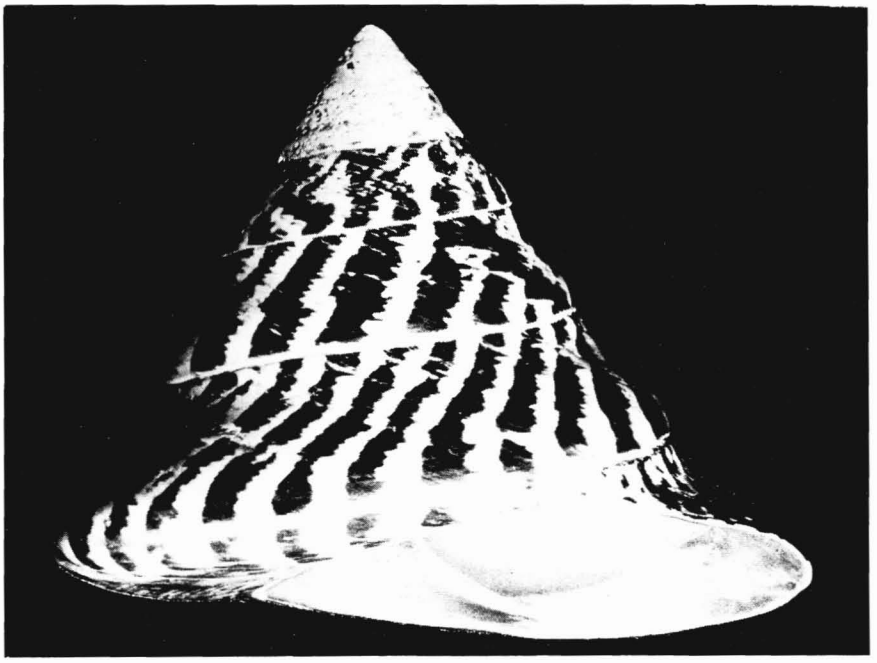

Figure 1.—Adult commercial topshell, *Trochus niloticus*, 10.2 cm base diameter.

remote areas. According to Glucksman and Lindholm (1982), who studied the commercial shell industry of Papua New Guinea:

"The importance of the shell trade to the coastal villager or to the nation cannot be measured solely in terms of cash earnings or Gross National Product. It is an industry ideally suited to coastal villages in that: The harvest of the shell does not require investment in expensive equipment or vessels; the reefs on which it is found are often contiguous with small population centres (a villager need not leave home to enter the cash economy); the saleable product requires no preservation and is easily packed and stored; and the meat (foot) of the snail is easily processed (salted and/or smoked) to provide a source of locally produced and preserved high quality protein."

Trochus depletion through unregulated or poorly regulated harvesting is of increasing concern in the Indo-West Pacific. Heslinga and Hillmann (1981) cite many cases where local stocks have been fished nearly to economic extinction, often in spite of regulatory measures. And, the International Union for the Conservation of Nature has recently added *T. niloticus* to its list of "commercially threatened invertebrates" (IUCN, In press).

Factors contributing to such declines include the large size, accessible habitat, and sedentary habit of *T. niloticus*. Complicating factors include a suite of problems commonly associated with resource management in developing countries. Examination of trochus management in the Republic of Palau, and documentation of a successful review and policy change in this paper is therefore both timely and relevant.

Since 1960, Palau's trochus management policy has included four components: 1) Size limit (7.6 cm base diameter); 2) restricted season (1 month/year, usually June); 3) a sanctuary system to protect designated areas; and 4) a moratorium system in which states or villages voluntarily stop collecting shells for one or more years. The moratorium system was invoked by Kyangle State in 1979, Angaur and Ngeremlengui States in 1980, and Koror, Kyangle, and Peleliu States in 1983.

The size limit and the seasonal restriction were originally implemented in the 1920's and 1930's during the Japanese occupation of Palau (Gail and Devambez, 1958). The sanctuary system was established under the American administration following a 2.5-year investigation by McGowan (1956, 1958, 1959).

McGowan (1956, 1958) presented data to support his position that "there has been a constant decline in the size of the catch from almost all of the trochus producing areas of the Pacific." He maintained that these declines occurred despite existing regulations on harvest and size. As for the decline in trochus harvests reported at various times from New Caledonia, the Philippines, the Andaman Islands, Yap, and Palau, McGowan (1959) concluded that "without a doubt, overfishing was the cause for these population declines, thus implying that the existing conservation practices were ineffective."

A trochus sanctuary system proposed by McGowan (1958), and later implemented in Palau, Truk, Ponape, and Yap, was based on the assumption that the protected areas would serve as spawning centers from which planktonic larvae would be distributed by currents up and down the reef. Although the early life history stages of *T. niloticus* had not been described during McGowan's studies, he hypothesized that trochus larvae must spend a short time in the plankton (days, as opposed to weeks or months) before settlement and metamorphosis (McGowan, 1958). Subsequent studies (Heslinga, 1981a,b; Heslinga and Hillmann, 1981) have corroborated McGowan's thesis.

T. niloticus larvae are now known to be of the short term lecithotropic type which, under favorable conditions, spend only a few days in the plankton. There is a high probability that trochus larvae which recruit successfully to the benthic environment do so within a few days drift of their point of origin. From a practical standpoint, this means that larvae produced in trochus sanctuaries probably do help populate nearby reefs. One would not necessarily expect the same to be true for gastropods with long-term planktotrophic larvae. In retrospect, the trochus sanctuary concept appears to have had a sound biological basis, in addition to obvious intuitive appeal.

At the outset of Palau's trochus sanctuary program, McGowan (1958) recommended establishing one sanctuary per 5 miles of barrier reef. This was evidently an arbitrary decision. It was stressed that to be effective, the sanctuaries must be "well made," i.e., placed in appropriate habitats for *Trochus niloticus*, and they must be patrolled regularly during the harvest season to discourage poaching. Subsequently, trochus sanctuaries were established in Palau by members of the local Conservation Division.[1] In Koror, the most populous state and the largest in terms of barrier reef perimeter, seven trochus sanctuaries were designated: Five on the east coast and two on the west coast (Fig. 2, 3).

At the request of the Palau Marine Resources Division, and with financial support from the Pacific Fisheries Development Foundation, we studied the original seven Koror State trochus sanctuaries in March-April 1982 to see if they were fulfilling their intended function. Underwater surveys provided a quantitative assessment of the distribution and abundance of harvestable trochus in sanctuary areas and in adjacent exploited areas. Another goal was to train Palauan Marine Resources Division personnel (Orak and Ngiramengior) to conduct and interpret quantitative field assessments of local trochus populations. The sampling techniques, methods of data analysis, and report format used for the Koror State trochus survey thus represent an attempt to

[1]Madraisau, B. 1981. Micronesian Mariculture Demonstration Center, Koror, Palau. Pers. commun.

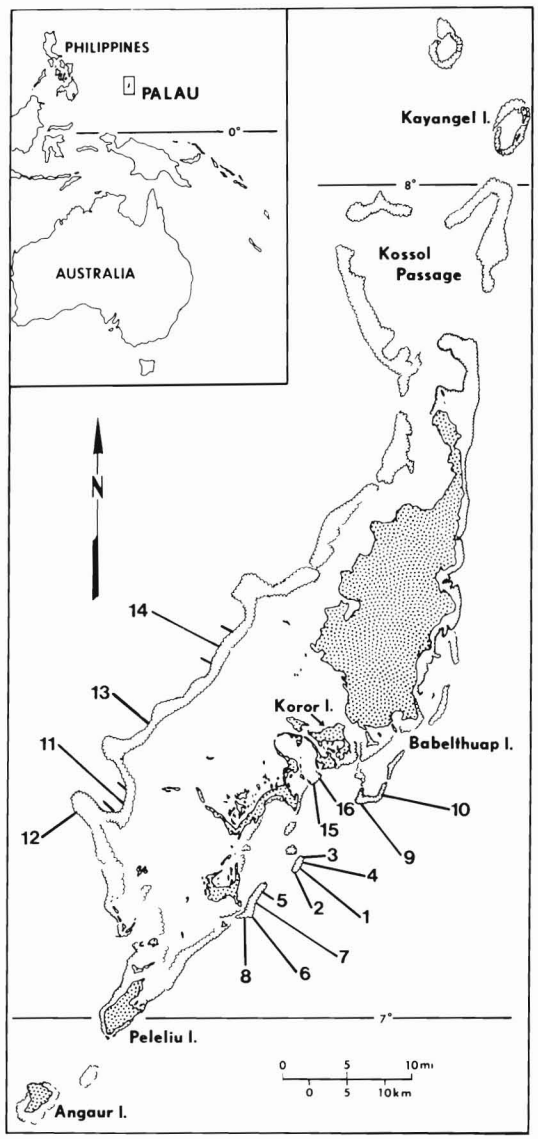

Figure 2.—The Palau archipelago, showing the 16 sites on the Koror State barrier reef surveyed for *Trochus niloticus*. Sites 11 and 14 on the western barrier reef are former trochus sanctuaries.

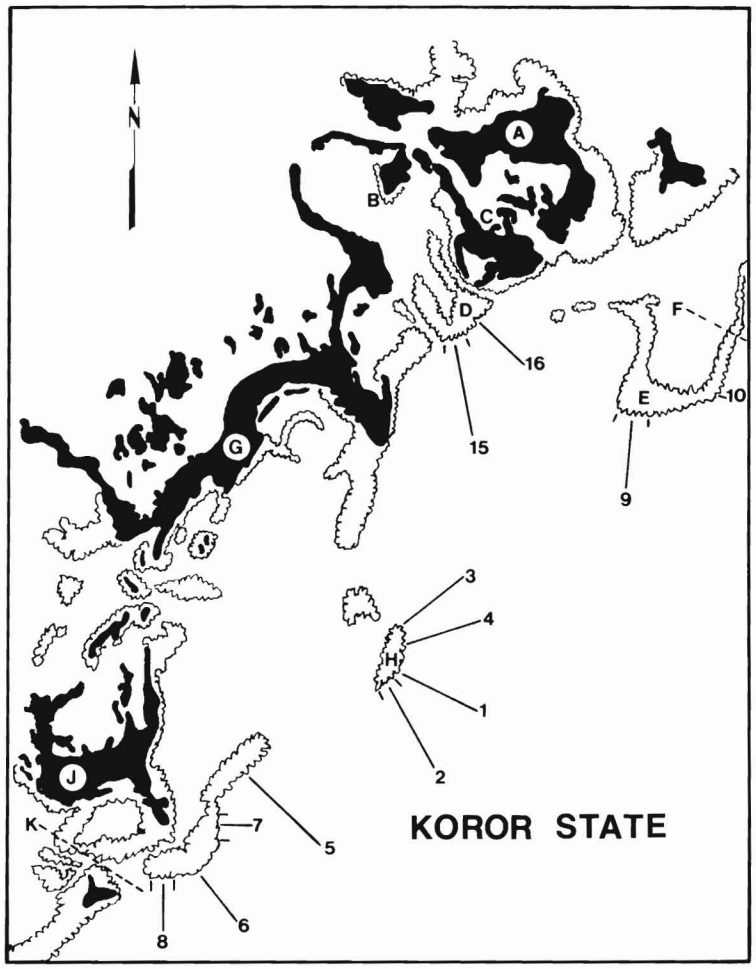

Figure 3.—Koror State eastern barrier reef complex, with numbered *Trochus niloticus* survey sites. A, Koror Island; B, Malakal Island, site of the MMDC Laboratory; C, Auluptagel Island; D, Ngederrak Reef, site of present trochus sanctuary; E, Augupelu Reef; F, Koror-Airai State boundary; G, Urukthapel Island; H, Ikedelukes Reef, site of present trochus sanctuary; J, Eil Malk Island; K, Denges passage (marks Koror-Peleliu State boundary). Sites 2, 7, 8, 9, and 15 are former trochus sanctuaries.

develop a pragmatic model that can be used for future surveys of this kind, both in Koror and elsewhere.

Methods

We surveyed 16 outer reef sites, 7 within existing trochus sanctuaries and 9 in exploited areas, generally within 2 km of the sanctuaries (Fig. 2, 3). At each site a 100 m lead core transect line was placed on the substrate (approximately parallel to the reef margin) along four depth contours at 7, 5, 3, and 1 m. These depths were chosen because they cover the ranges commonly accessible to free diving trochus fishermen. In Palau and elsewhere, most trochus are harvested between 1 and 5 m depth.

Two scuba divers carefully searched the substrate along each depth contour and recorded all *T. niloticus* within 2 m of each side of the transect line. About 400 m² of substrate were surveyed at each depth contour and 1,600 m² were covered at each of the

sites shown in Figure 2. Divers used measuring boards fitted with underwater paper to record the number and size of specimens in the following categories:

1) Live *T. niloticus*,
2) dead *T. niloticus* with empty shells,
3) dead *T. niloticus* occupied by the hermit crab *Dardanus megistos*,
4) dead *T. niloticus* occupied by the crab *D. lagopodes*, and
5) live *T. pyramis*.

In addition, notes were made regarding the following habitat characteristics:

1) Depth,
2) compass orientation of reef margin (N, S, E, W, etc.),
3) degree of wave exposure,
4) bottom slope, and
5) substrate type and composition.

Data on dead *T. niloticus* shells, hermit crabs, and *T. pyramis* were collected for an ancillary study on predation and competition. The design of this study thus allows quantitative data to be collected simultaneously on a variety of species or phenomena.

The time required for searching each 100 m transect was about 15 minutes/diver, and about 2 manhours of underwater search effort were expended at each site. The surveys were deliberately conducted during Palau's calmest months to take advantage of the lull between northeast trade winds and southwest monsoons. We doubt that transect-type trochus surveys can be conducted accurately or safely in shallow water if surf heights exceed 1 m. Nash (1981) reached a similar conclusion. Although surveys in our study were conducted on different days of the lunar month (hence at different tidal levels), the effect on accuracy of the stated depth contours is minimal since the mean tidal range in Palau is only 1 m.

Locations of the surveyed sites were determined from U.S. Defense Mapping Agency Chart No. 8841 (Palau Islands; scale 1:165,000) and from U.S. Geological Survey Maps (Republic of Palau; scale 1:10,000).

Results

Trochus niloticus abundance and distribution data at 16 Koror State sites are presented in Table 1. Densities ranged from 0 to 750 animals/hectare, with an overall mean of 119.

Table 2 compares trochus densities in sanctuary and exploited areas. Although there was high within-contour variance in both categories, sanctuary sites had significantly lower trochus densities than exploited areas at the 1 and 3 m contours. On average, sanctuary sites had only half as many trochus as exploited sites.

Figure 4 indicates the existence of a significant negative correlation between water depth and trochus density in exploited sites. Shallow sites had larger numbers of relatively small animals. As depth increased fewer trochus were found but their mean size was larger. A similar trend in size zonation has been reported for trochus populations at Guam (Smith, 1979) and elsewhere (Moorhouse, 1932; Rao, 1937); however, the depth-density correlation found in Palau has not been reported previously. In New Caledonia, maximum trochus densities are said to occur in the boulder zone of shallow reef flats (Bour and Gohin, 1982).

Despite considerable searching we found no small (<20 mm) *T. niloticus* juveniles in the subtidal contours surveyed. Young *T. niloticus* appear to settle exclusively in outer reef flat intertidal areas and migrate into deeper water as they grow (Heslinga, 1981b).

The relationship between depth and size of *T. niloticus* is evident when size-frequency histograms are plotted for subpopulations at successive depth contours (Fig. 5). Clearly, deep-water populations have higher percen-

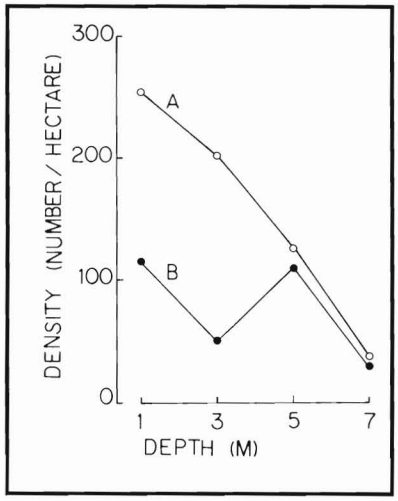

Figure 4.—Relationship between depth and mean density of *Trochus niloticus* on the seaward barrier reefs of Koror State. A significant negative correlation ($r = -0.99$; $p < 0.01$) between depth and density was found between 1 and 7 m depth in exploited area. A, exploited areas; B, sanctuaries.

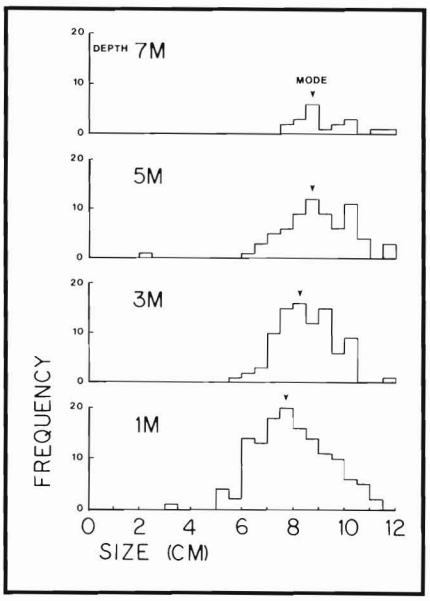

Figure 5.—Size-frequency distributions of *Trochus niloticus* at four depth contours on the seaward barrier reefs of Koror State, 1982. Data were pooled from 16 sites covering 25,600 m². Modal size (arrows) increased with depth while density decreased with depth. Sample sizes at the 7, 5, 3, and 1 m contours were 19, 70, 91, and 136, respectively.

tages of relatively large specimens. The modal size of *T. niloticus* in the 7 m and 5 m contours was 86-90 mm, and this decreased to 76-80 mm at the 1 m contour. If it is assumed that the depth-density correlation in Figure 4a is roughly linear, we can predict that trochus density would approach zero at about 8 m. This prediction agrees well with our field observations, and supports the position of McGowan (1958) that there are no "large, untapped reserves of trochus in deeper water."

In addition to being correlated with depth, trochus densities in the areas surveyed were dependent on reef orientation (Fig. 6). On individual east-coast reefs (Ngederrak, Ikedelukes, and Pelugauar) there was a general trend of decreasing density along a gradient running clockwise from northeast to south. In nearly all cases the south and southeast facing reef sections supported fewer trochus than nearby east or northeast facing sections. The south and southeast facing reef sections were calmer sites, consistently characterized by a sandier, more heterogeneous substrate than the exposed north and northeast facing sections. These latter areas were high energy zones which displayed a more consolidated substrate with broad patches of pavement, coralline algae, and low filamentous algae. Live coral cover was uniformly lower in the shallow contours of the high energy sites.

Spot checks of shallow subtidal zones on the lagoonward (west-facing) side of the surveyed reefs revealed broad sandy patches, occasional live coral heads, and a total absence of *T. niloticus*. All these

Table 1.—Commercial *Trochus niloticus* stock densities in Koror State survey areas, March-April 1982.

Site	Date surveyed	Exposure	Depth (m)	Number of trochus per quadrat	Maximum size (mm)	Mean size (mm)	Density by depth (no. per hectare)	Mean site density
1	3/18	ESE	7	6	116	101	150	
			5	7	119	106	175	
			3	6	101	92	150	
			1	2	79	64	50	131
2[1]	3/18	SE	7	2	103	96	50	
			5	9	102	86	225	
			3	2	95	87	50	
			1	6	86	76	150	119
3	3/30	NE	7	1	100	100	25	
			5	14	106	93	350	
			3	20	101	87	500	
			1	29	113	81	725	400
4	3/30	ENE	7	0			0	
			5	13	109	93	325	
			3	9	103	87	225	
			1	30	106	81	750	325
5	4/20	SE	7	0			0	
			5	1	24	24	50	
			3	20	101	80	500	
			1	15	110	85	375	231
6	4/02	SSE	7	1	82	82	25	
			5	3	77	73	75	
			3	2	74	71	50	
			1	7	82	64	175	81
7[1]	4/06	ENE	7	4	103	92	100	
			5	15	100	86	375	
			3	7	103	80	175	
			1	15	100	83	375	256
8[1]	4/06	S	7	1	78	78	25	
			5	0			0	
			3	1	72	72	25	
			1	9	86	71	225	69
9[1]	4/08	S	7	1	85	85	25	
			5	4	91	88	100	
			3	2	83	80	50	
			1	0			0	44
10	4/08	E	7	2	89	85	50	
			5	1	101	101	25	
			3	0			0	
			1	0			0	19
11[1]	4/13	W	7	0			0	
			5	0			0	
			3	0			0	
			1	2	82	78	50	13
12	4/13	SSW	7	1	86	86	25	
			5	3	95	82	75	
			3	1	101	101	25	
			1	0			0	312
13	4/19	WNW	7	0			0	
			5	0			0	
			3	0			0	
			1	0			0	0
14[1]	4/19	WNW	7	0			0	
			5	0			0	
			3	0			0	
			1	0			0	0
15[1]	4/22	SSE	7	1	86	86	25	
			5	3	95	82	75	
			3	1	101	101	25	
			1	0			0	31
16	4/22	SE	7	0			0	
			5	2	103	89	50	
			3	14	102	88	350	
			1	8	98	83	200	150

[1]Former sanctuary site.

Table 2.—Comparison of commercial *Trochus niloticus* densities in sanctuaries and exploited areas, Koror State, 1982. Densities are expressed in mean number per hectare. Exploited areas had significantly higher (T-test of means) trochus densities than sanctuaries at the 1 and 3 m contours. Sites where no trochus were found were excluded from the analysis.

Depth contour (m)	Density: Sanctuary	Density: Exploited	Significant difference?
1	200	379	Yes ($p < 0.1$)
3	65	257	Yes ($p < 0.05$)
5	255	153	No
7	45	55	No

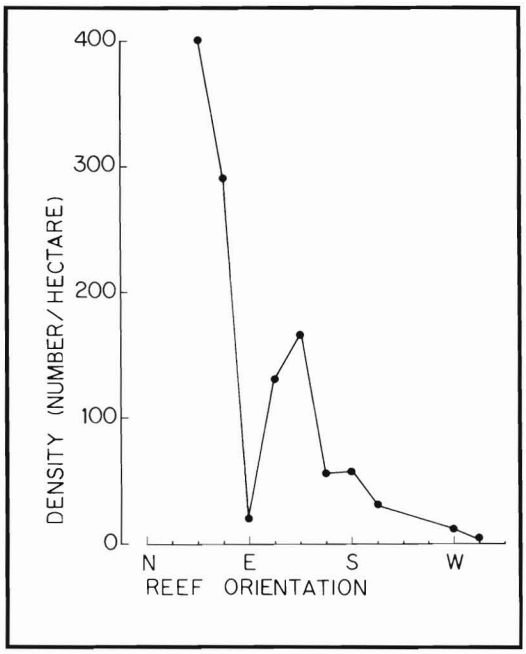

Figure 6.—Relationship between reef orientation and mean density of *Trochus niloticus* at surveyed sites in Koror State, 1982. Density was positively correlated with degree of exposure to surf, and generally decline along a NE, E, S, W gradient.

observations are consistent with the generalization that, in Palau, this species is virtually restricted to hard substrates on seaward reefs. McGowan (1958), however, lists examples of other islands in Micronesia where substantial trochus populations were found on lagoonward reef slopes.

Discussion

Our survey results provide a quantitative picture of commercial trochus populations inside and outside marine sanctuaries that have existed for over 20 years in Koror State. Three questions must now be addressed.

1) Was the sanctuary system working as originally intended?
2) If not, why?
3) What constitutes an appropriate habitat for a trochus sanctuary?

Koror State survey data indicate that, on average, the seven surveyed sanctuary sites had only half as many trochus as nearby exploited areas. Had the system been working as originally planned, higher trochus densities should have been found inside the sanctuaries. Thus, the sanctuary system was only marginally effective at the time of the survey.

The two sanctuaries located on Koror's western barrier reef (sites 11 and 14) had such low numbers of trochus that they were essentially useless. These sites appear to have been chosen arbitrarily. Because most of Koror's western barrier reef drops off steeply, minimal intertidal and shallow subtidal habitats are available for trochus. Moreover, the outer reef flats are generally submerged at low tide and lack the boulder and rubble-strewn intertidal zone that seems favorable to the recruitment of juvenile trochus (Heslinga, 1981b). Our census data support the position that Koror's west coast barrier reef is marginal-to-poor trochus habitat. Not surprisingly, this area is seldom visited by trochus harvesters.

Of the five remaining trochus sanctuaries in Koror State, four (sites 2, 8, 9, and 15) were located on the south or southeast facing sections of their respective reefs. As noted, these were relatively calm sites with sand and live coral dominating the surveyed depth contours. These substrate types offer numerous hazards to *T. niloticus* of all ages and are probably actively avoided. Settling larvae and post-larvae can be consumed by live corals or buried under shifting sand. Juvenile and adult trochus probably avoid sand because it inhibits locomotion and adhesion of the foot. Locomotion across live coral is undesirable because it would expose the foot to stinging nematocysts. We have never observed *T. niloticus* crawling on or adhering to live coral in nature. Perhaps most important, live coral and loose sand do not promote growth of the low filamentous algal species which form a principal part of the *T. niloticus* diet.

Based on this line of reasoning, we concluded that four of the five trochus sanctuaries on Koror's east coast had been placed in marginal or poor habitats. Only one of the east-coast sanctuaries (site 7), located on an east-northeast facing reef, had a suitable substrate composition (dominated by pavement and coralline algae) and a high density of trochus relative to nearby areas.

Of the areas surveyed, the one with the most favorable conditions for *T. niloticus* was Ikedelukes, an exposed barrier reef segment about 5 km south of the Malakal Lighthouse (Fig. 7). Ikedelukes embodies a number of physical and biotic characteristics which we believe are ideal for trochus sanctuaries. These include an unobstructed exposure to surf generated by northeast trades, a gently sloping bottom, a wide reef flat that is exposed at spring low tides, a subtidal substrate that is predominantly pavement (especially in shallow contours), and an abundance of coralline algae and low filamentous algae at 1-3 m.

Ikedelukes supports an immense number of grazing herbivorous fishes, with acanthurids and scarcids being particularly abundant. The blueline surgeonfish, *Acanthurus lineatus*, is especially conspicuous at Ikedelukes and may be a useful "indicator" organism for superior *T. niloticus* habitats. Similarly, the presence of other herbivorous archaeogastropods at Ikedelukes, including *T. pyramis*,

T. incrassatus, *T. maculatus*, and *Turbo argyrostoma*, implies that this reef is particularly favorable for grazers.

Ikedelukes is far enough from the commercial port of Palau (35 minutes by speedboat) to make pollution a minimal concern; however, the reef is close enough to allow surveillance and experimental work. Most important, Ikedelukes had high numbers of mature *Trochus niloticus* relative to other nearby sites. All of these considerations figured in our eventual decision to recommend Ikedelukes as a permanent trochus sanctuary for Koror State.

We emphasize that trochus sanctuaries must be placed near enough to district centers to allow periodic surveillance. In the case of Koror State's western barrier reef sanctuaries, it is unlikely that they were ever visited by conservation personnel simply because of their great distance from Koror Island. Similarly, the number of reefs designated as sanctuaries should not place an excessive burden on the surveillance capabilities of local authorities. In retrospect, this was certainly the case in the Koror State system.

Ecologically and economically, the optimum number and size of trochus sanctuaries for a given locale are unknown and open to debate (Bradbury and Reichelt, 1981). Thus, in many respects the sanctuary concept must still be regarded as an experimental management policy. A scientific approach to the questions involved is highly desirable but would undoubtedly demand far more time and expense than are likely to be available. In any event, it is clear that in most trochus producing countries the amount of reef area devoted to preservation is likely to depend more on political and economic realities than on the persuasiveness of theoretical arguments. Until more is known about coral reef ecology and about reef ecosystem management, the best that can be achieved is some form of compromise between exploitation and conservation, based on as much quantitative information as possible and an appreciation for local conditions and customs.

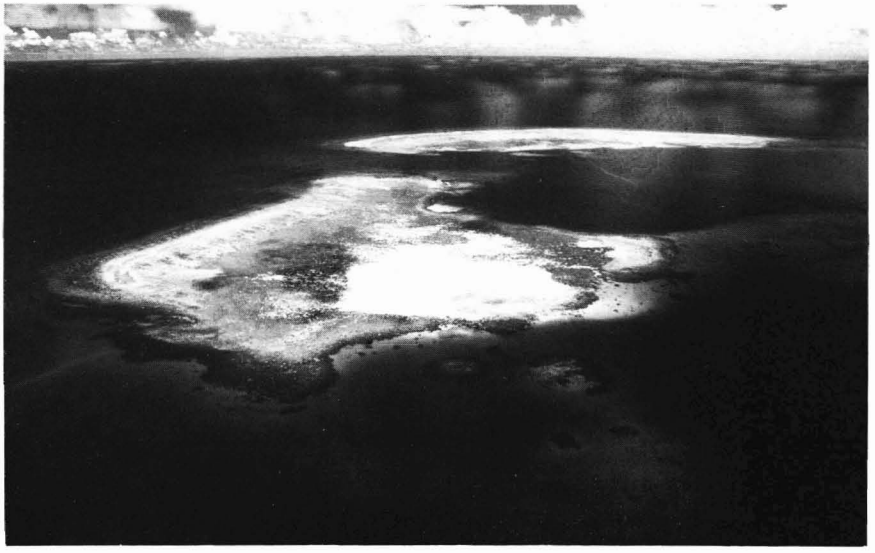

Figure 7.—Aerial view of Ikedelukes Reef in Koror State, presently a sanctuary for commercial trochus. Photograph courtesy of and copyright by Douglas Faulkner, N.Y.

Following the completion of the trochus surveys in Koror State, we recommended to government officials that the trochus sanctuaries be reduced and consolidated into two moderately sized, centrally located reefs near enough to Koror to be visited frequently by conservation personnel. Ikedelukes Reef and Ngederrak Reef (Fig. 7) were selected as sanctuaries because they fulfilled the necessary physical, biotic, and geographic requirements reasonably well.

We also recommended that whole reefs (from channel to channel) be designated as sanctuaries because this would eliminate the time-consuming annual task of placing markers on the reefs to delineate sanctuaries. It seems practical, where possible, to treat whole reefs rather than portions of reefs as management units.

The proposed revisions to the Koror State trochus sanctuary system were approved in May 1982 by the Mayor and Chief, Ibedul Yutaka Gibbons (Heslinga, 1982). The harvest season opened the following month and lasted 4 weeks. The new sanctuary regulations were broadcast over local radio in the weeks before harvesting began. During the season the new trochus sanctuaries were patrolled regularly by Marine Resources Division personnel, including the authors. A few sporadic incidents of sanctuary poaching were observed; the fishermen involved claimed ignorance of the radio broadcasts and willingly moved out of the sanctuaries when informed of the new regulations. In 1983 Koror State officials declared a moratorium on trochus harvesting, and no violations were observed during routine checks of the sanctuary reefs. We believe that future trochus poaching incidents in Koror State will be negligible if surveillance is maintained during the harvest season.

The need to establish coral reef sanctuaries and other conservation measures in the nations of the tropical Pacific is widely recognized (Johannes, 1978, 1982; Salvat, 1981; Stoddart, 1981; Wells, 1981b; Kelleher and Kenchington, 1982), especially in areas where traditional forms of reef tenure and resource protection have

been eroded by urbanization and the effects of Western contact. Our study is instructive because it illustrates a case in which quantitative data were used successfully to lobby for the improvement of a coral reef management program. We assembled evidence showing that a 20-year-old trochus sanctuary system would likely be improved by some simple modifications, specifically, consolidation and relocation to superior habitats. Local Marine Resources Division personnel were trained to evaluate the problem and subsequently participated in proposing a solution. The assistance and approval of the Koror State Mayor and Chief were actively sought and proved instrumental in achieving an acceptable modification of policy. It is significant, too, that baseline data were established and practical methods developed to serve as a model for future comparative analyses.

Acknowledgments

Financial support for this work was provided by the Pacific Fisheries Development Foundation (PFDF) and the Division of Marine Resources, Republic of Palau. We are grateful to the staffs of PFDF, the National Marine Fisheries Service at Honolulu, Hawaii, and Living Marine Resources, Inc., of San Diego, Calif., for their cooperation. Invaluable logistical assistance in Palau was provided by Ibedul Gibbons, Alan Seid, Koichi Wong, Toshiro Paulis, and the entire staff of Micronesian Mariculture Demonstration Center. We thank Douglas Faulkner for permitting us to use his aerial photograph of Ikedelukes Reef for Figure 7.

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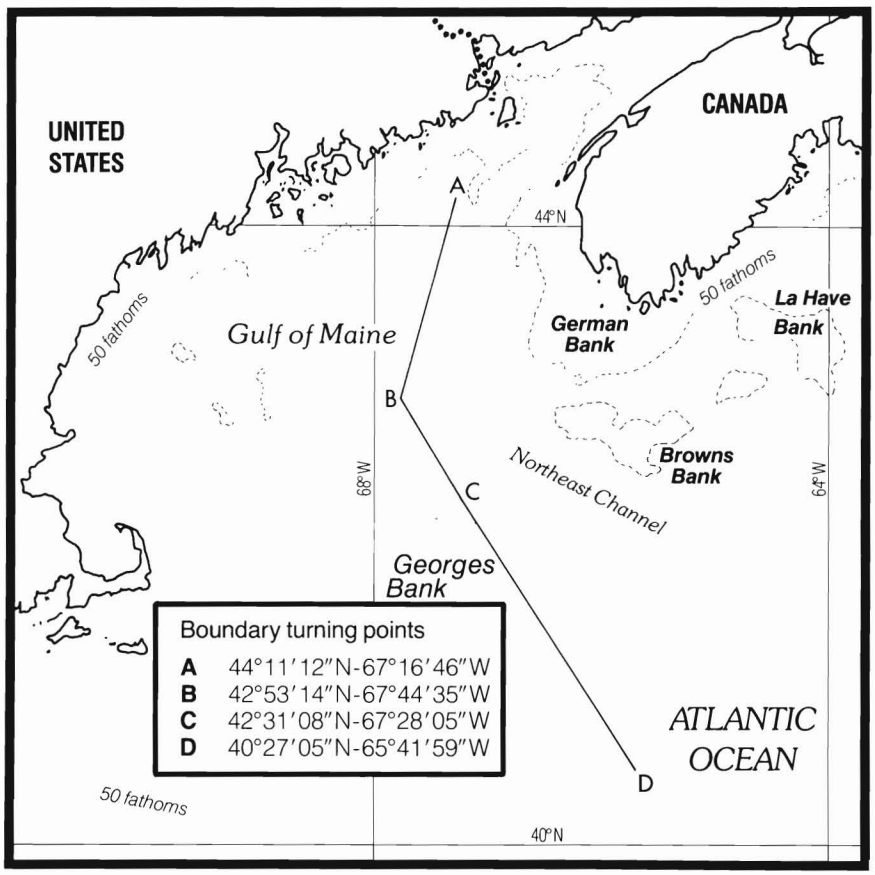
Eastern U.S.-Canada Boundary Line Drawn by World Court

A compromise North Atlantic boundary line, dividing Georges Bank and its resources between the United States of America and Canada, has been drawn by the World Court in The Hague, Netherlands. The new boundary between New England and Nova Scotia gives part of the Bank to Canada for the first time. The issue was settled on 12 October 1984 and the decision was enforced as of midnight, 26 October 1984. Both Canada and the United States had agreed to a 14-day grace period to allow fishing vessels from both sides to return to their respective sides of the new boundary (see map).

The heart of the issue, which has been a source of dispute since 1976 when both Canada and the United States extended their eastern boundaries, was control of an area of between 13,000 and 18,000 square nautical miles that included the northeastern half of Georges Bank, one of the world's richest fishing grounds. The area may also contain oil and natural gas reserves. The United States had argued that it was entitled to a boundary line that retained all of Georges Bank. Canada had asked for a line dividing the Bank virtually in half, leaving all of the northeastern segment under its control. The World Court, in essence, split the difference, setting a line that cut Georges Bank about midway between the two claims. According to the National Oceanic and Atmospheric Administration, which has jurisdiction over fisheries out to 200 miles off the U.S. coast, including the Georges Bank area, the new boundary will make management of Atlantic fisheries, including cod and haddock, very complex, and will require close consultation with all interested parties. High seas rights pertaining to the area, such as freedom of navigation, are not affected.



The Court, at the request of Canada and the United States, established a Special Chamber of five judges to hear the case, and had considered extensive written and oral submissions presented by both sides during the previous 2 years. Members of the Chamber included: Judge Roberto Ago of Italy, President of the Chamber; Judge Andre Gros of France; Judge Herman Mosler of the Federal Republic of Germany; Judge Stephen Schwebel of the United States; and Judge ad hoc Maxwell Cohen of Canada.

Symposium Honors NEFC Gloucester Laboratory

In honor of the 25th anniversary of the National Marine Fisheries Service's Gloucester Laboratory of the Northeast Fisheries Center, a 1-day "International Symposium on Fisheries Technology" has been scheduled in conjunction with the 30th Atlantic Fisheries Technological Conference 25-29 August 1985.

The Conference will be held at the Copley Plaza Hotel in Boston, Mass., and is chaired by Ron Lundstrom. Keynote speaker for the Symposium will be Jack Connell, Director of the United Kingdom's Torry Research

Station. In addition, a program has been assembled which features some of the world's foremost fishery technologists and the Symposium will be an excellent opportunity to examine the state of the art in the field of fisheries technology.

The entire program of the 30th AFTC has been in preparation, as well, with the first call for papers being sent out in early March. The second and final call for papers was to be issued in early June, with an abstract submission deadline of 1 July 1985. A final mailing, 1 month prior to the conference, will include the final program and registration and hotel information.

American Lobster Size, Gear Requirements Told

Effective 1 January 1985, federal regulations which implement the American Lobster Fishery Management Plan (FMP) require that lobsters landed in whole form must have a minimum carapace length of 3 3/16 inches, and gear must be appropriately marked and vented. Richard H. Schaefer, Acting Northeast Regional Director of the National Marine Fisheries Service, stated that these provisions apply to all lobster fishermen who are permitted to fish in the fishery conservation zone (FCZ), either by his office or through an endorsement on a State lobster permit.

Lobster gear deployed in the FCZ or possessed by a person whose vessel is permitted to fish in the FCZ must be marked with the vessel's Federal fishery permit number, or the markings required by the vessel's homeport State. This gear must also include an escape vent(s) in the parlor section of the trap. The vent may either be: 1) A rectangular portal with an unobstructed opening not less than 1 3/4 inches (44.5 mm) by 6 inches (152.5 mm); or 2) two circular portals with unobstructed openings not less than 2 1/4 inches (57.2 mm) in diameter.

According to Schaefer, these provisions for the minimum carapace size and the gear marking and venting requirements will not affect most lobstermen because they are already required in many of the states. The American Lobster FMP was prepared by the New England Fishery Management Council, and is intended to implement the Federal share of the coastwide lobster management program for this valuable fishery.

Misleading Reports Given by Japanese Fish Groups

The National Marine Fisheries Service announced at the North Pacific Fishery Management Council meeting in Anchorage last fall that documents seized from Japanese fishing vessels indicate that organized measures had been used by Japanese fishing associations to frustrate U.S. observer programs and at-sea enforcement.

During fishing violations investigations conducted for improper catch logging and reporting, Japanese language documents were seized and subsequently translated. Those documents indicate that the Japanese Longline and Gillnet Association and the National Federation of Medium Trawlers used highly organized schemes to manipulate U.S. observer coverage on foreign vessels. The tactics included purposeful reductions in catch and restricting fishing areas. U.S. observers are used to monitor foreign catch levels and composition. The biased observer data may have allowed the foreign vessels to avoid payment of poundage fees and resulted in improper estimates of fish stocks by fishery managers.

Fishery managers use observer catch estimates when coverage of each class of foreign vessel is 20 percent or more in a statistical area each week. The schemes employed often prevented achieving 20 percent observer coverage so that foreign reported catch would be used. The documents infer that vessels without observers aboard could fish unrestricted but report only assigned quotas.

The schemes also involved monitoring of U.S. patrols to prevent at-sea boardings of vessels that did not have observers assigned. Patrol craft location and movement information was sent by code to fishing vessels to allow movement away from patrol vessels. When vessels without observers were boarded, catch underlogging violations were often found.

Beginning in 1984, U.S. observer coverage was increased to nearly 100%. That has eliminated the effects of some of the tactics that had been used. The level of foreign fishing off Alaska was significantly reduced in 1984 and in part stems from increased levels of observer coverage. Observers, however, cannot monitor the entire catch of a vessel that fishes continuously and opportunities to bias observer catch estimates still exist.

The investigation results were provided to Department of State officials who asked the Japanese Government to conduct an inquiry. While awaiting that report, the North Pacific Fishery Management Council and fishery managers were studying possible actions available to prevent recurrence of such schemes.

Gulf Reef Fish Fishery Regulation Established

Regulations to conserve and manage reef fish resources of the Gulf of Mexico became effective on 8 November 1984, announced Jack T. Brawner, Southeast Regional Director, National Marine Fisheries Service (NMFS).

The regulations implement the fishery management plan (FMP) for reef fish resources prepared by the Gulf of Mexico Fishery Management Council under the Magnuson Fishery Conservation and Management Act. The regulations apply in the Gulf of Mexico portion of the fishery conservation zone (FCZ), which generally includes all waters extending from 3 n.mi. off Alabama, Mississippi, and Louisiana, and 9 n.mi. off Florida

(west coast) and Texas, to a distance of 200 n.mi. offshore. Species regulated under the FMP are snappers, groupers, and sea basses.

The regulations establish a "stressed area" in the nearshore waters of the FCZ off Florida and Alabama and portions of Mississippi and Texas where reef fish resources are subjected to intensive fishing effort and where some species, especially red snapper, are overfished. In this area, the use of fish traps and roller-rigged trawls is prohibited altogether, while powerheads (a projectile-firing device used by divers) may not be used to harvest any regulated species. These restrictions are intended to reduce fishing effort and the potential for user conflicts.

Fish traps used outside the "stressed area" are subject to certain construction specifications, number and size limitations, and permitting and tagging requirements. Individuals tending to use traps in the FCZ were required to apply for a permit from the Regional Director at least 45 days in advance of the desired fishing date. Trap fishermen were given until 23 November 1984 to comply with the permit and tag requirements. There is no charge for permits and tags for fish traps. Permit applications may be obtained by writing or phoning the Fishery Operations Branch, National Marine Fisheries Service, 9450 Koger Boulevard, St. Petersburg, FL 33702, (813) 893-3723. A copy of the reef fish regulations containing details of fish trap construction features, a description of the "stressed area," and other prohibitions also may be obtained from the Fishery Operations Branch.

In addition, the regulations prohibit the use of poisons or explosives for taking any regulated species, and establish a minimum size limit of 12 inches fork length (13 inches total length) on red snapper harvested in the FCZ with three exceptions: 1) An incidental catch of five undersized red snappers per person per trip is allowed; 2) domestic vessels lawfully fishing trawls in the FCZ are exempt from the minimum size limit and incidental catch allowance for red snapper; and 3) persons fishing in the FCZ from headboats (generally vessels that carry seven or more persons who fish for a fee) are exempt from the minimum size limit and incidental catch allowance for red snapper until 8 May 1986. All red snapper harvested in the FCZ must be landed with the head and fins intact. Federal civil penalties up to $25,000 may be assessed for violation of these regulations.

NEFC Increases Salmon Research

The United States, Canada, and many European countries as far south as Spain produce Atlantic salmon, *Salmo salar*, which annually migrate to the waters off West Greenland where they remain from one to several years before returning to their native rivers to spawn. Greenland has no Atlantic salmon rivers but conducts a significant fishery that has been the focus of international concern since the mid-1960's. In 1971, for example, 2,700 metric tons (t), or 750,000 salmon, were caught in the high seas fishery off West Greenland. Scientists have estimated that on average about 42 percent of these fish come from the United States and Canada.

In 1972, the ICNAF (International Commission for Northwest Atlantic Fisheries) was able to set national quotas on fished species in the Northwest Atlantic for the first time and shortly thereafter the West Greenland high seas fishery also came under control of ICNAF. The total catch was gradually reduced to about 1,100 t annually, and the high seas fisheries of Norway, the Faroe Islands, Sweden, and Denmark were completely eliminated by 1976. The ICNAF measures continued in force until 1977 when the U.S. extended its fisheries jurisdiction to 200 miles.

In March 1983 the NMFS Northeast Fisheries Center (NEFC), was tasked to begin an Atlantic salmon research program which would address the high seas fisheries and the interception problem of U.S. salmon in the Northwest Atlantic. On 25 March 1983, NEFC representatives met with Canadian scientists in Halifax, Nova Scotia, to review the Canadian research on Atlantic salmon. On 21 April 1983, many of the U.S. scientists who are working directly with Atlantic salmon from the States, Universities, and Federal Government met at the NEFC in Woods Hole, Mass., to plan a detailed program of research for the National Marine Fisheries Service.

After review of the current U.S. research programs the group decided that the NEFC could contribute a significant amount of information primarily in four areas: 1) Exploration and assessment of the methods other than external tagging to separate U.S. stocks of Atlantic salmon from other stocks on the high seas, 2) provide assistance to the states in analyzing their tagging data, 3) provide assistance to the states in expansion of their tagging programs, and 4) sponsorship of technical workshops which would bring together people within the New England area working on Atlantic salmon to discuss common problems.

Thus, the NEFC has taken several steps. It is providing money to the Atlantic Sea Run Salmon Commission in Maine to evaluate the timing, magnitude, and distribution of commercial and home-water exploitation of 50,000 tagged hatchery-reared Atlantic salmon smolts in 1984. The Center is also helping them to summarize and evaluate their tag return data and establish a data processing system for tagging studies.

Also, the NEFC is providing funds to the University of Rhode Island, Narragansett, for the assessment of certain characteristics associated with scales, otoliths, and body measurements which may be used in identifying U.S. Atlantic salmon stocks on the high seas. In addition the Center has requested proposals, nationwide, for two studies on the review and evaluation of genetic and nongenetic

techniques to distinguish U.S. Atlantic salmon stocks from all other stocks. Proposals are under review. The Center also held a workshop to evaluate the value of the stock identification techniques that will be studied during the coming months.

Much effort has been spent over the years to restore runs of Atlantic salmon to the New England area by many people. Their efforts are now being rewarded with a significant increase in runs in several rivers. The National Marine Fisheries Service, which has responsibility for research in the FCZ (3-200 miles from the coast) and beyond, is now significantly developing an Atlantic salmon research program which will assist the States and the Fish and Wildlife Service. By summer 1985, the Center hopes to be in a position to know which procedures are most useful for identifying U.S. Atlantic salmon, regardless of where they are on the high seas. This will be useful in evaluating the degree of exploitation of U.S. Atlantic salmon off West Greenland as well as in the Canadian fisheries as the salmon migrate from West Greenland back to the United States. If a proportion of U.S. Atlantic salmon are being killed by other countries on the high seas, then it is very important that the United States be in a position to evaluate its significance.

Witch Flounder Eyed As Fishing Pressure Rises

The witch flounder, *Glyptocephalus cynoglossus*, also called gray sole, is a slow-growing deep-water flatfish that is fairly common in the Gulf of Maine-Georges Bank region. Over the years, the species has been taken primarily as a by-catch and landings have generally been minor, averaging about 3,000 metric tons (t) during the 1960's and 1970's. Since 1980, however, landings have increased substantially; the 1982 total was 5,100 t and an increase to perhaps 7,000 t was projected for 1983. This increase has been accompanied by an increase in effort and in landings of smaller fish. In response to these trends, the NMFS Northeast Fisheries Center has developed a preliminary assessment to evaluate the current status of the witch flounder resource.

In U.S. waters, witch flounder are most abundant throughout the Gulf of Maine and in deeper areas along the fringes of Georges Bank. In 1982 the primary fishing areas were located in the west-central Gulf of Maine, off Cape Cod, and along the northwestern rim of Georges Bank. Specific spawning grounds have not been found, but the species appears to spawn widely throughout the western Gulf of Maine from March to October, with a peak in May and June.

Witch flounder are prized as a food fish and command a high market price, but they are not abundant enough off New England to support a continuous directed fishery. Therefore they have been caught primarily as part of a mixed fishery and as a by-catch in other directed fisheries.

The bulk of U.S. landings in recent years has been taken by small vessels fishing year-round in the Gulf of Maine and by larger vessels fishing on Georges Bank during late spring and early summer. In general, effort and total catch have increased for all tonnage classes. Another noteworthy trend in the witch flounder fishery has been an apparent increase in landings of small "peewee" flounder of 11-12 inches in length. Future prospects for this resource are uncertain. Research vessel survey data suggest a declining trend since the late 1970's implying that the 1982-83 landings average about 6,000 t.

Northern Gadoid Workshop Scheduled at NWAFC

An international "Workshop on Comparative Biology, Assessment, and Management of Gadoids from the North Pacific and Atlantic Oceans" will be held 24-28 June 1985 at the NMFS Northwest and Alaska Fisheries Center, Seattle, Wash. It is cosponsored by the Center, the Institute of Marine Research, Bergen, Norway, and other Seattle and Bergen institutions.

At the Workshop, specialists from several nations will review and discuss the life history, ecology, management, and utilization of these important gadoids and provide recommendations for future studies. Papers will be submitted for the workshop, but not formally presented. Instead, rapporteurs will provide a synthesis of the contributed papers by category. Workshop papers will be compiled in proceedings and selected papers will be published in a special journal issue. Additional information can be obtained from the Gadoid Workshop Organizing Committee, c/o Miles Alton, F/NWC1, Northwest and Alaska Fisheries Center, NMFS, NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115.

NOAA/USGS Will Map 200-Mile EEZ

NOAA and the Department of the Interior's U.S. Geological Survey (USGS) have launched a cooperative multi-year program to provide basic "roadmaps" vital to systematic resource exploration, development, and conservation of the U.S. EEZ (exclusive economic zone). When President Ronald Reagan proclaimed the EEZ 200 miles from the shores of the United States in 1983, the size of the United States nearly doubled.

NOAA's responsibilities for the largely uncharted 6 million square mile area in the EEZ include surveying, mapping, oceanic and resource analysis, and fisheries management. USGS responsibilities include definition of seafloor geology, geological processes, and resources, which include sand and gravel, placers, phosphorites, manganese nodules, cobalt crusts and sulfides, all with major stragetic and economic potential. The project began in the Pacific, with the West Coast schedule for 1984-85; Alaska in 1986; the Hawaiian Islands in 1987; and then the Trust Territories. East and Gulf Coast schedules have not yet been set.

The British Salmon Market

The United Kingdom is an important fish consuming nation, with an annual per capita consumption of about 17.3 kg. Most Britons, however, have no tradition of eating Atlantic salmon, *Salmo salar*, both because of its expense and seasonal availability. Consumer surveys indicate, for example, that only about 1 in 10 British consumers purchase fresh, frozen, or smoked salmon, and those purchases are primarily made by more affluent and older consumers.

Salmon consumption, however, is increasing. The NMFS estimates that about 10,400 t of fresh and frozen salmon were available for consumption or smoking in the United Kingdom during 1983, a 50 percent increase over the 7,000 t available in 1980 (Table 1). No data exist to show in what product form that salmon was consumed. University of Stirling researchers estimate that about 70-75 percent of the fresh and frozen salmon available in 1980 was smoked[1]. Actual smoked consumption in the United Kingdom was less because about 20 percent of the salmon smoked was subsequently exported. It is likely that the consumption levels of fresh salmon have increased sharply since 1980 because of the increased production in Scotland, but no data is available to substantiate this.

Fresh and Frozen

Salmon has traditionally been marketed primarily in the restaurant/catering sector. One estimate suggests that up to 70 percent of the fresh and frozen salmon consumed in the United Kingdom is prepared by the catering sector. Luxury restaurants generally insist on fresh Atlantic salmon. In the past they have preferred wild-caught salmon, but farmed salmon are increasingly accepted. Most luxury restaurants still generally prefer to serve Scottish salmon because of its premium image with the British consumer. Managers of medium-priced restaurants are much more cost conscious and many use frozen Pacific salmon, *Oncorhynchus* spp., because it is cheaper. Some of those managers believe that few consumers would be able to tell the difference once the salmon was cooked. Many managers also mention the convenience of the frozen product and more stable seasonal prices. The remainder of the fresh and frozen salmon marketed to consumers is mostly sold by fishmongers and supermarket chains. Traditionally, fishmongers have been the most important outlet, but the current trend of adding fresh (or thawed frozen fish) counters is making increasing inroads.

The salmon price structure is extremely complex. Fresh Atlantic salmon prices vary according to the source, season, and size, with wild salmon commanding the higest prices. At the beginning of the year, wild salmon prices may be over £5 per kg higher than farmed prices (Tables 2-4). Prices fall during the summer, especially for the wild-caught salmon when the natural runs increase supplies. Farmed salmon show much greater price stability than the wild salmon (Fig. 1). In 1984, for example, large wild salmon varied from £5.51 to 11.02/kg while large farmed salmon only varied from £4.85 to 6.61 (Table 4). There are also substantial price differences as a result of size. Larger fresh fish, which can be used for banquets or parties, command as much as twice the price per kilogram than smaller fish command. The price structure may change in the future if

[1]Canned products not considered because all are believed to be imported.

Table 1.—United Kingdom fresh and frozen salmon supply, 1983 (NMFS estimates).

Source	Product form	Quantity (t)[1] 1980	1983
Catch	Fresh	1,700[2]	1,500[2]
Cultured	Fresh	598	2,536
Imports	Fresh	333	1,524
Imports	Frozen	5,354	6,483
Exports	Fresh	−343	−1,110
Exports	Frozen	−596	−490
Total		7,046	10,443

[1]Import and export data and Tables 5 and 9 have been adjusted to approximate live-weight equivalents.
[2]Estimated reported and illegal catch.

Table 2.—Salmon prices[1] on the London Billingsgate market, 1982.

Date[2]		Price (£/kg) Farmed[3]	Wild Scottish[4]
January	22	2.87-4.41	6.61-11.02
March	26	3.09-5.07	6.83- 9.37
April	8	3.09-5.18	5.51- 8.82
	30	3.09-5.51	5.73- 7.16
May	7	3.53-5.51	6.17- 7.72
	14	3.09-5.95	6.17- 7.72
June	11	2.20-5.95	5.51- 6.61
July	16	2.43-3.53	3.53- 5.29
	23	1.76-4.85	4.08- 5.51
	30	1.76-4.85	4.08- 5.51
August	6	1.98-5.29	3.97- 5.73
	13	1.76-5.07	4.85- 5.73
	27	1.76-5.73	4.18- 5.73
September	3	2.20-3.53	3.97- 5.51
	10	2.20-4.63	5.07- 5.51
	24	2.43-5.51	
October	1	3.31-6.17	
	8	3.09-5.95	
	15	1.98-5.07	
	22	3.09-5.51	
November	12	3.09-5.95	
December	3	2.76-6.06	
	22	3.31-6.17	

[1]Price range is for salmon of different sizes; larger fish command the higher prices.
[2]Dates selected are Friday or the last working day of each week. Missing weeks are due to an incomplete set of the source publication, *Fish Trader*, or no quotation for that week.
[3]Both grilse and salmon.
[4]Excluding grilse.

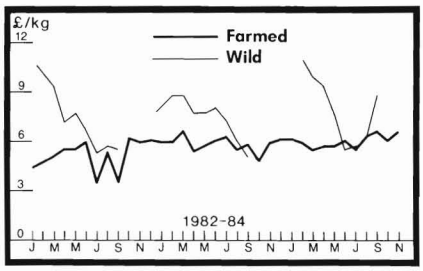


Figure 1.—U.K. prices on the London Billingsgate Market for large Scottish farmed and wild salmon, 1982-84.

Table 3.—Salmon prices[1] on the London Billingsgate market, 1983.

Date[2]		Price (£/kg) Farmed[3]	Wild Scottish[4]
January	7	3.09-5.95	
	14	3.09-5.95	
	21	2.65-5.95	
	28	2.65-5.95	
February	4	2.20-5.95	
	11	2.76-5.51	
	18	2.76-5.51	
	25	2.43-5.95	4.85-8.81
March	11	2.43-6.61	5.51-8.81
	18	2.65-6.61	4.41-7.72
April	15	2.98-5.40	5.95-7.72
	22	3.20-6.06	6.06-8.82
May	6	2.87-5.73	5.51-7.72
	13	2.76-5.73	6.06-8.27
	20	4.40-5.95	6.61-8.27
	27	2.65-6.06	4.74-8.27
June	3	3.31-6.06	5.51-8.05
	10	1.87-6.06	5.18-7.28
	17	3.31-5.95	4.96-7.72
	24	2.43-5.51	3.53-6.28
July	1	2.20-6.28	4.41-7.28
	8	2.20-5.51	4.19-7.05
	15	2.20-5.51	3.97-6.83
	22	2.43-5.51	3.74-6.83
	29	2.20-5.29	3.30-5.95
August	5	2.20-5.51	3.42-6.06
	12	2.20-5.07	3.53-5.73
	19	2.20-5.07	3.75-5.07
	26	2.20-4.96	3.75-5.07
September	2	1.87-5.84	3.53-5.07
	9	2.87-5.29	3.53-5.07
	16	2.65-5.73	4.85-5.73
	23	3.75-5.95	
	30	3.75-5.07	
October	7	3.53-4.85	
	14	2.65-5.73	
	21	2.20-5.73	
	28	1.76-5.73	
November	4	3.53-5.95	
	11	2.20-5.95	
	18	2.87-5.73	
	25	2.87-5.73	
December	2	2.87-6.17	

[1]Price range is for salmon of different sizes; larger fish command the higher prices.
[2]Dates selected are Friday or the last working day of each week. Missing weeks are due to an incomplete set of the source publication, *Fish Trader*, or no quotation for that week.
[3]Both grilse and salmon.
[4]Excluding grilse.

Table 4.—Salmon prices[1] on the London Billingsgate market, 1984.

Date[2]		Price (£/kg) Farmed[3]	Wild Scottish[4]
January	6	3.53-6.17	
	13	2.65-6.61	
	20	3.09-5.95	
February	3	3.09-5.95	
	10	3.09-5.95	8.82-11.02
	24	3.09-5.95	8.82-11.02
March	2	3.53-5.51	6.61- 9.92
	9	3.09-5.51	6.61- 9.92
	16	2.98-5.95	7.72-11.02
	30	2.87-4.85	6.61- 9.92
April	6	2.87-5.73	7.16- 9.36
	19	2.65-5.51	4.96- 7.16
May	11	2.43-5.73	4.41- 7.71
	18	2.43-5.51	4.41- 5.95
	25	2.43-5.51	4.41- 6.17
June	1	2.43-6.06	4.41- 5.51
	8	2.43-6.06	4.41- 6.17
	15	2.43-6.06	4.41- 6.61
	29	2.43-5.62	4.19- 5.95
July	6	3.53-5.51	4.41- 5.73
	13	2.20-5.73	4.63- 5.95
	27	2.20-5.73	5.07- 6.17
August	4	4.08-6.28	5.07- 6.17
	10	2.20-5.51	5.07- 6.17
	17	2.20-5.51	5.07- 6.17
	24	3.31-5.95	4.96- 6.61
	31	3.96-5.51	5.51- 7.72
September	14	3.53-6.61	6.61- 8.82
	21	3.31-6.06	
	28	3.31-5.95	
October	5	3.09-6.06	
	12	3.31-6.61	
	19	3.31-4.84	
November	3	3.31-6.61	
	10	2.65-7.06	
	16	3.31-5.70	

[1]Price range is for salmon of different sizes; larger fish command the higher prices.
[2]Dates selected are Friday or the last working day of each week. Missing weeks are due to an incomplete set of the source publication, *Fish Trader*, or no quotation for that week.
[3]Both grilse and salmon.
[4]Excluding grilse.

growers succeed in expanding the market for smaller fish. Frozen salmon is also available, mostly imported Pacific salmon. There are also considerable price differences among the Pacific species, depending on the species and size. Generally, Pacific salmon is cheaper, but Scottish growers can undersell chinook, *O. tshawytscha*, and are close enough to the coho salmon, *O. kisutch*, to begin to compete if the price gap narrows much more.

At first, retailers were primarily interested in farmed salmon to extend the season beyond the time when wild salmon is available. The SSGA (Scottish Salmon Growers Association) hired a London public relations firm to run a Scottish Salmon Information Service in an effort to publicize the high quality of farmed salmon. The initial campaign cost £50,000. Growers hoped to reduce the price differential between wild and farmed salmon by making consumers more familar with the high quality of the farmed product. Growers are convinced that their product is superior to wild-caught salmon. In some cases, fresh salmon marketed in the United Kingdom is not now identified as being wild or farmed. Some conservative bastions, however, such as the exclusive London department store Harrods[2] still insist on the distinction.

The concern among some growers that increasing salmon supplies would depress prices has not materialized. Despite the fact that growers have increased production 300 percent since 1980, salmon prices in the United Kingdom have not declined (Fig. 1). Some companies report a greater seasonal stability in salmon prices. Marketing specialists believe that the increased production has enabled fishmongers to sell salmon at reasonable prices throughout the year, helping to stabilize the market. Expanding salmon production in Scotland may, in the long run, have little impact on the prices for salmon in the United Kingdom. Scottish production, even if it reaches 10,000 t by 1990, will be only a fraction of the expected Norwegian production of Atlantic salmon and an even smaller proportion of the total world production of Atlantic and Pacific salmon, which exceeds 500,000 t. Prices on the British market will probably be primarily determined by developments in Norway and other more important salmon producing countries.

Salmon growers have benefited from the resurging popularity of fresh fish in the United Kingdom. Many supermarkets and even some department stores have opened fresh fish counters where salmon is readily available to a much wider cross section of British consumers than was the case previously. Salmon marketed through Marks and Spencers, for example, is apparently reaching new customers that did not normally buy from fishmongers.

Smoked and Canned

The catering sector also dominates the marketing of smoked salmon, which is widely available in both luxury and medium-priced restaurants. The ease of handling and minimal preparation make it an attractive product. Most of the remaining product is sold in the delicatessen department of supermarkets. There is also a small mail-order trade. The premium-priced product is still Scottish wild salmon, although the quality of farmed salmon is increasingly narrowing the price gap. Imported Pacific salmon is also available for the price-

[2]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

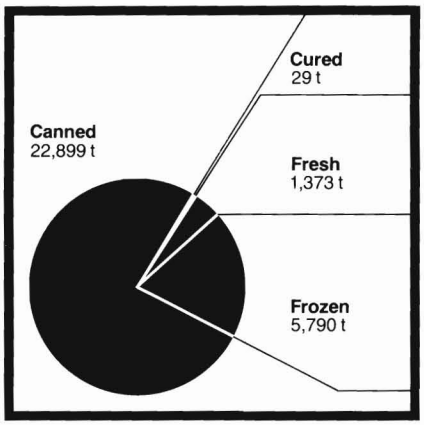


Figure 2.—United Kingdom salmon imports by commodity, 1983. Total is 30,000 t.

conscious consumer.

Most salmon consumed in the United Kingdom is canned, and all is imported. British consumers bought almost 23,000 t of canned salmon in 1983, about three times as much as the total of all fresh, frozen, and smoked purchases combined. Canned salmon is the cheapest salmon product regularly available to British consumers. Industry sources believe there is little competition between the fresh and the canned product. Canned consumption declined in 1982 as a result of a botulism incident in Belgium which received considerable publicity throughout Europe. Consumption recovered in 1983, but did not equal 1981 levels.

Trade

Imports

The United Kingdom imported over 30,000 t of salmon in 1983, valued at over $140 million, more than a 35 percent increase over the 22,000 t imported in 1982. Nearly 23,000 t of the 1983 total, or over 75 percent, was canned salmon from the United States, Canada, and the Soviet Union (Fig. 2). The 1983 increase was primarily in canned products and probably reflects the recovering demand as consumers increased purchases after the botulism scare in 1982. Even though Scottish growers increased salmon production in 1983, imports of fresh salmon also increased. Fresh imports totaled almost 1,400 t in 1983, nearly double the 800 t imported in 1982. Most of the fresh salmon was imported from Norway, but some was also purchased from Ireland (Tables 5, 6).

The United States is the principal supplier of salmon to the British market. The United States supplied over 55 percent of the frozen salmon, mostly headed and gutted, and 55 percent of the canned salmon imported in 1983 (Table 5). Canada is the United Kingdom's second leading supplier.

United States and Canadian exporters have been concerned about the impact of the increasing produc-

Table 5.—U.K. salmon imports in metric tons by commodity and country, 1980-83.

Commodity and origin	Imports (t) 1980	1981	1982	1983
Fresh/chilled				
Norway	106	326	602	880
Ireland	154	127	156	440
France		2	2	23
Denmark	6	20		13
United States	16			8
Netherlands	2	25		1
Other	16	1	3	8
Subtotal	300	501	763	1,373
Frozen				
United States	2,601	2,983	3,100	3,293
Canada	1,115	1,484	1,059	1,266
Norway	157	344	382	556
Ireland	250	85	220	228
Faroe Islands	62	267	321	153
Denmark	252	265	237	129
France	5	4	26	67
Japan	234	74	18	33
Sweden	94	1	25	25
Belgium/Lux.	4	3		14
Netherlands	16		12	10
Chile		88	16	8
Germany	30	10	5	5
Greenland			20	3
Other	1	10	13	
Subtotal[1]	4,821	5,618	5,454	5,790
Cured				
Denmark	11	11	9	13
Ireland	9	2	8	8
France	13		3	4
Other	25	1	12	3
Subtotal[1]	58	15	34	29
Canned				
United States	15,375	15,263	7,195	12,658
Canada	7,565	10,014	6,572	8,642
Soviet Union	1,286	3,143	1,450	989
Netherlands	156	58	178	373
Belgium/Lux.	2		17	155
Iceland				61
Denmark		19		9
Ireland			219	4
South Korea		63	118	
Japan	37	593	32	
Germany		16		
Other	43	26	39	8
Subtotal[1]	24,464	29,195	15,820	22,899
Grand Total[1]	29,643	35,329	22,071	30,090

[1]Totals may not agree due to rounding. Source: Eurostat trade statistics.

Table 6.—U.K. salmon import values by commodity and country, 1980-83.

Commodity and origin	Imports (in U.S. $1,000) 1980	1981	1982	1983
Fresh/chilled				
Norway	1,170	2,370	3,979	5,406
Ireland	1,193	715	774	1,832
France	3	15	14	131
Denmark	67	113	5	80
United States	79			36
Netherlands	14	119	9	6
Other	106	13	10	30
Subtotal[1]	2,632	3,345	4,790	7,521
Frozen				
United States	11,285	10,789	11,160	9,695
Canada	6,076	6,988	4,765	4,450
Norway	1,717	2,759	2,818	3,694
Ireland	2,618	658	934	1,424
Faroe Islands	514	2,046	2,101	1,024
Denmark	1,912	1,674	1,382	740
France	35	20	119	304
Sweden	337	4	168	146
Japan	923	327	78	117
Belgium/Lux.	18	15		65
Netherlands	58	2	58	32
Germany	58	57	70	24
Chile		392	54	24
Greenland			119	17
Other	2	66	63	3
Subtotal[1]	25,553	25,797	23,887	21,758
Cured				
Denmark	146	109	91	127
Ireland	212	32	94	101
France	393	6	47	17
Other	65	33	178	44
Subtotal[1]	816	180	410	289
Canned				
United States	80,709	74,133	31,285	57,306
Canada	43,378	58,437	33,550	47,490
Soviet Union	4,813	8,252	6,877	4,330
Netherlands	672	250	951	1,804
Belgium/Lux.	4	2	87	893
Iceland				255
Denmark		77	29	50
Ireland			1,014	23
Korea (ROK)		282	555	
Japan	145	2,638	122	
Germany		68	2	
Other	178	99	95	78
Subtotal[1]	129,900	144,239	74,568	112,229
Grand Total[1]	158,901	173,561	103,655	141,797

[1]Totals may not agree due to rounding. Source: Eurostat trade statistics.

tion of farmed salmon on the British market for frozen salmon. Increasing Scottish production and imports of fresh salmon from Norway and Ireland, however, have not yet resulted in lower total imports of frozen salmon. Total frozen imports, however, were not affected by the increase in fresh imports during 1983. Purchases of frozen salmon totaled 5,800 t, slightly more than in 1982. Both the United States and Canada increased shipments to the United Kingdom in 1983. No one knows if this trend will continue, but most observers believe that frozen imports of Pacific salmon are unlikely to be greatly affected by Scottish production of fresh Atlantic salmon as long as there is a substantial price differential.

U.S. shipments of the higher-priced Pacific species such as chinook and sockeye, *O. nerka*, however, have been affected since 1981 (Table 7). Most buyers report that price is the major reason for selecting frozen salmon, although some also say that convenience is important.

Projecting future prices of farmed salmon is difficult. There seems to be little prospect for substantially reducing farmed salmon production costs. Feed is the major cost in culturing salmon and feed costs are largely determined by fishmeal prices. Continuing research on salmon culture may enable growers to make small reductions in production costs, but only a substantial reduction in fishmeal prices would enable growers to reduce prices to a point where they could more effectively compete with imported Pacific salmon. The continued growth of the Norwegian salmon culture industry, however, may depress prices. Any significant price decline would make farmed salmon more competitive with imported Pacific salmon.

U.S. and Canadian exporters are also concerned about the U.K. market for canned salmon. However, the increasing supplies of farmed salmon will probably not affect the canned salmon market. Canned salmon appeals to a different clientele than fresh salmon, and expanded Scottish production of fresh salmon is unlikely to affect U.S. canned salmon exports. U.S. exporters, however, are still concerned about depressed consumption levels in the United Kingdom and other European countries. Consumption in 1983 improved, but did not recover to pre-1982 levels. U.S. exporters do not yet know whether consumption in 1983 was still affected by the 1982 botulism incident or represents new, lower consumption patterns in the United Kingdom.

Table 7.—U.S. frozen salmon[1] exports to the United Kingdom by species, 1980-83.

Species	U.S. exports (t) 1980	1981	1982	1983
Chum		838.9	1,068.8	1,500.0
Sockeye		513.0	140.6	108.9
Pink		1,068.2	286.3	243.4
Chinook		49.0	36.3	11.7
Other		1,381.0	1,373.1	1,331.4
Total	2,603.8	3,850.1	2,905.1	3,195.4

[1]May include small quantities of fresh salmon.

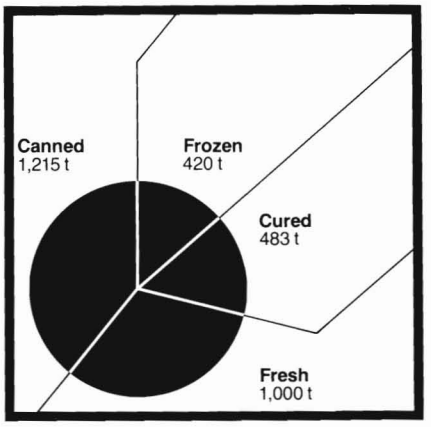


Figure 3.—United Kingdom salmon exports by commodity, 1983. Total is 3,118 t.

Exports

The United Kingdom imports much more salmon than it exports. British salmon exports are only a fraction of the large quantities imported and consumed domestically. The leading export commodity is canned salmon (Fig. 3), but this is believed to be primarily the re-export of canned salmon imported from other countries. Export shipments of fresh salmon increased sharply in 1983, as production of farmed salmon rose in Scotland. Shipments totaled 1,000 t in 1983, a 60 percent increase over the 625 t exported in 1982. The principal market for the fresh exports is France (Tables 8, 9). Some of the major ex-

Table 8.—U.K. salmon exports by quantity, 1980-83.

Commodity and destination	Exports (t) 1980	1981	1982	1983
Fresh/chilled				
France	212	416	538	814
Netherlands	17	16	24	55
Belgium/Lux.	26	12	10	45
Ireland	29	34	33	41
Denmark	13			
Other	17	17	20	45
Subtotal[1]	314	495	625	1,000
Frozen				
France	316	206	299	171
Ireland	52	47	22	48
Denmark	30		111	35
Netherlands	11	9	49	34
Switzerland	7	7	12	29
Germany	3	42	7	24
Belgium/Lux.	7	22	42	23
Spain	39	16	7	18
Italy		4	14	8
South Africa	13	15		2
Other	59	23	22	28
Subtotal[1]	537	391	585	420
Cured				
United States	44	40	157	115
France	70	107	89	111
Italy	21	25	30	32
Australia	13	8	21	31
Switzerland	16	21	20	27
South Africa	31	25	17	24
Belgium/Lux.	28	16	23	23
Hong Kong	14	22	13	18
Ireland		14	30	16
U.A. Emirates	12	8	11	16
Other	85	44	54	70
Subtotal[1]	334	330	465	483
Canned				
Ireland	428	486	370	663
Netherlands	211	433	423	438
United States		46	40	55
Belgium/Lux.	9	9	32	18
Nigeria	23			
Other	72	40	34	41
Subtotal[1]	743	1,014	899	1,215
Grand Total[1]	1,928	2,230	2,574	3,118

[1]Totals may not agree due to rounding. Source: Eurostat trade statistics.

Table 9.—U.K. salmon exports by value, 1980-83.

Commodity and Destination	Exports (in U.S. $1,000) 1980	1981	1982	1983
Fresh/chilled				
France	2,001	2,957	3,504	4,706
Netherlands	202	137	169	360
Belgium/Lux.	287	119	72	304
Ireland	216	127	201	203
Denmark	167			
Other	262	159	240	424
Subtotal[1]	3,134	3,500	4,186	5,997
Frozen				
France	3,602	1,540	1,912	1,054
Ireland	302	303	138	232
Netherlands	72	77	312	174
Switzerland	60	50	67	164
Denmark	191		524	127
Belgium/Lux.	72	145	272	127
Germany	31	282	35	82
Spain	479	141	49	72
Italy		28	89	33
South Africa	149	605		17
Other	517	181	208	241
Subtotal[1]	5,475	3,352	3,606	2,323
Cured				
France	1,740	2,370	1,732	1,912
United States	1,149	907	1,462	1,890
Switzerland	372	452	361	463
Italy	540	499	141	457
South Africa	493	392	281	362
Australia	160	97	256	351
Belgium/Lux.	659	349	421	338
Hong Kong	323	363	256	255
U.A. Emirates	280	192	231	229
Ireland		160	272	106
Other	1,801	934	1,289	1,107
Subtotal[1]	7,517	6,715	6,702	7,470
Canned				
Ireland	1,820	1,934	1,322	2,205
Netherlands	1,114	1,643	1,568	1,466
United States		184	199	289
Belgium/Lux.	42	25	107	59
Nigeria	191			3
Other	420	281	189	233
Subtotal[1]	3,587	4,067	3,384	4,255
Grand Total[1]	19,713	17,534	17,878	20,045

[1]Totals may not agree due to rounding. Source: Eurostat trade statistics.

porters are now studying the possibility of exporting fish to the United States, and have already shipped samples. The United Kingdom already exports roughly similar quantities of smoked salmon to the United States and France. (Source: IFR-84/100-B.)

Fisheries Policy in the European Community

The European Community (EC) has a unique mechanism for making fisheries policy. The Community's centralized institutions, not the governments of the individual EC member-states, regulate EC fishermen. The 200-mile zones of all 10 EC members are combined to form a single jurisdiction. The member-states still maintain jurisdiction over waters within 12 miles (in some cases 6 miles) from their coasts. Also, the EC's jurisdiction does not apply to the Mediterranean waters of member countries.

The EC determines the total allowable catch (TAC) for the common zone as well as the amounts of the TAC that each member-state is allocated. Fishery agreements with non-EC countries and other regulations for fishing in EC waters are also handled by EC institutions.

Three of the Community's four centralized institutions, the European Commission, the Council of Ministers, and the European Parliament, participate in the formulation of EC fisheries law and policy (Fig. 1). The European Court of Justice, the remaining EC institution, ensures that member-states conform to Community law, but does not participate in the policy-making process.

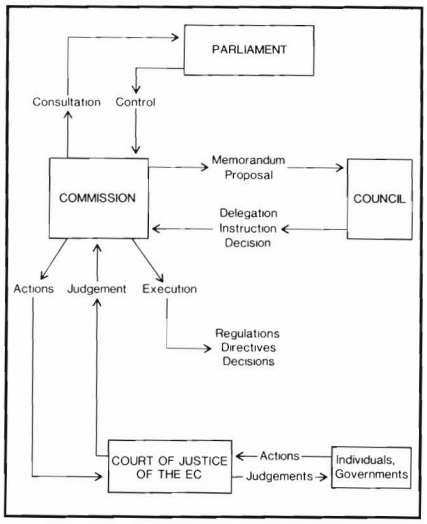


Figure 1.—The institutions of the European Community.

The Commission, the EC's main policy-making body, makes proposals for European laws, executes agreed-on policies, and acts as a mediator between the governments of the member-states. European laws may be specific measures or general outlines of policy, such as the Common Fisheries Policy. The laws are binding on all member states upon their ratification by the Council of Ministers.

The Commission is composed of 14 civil servants recruited from the EC member-states. The Members of the Commission are appointed to 4-year terms by agreement between the member-state governments to draft the Community's legislation. They cannot be removed except by Parliamentary censure. Each Member is responsible for formulating general policy on specific issues, such as agriculture, foreign policy, industrial policy, etc. At present, Giorgios Contogeorgis of Greece is the Commission Member responsible for fisheries (plus transport and tourism).

The Commission Members are not specialists on the specific issues for which they have responsibilities, and they do not handle the details of legislative proposals. Specific issues are addressed by the 23 Directorates General of the Commission, each of which covers a different issue.

Directorate General XIV (DG XIV) is in charge of fisheries and plays the most important role in the making of EC fishery policies. DG XIV, through the European Commission, submits detailed proposals for all EC fishery regulations to the Council of Ministers for approval. Besides proposals that deal with specific issues, memoranda on general guidelines may also be submitted to the Council.

DG XIV, currently headed by Eamonn Gallagher of Ireland, is divided into three main sections: Directorate A—International Questions, Directorate B—Markets and Internal Resources, and Directorate C—Structures, Aids, and National Measures (Fig. 2).

The Commission has also established a number of special advisory

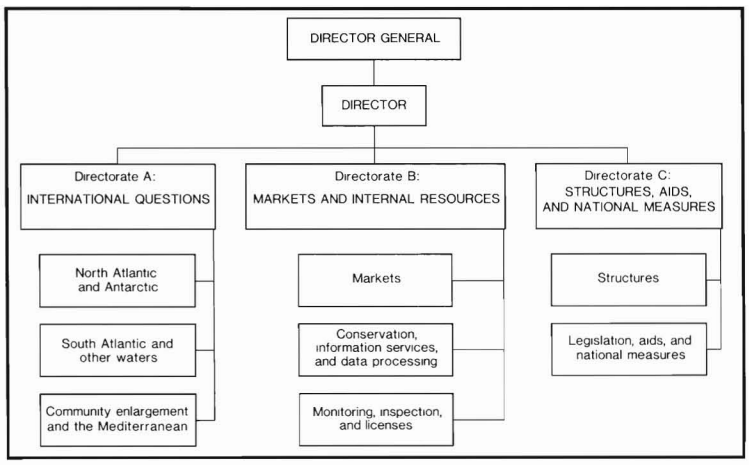


Figure 2.—Organizational chart of the Directorate General XIV: Fisheries of the European Community.

committees composed of representatives of industry, academic, professional, and economic interests. These committees advise the Commission in drafting legislation on issues which affect specific sectors of the Community. There are currently five such committees currently covering fisheries: 1) Advisory Committee on Fishery Products (established in 1973), 2) Joint Committee on Social Problems in Marine Fisheries (1974), 3) Scientific and Technical Committee on Fisheries (1979), 4) Management Committee for Fishery Products (1976), and 5) Standing Committee on the Fishing Industry (1976).

The European Parliament

The European Parliament, a relatively new body, advises the Commission on legislation. Members of the European Parliament are elected by the citizens of the member-states which they represent. There are 434 European Members of Parliament (Euro-MP's): United Kingdom (81), Italy (81), France (81), Federal Republic of Germany (81), the Netherlands (25), Belgium (24), Greece (24), Denmark (16), Ireland (15), and Luxembourg (6). The Members do not sit in Parliament according to country, but rather by political affiliation (Socialists, Christian-Democrats, Conservatives, Communists, Liberals, etc.).

The Parliament has mainly a consultative and advisory role. Legislation proposed by the Commission must first be sent to the Parliament for recommendations before the Council of Ministers can vote on it. The Parliament also prepares reports on various issues which the Commission must review before making legislation. Euro-MP's also present oral questions on specific issues to the Commission and monitor the status of legislative proposals which could affect their constituencies. The Parliament, however, has no formal legislative power and can only block budgetary legislation.

Since the adoption of the Common Fisheries Policy (CFP) in January 1983, the Parliament has been trying to obtain more responsibility in its management. The Parliament has asked the EC Commission to consult with it on all fishery matters related to conservation, technical measures, the fixing of TAC's and quotas, supervisory regulations, and annual agreements with third countries. The Parliament earlier called for the establishment of a separate Parliamentary committee on fisheries since fishery matters are currently handled by the Parliament's agricultural committee.

In July 1984, however, the Parliament voted against the separate fisheries committee. Observers believe that the separate fisheries committee was not approved because it is politically advantageous for fisheries to be under the agricultural committee, which is more powerful and has a considerably larger budget. The Parliament's fisheries working group, chaired by Bob Battersby of the United Kingdom, thus remains as a subcommittee of the agriculture committee.

The Council of Ministers

The Council of Ministers is composed of cabinet-level ministers from the 10 EC member-states who approve legislation drafted by the Commission. The Ministers make final decisions on all EC legislation and act on behalf of their countries' national interests. The Council members vary, depending on the nature of the legislation before them and on who the member-states decide to send to the meetings.

When fisheries legislation is debated, the Council is usually composed of the fisheries or agriculture ministers of the member states. In some cases, however, important fishery issues are handled by other ministers who may have a greater interest in the legislation. For instance, in February 1984, foreign ministers of EC member-states, not the fishery ministers, decided the terms of Greenland's withdrawal from the Community. While the issue dealt mainly with fisheries, foreign ministers participated in the Council because of Greenland's strategic importance to the Community.

The Council makes the final decisions on Commission proposals and memoranda but may amend or change the proposed legislation by an unanimous vote. Since Commission Members are constantly in touch with the member-states and know what legislation is politically acceptable to each country, Commission proposals generally stand a good chance of passage by the Council of Ministers. Several Council decisions in the past, however, have been hard-fought affairs; the debate over the Common Fisheries Policy lasted nearly 2 years before all Council members could agree on the final version. (Source: IFR-84/41R.)

New NMFS Scientific Reports Published

NOAA Technical Report NMFS 4. Roppel, Alton Y. **"Management of northern fur seals on the Pribilof Islands, Alaska, 1786-1981."** April 1984, iii + 26 p., 3 figs., 4 tables.

ABSTRACT

This paper includes information about the Pribilof Islands since their discovery by Russia in 1786 and the population of northern fur seals, *Callorhinus ursinus,* that return there each summer to bear young and to breed. Russia exterminated the native population of sea otters, *Enhydra lutris*, here and nearly subjected the northern fur seal to the same fate before providing proper protection. The northern fur seal was twice more exposed to extinction following the purchase of Alaska and the Pribilof Islands by the United States in 1867. Excessive harvesting was stopped as a result of strict management by the United States of the animals while on land and a treaty between Japan, Russia, Great Britain (for Canada), and the United States that provided needed protection at sea. In 1941, Japan abrogated this treaty which was replaced by a provisional agreement between Canada and the United States that protected the fur seals in the eastern North Pacific Ocean. Japan, the U.S.S.R., Canada, and the United States again insured the survival of these animals with ratification in 1957 of the "Interim Convention on the Conservation of North Pacific Fur Seals," which is still in force. Under the auspices of this Convention, the United States launched an unprecedented manipulation of the resource through controlled removal during 1965-68 of over 300,000 females considered surplus. The biological rationale for the reduction was that production of fewer pups would result in a higher pregnancy rate and increased survival, which would, in turn, produce a sustained annual harvest of 55,000-60,000 males and 10,000-30,000 females.

Predicted results did not occur. The herd reduction program instead coincided with the beginning of a decline in the number of males available for harvest. Suspected but unproven causes were changes in the toll normally accounted for by predation, disease, adverse weather, and hookworms. Depletion of the animals' food supply for foreign fishing fleets and the entanglement of fur seals in trawl webbing and other debris discarded at sea became a prime suspect in altering the average annual harvest of males on the Pribilof Islands from 71,500 (1940-56) to 40,000 (1957-59) to 36,000 (1960) to 82,000 (1961) and to 27,347 (1972-81). Thus was born the concept of a research control area for fur seals, which was agreed upon by members of the Convention in 1973 and instituted by the United States on St. George Island beginning in 1974. All commercial harvesting of fur seals was stopped on St. George Island and intensive behavioral studies were begun on the now unharvested population as it responds to the moratorium and attempts to reach its natural ceiling. The results of these and other studies here and on St. Paul Island are expected to eventually permit a comparison between the dynamics of unharvested and harvested populations, which should in turn permit more precise management of fur seals as nations continue to exploit the marine resources of the North Pacific Ocean and Bering Sea.

Understanding the Vibrios

"Vibrios in the Environment," edited by Rita R. Colwell, has been published by John Wiley & Sons, Inc., 605 Third Ave., New York, NY 10158, in their Environmental Science and Technology series. Interest in the Vibrionaceae has increased in the past decade considerably. Taxonomy of this family of bacteria has improved and recognition of the pathogenic potential of vibrios other than *V. cholerae* has grown (i.e., *V. parahaemolyticus).*

The book begins with an outline of vibrios in the environment, followed by sections on epidemology and serology, pathogensis, molecular genetic aspects of vibrios, methods for isolation, enumeration, characterization, and identification, and ecology of vibrios. An important part of the book for seafood producers is the final section, "Implications for the Seafood Industry," which includes chapters on prevention of food-borne disease caused by vibrios, sanitary precautions for the seafood packer in preventing such disease, factors affecting the adherence of *V. cholerae* to blue crab shell, and the effects of storage on vibrio concentrations in shellfish.

In short, the research reported here shows the widespread distribution of pathogenic and nonpathogenic vibrios in the natural aquatic environment, and addresses the risks the vibrios pose. The authors provide recent information on identification, isolation and characterization, assessment of distribution and useful data on human exposue, toxin potency and measurement, and vibrio ecology. The volume also details the much improved taxonomy of the genera and species of the Vibrionaceae and reports on the increasing number of cases whereby *V. cholerae* is implicated in human disease in widely different geographical areas. Practical applications of research are presented in sections on prevention of vibrio transmission and analytical methods for detection and monitoring. Thus, the book is an excellent source of data on recent developments, seafood quality control, and *V. cholerae* identification and monitoring. The 634-page hardbound volume is indexed and is available from the publisher for $45.00.

Sea Turtle History, Ecology, and Management

"Biology and Conservation of Sea Turtles," edited by Karen A. Bjorndal and published by the Smithsonian Institution Press, Washington, DC 20560 in cooperation with the World Wildlife Fund, Inc., constitutes the

NOAA Technical Report NMFS 5. Smith, Daniel E., and Jack W. Jossi. **"Net phytoplankton and zooplankton in the New York Bight, January 1976 to February 1978, with comments on the effects of wind, Gulf Stream eddies, and slopes water intrusions."** May 1984, iv + 41 p., 12 figs., 22 app. tables.

ABSTRACT

Results are given of monthly net phytoplankton and zooplankton sampling from a 10 m depth in shelf, slope, and Gulf Stream eddy water along a transect running southeastward from Ambrose Light, New York, in 1976, 1977, and early 1978. Plankton abundance and temperature at 10 m and sea surface salinity at each station are listed. The effects of atmospheric forcing and Gulf Stream eddies on plankton distribution and abundance are discussed. The frequency of Gulf Stream eddy passage through the NewYork Bight corresponded with the frequency of tropical-subtropical net phytoplankton in the samples. Gulf Stream eddies injected tropical-subtropical zooplankton onto the shelf and removed shelfwater and its entrained zooplankton. Wind-induced offshore Ekman transport corresponded generally with the unusual timing of two net phytoplankton maxima. Midsummer net phytoplankton maxima were recorded following the passage of Hurricane Belle (August 1976) and a cold front (July 1977). Tropical-subtropical zooplankton which had been injected onto the outer shelf by Gulf Stream eddies were moved to the inner shelf by a wind-induced current moving up the Hudson Shelf Valley.

NOAA Technical Report NMFS 7. Turner, Jefferson T. **"The feeding ecology of some zooplankters that are important prey items of larval fish."** July 1984, 28 p.

ABSTRACT

Diets of 76 species of fish larvae from most oceans of the world were inventoried on the basis of information in 40 published studies. Although certain geographic, size- and taxon-specific patterns were apparent, certain zooplankton taxa appeared in the diets of larvae of a variety of fish species in numerous localities. Included were six genera of calanoid copepods (*Acartia, Calanus, Centropages, Paracalanus, Pseudocalanus, Temora*), three genera of cyclopoid copepods (*Corycaeus, Oithona, Oncaea*), harpacticoid copepods, copepod nauplii, tintinnids, cladocerans of the genera *Evadne* and *Podon*, barnacle nauplii, gastropod larvae, pteropods of the genus *Limacina*, and appendicularians. Literature on feeding habits of these zooplankters reveals that most of the copepods are omnivorous, feeding upon both phytoplankton and other zooplankton. Some taxa, such as *Calanus, Paracalanus, Pseudocalanus,* and copepod nauplii appear to be primarily her-

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Proceedings of the World Conference on Sea Turtle Conservation held in Washington, D.C., in late 1979.

The contents are divided into four parts: Sea turtle biology; status of sea turtle populations by area (historical review; Hawaii, Oceania, and Australia; East and Southeast Asia; Indian Ocean; and Atlantic Ocean); conservation theory, techniques, and law; and a sea turtle conservation strategy, action plan, and action projects. The volume provides an excellent summary of sea turtle biology, especially as applied to conservation problems and solutions. Seven papers in the first section detail research on sea turtle reproduction and nesting studies. Others report research on migration, nutrition, growth, and hibernation.

The second section on population status includes reports with data on subsistence hunting in different regions, and provides excellent summaries of data and research on sea turtle distribution and densities. Papers in part three discuss general sea turtle conservation problems, conservation theory and techniques, and laws and enforcement, as well as discussing incidental capture, habitat disruption and protection, and the questions of turtle culture and head-starting. Unindexed, the paperbound 583-page volume provides a wealth of information on sea turtles and is available from the publisher for $25.00.

Shellfish Culture and Nutrition

The **"Proceedings of the Second International Conference on Aquaculture Nutrition: Biochemical and Physiological Approaches to Shellfish Nutrition,"** edited by Gary D. Pruder, Christopher J. Langdon, and Douglas E. Conklin, has been published by the World Mariculture Society, 178 Pleasant Hall, Division of Continuing Education, Louisiana State University, Baton Rouge, LA 70803.

Following a brief introduction, contributors review the relevance of fish and insect nutrition to marine invertebrates. Also reviewed are biochemical aspects of penaeid nutrition, crustacean bioenergetics, feeding mechanisms and digestive physiology of decapod crustaceans, protein and amino acid nutrition of *Penaeus japonicus*, a crustacean fatty acid metabolism, *Artemia* nutrition, zooplankton as a crustacean food source, and the role of micronutrients in the biosynthesis of the crustacean exoskeleton.

In addition, the volume contains the abstracts of posters presented at the conference dealing with research into American lobster diet and growth, penaeid shrimp, American oyster, and other aspects of molluscan and crustacean nutrition. Finally, two reports summarize the conference and review future prospects in mollusk and crustacean nutrition and its research needs. The 444-page hardbound volume is available from the publisher for $35 (U.S.) and $40 (foreign).

Canada's Atlantic Fisheries Report

"The Future of the Atlantic Fisheries" by Ernie Weeks and Leigh Mazzany has been published by the Institute for Research on Public Policy (IRPP) in Montreal, Quebec, Canada, and is distributed by Brookfield Publishing Co., Old Post Road, Brookfield, VT 05036.

bivorous, while others, such as *Acartia, Centropages, Temora,* and cyclopoids exhibit broad omnivory or carnivory.The noncopepod zooplankters are primarily filter-feeders upon phytoplankton and/or bacterioplankton. Despite the importance of zooplankters in larval fish food webs, specific knowledge of the feeding ecology of many taxa is poor. Further, much present knowledge comes only from laboratory investigations that may not accurately portray feeding habits of zooplankters in nature. Lack of knowledge of the feeding ecology of many abundant zooplankters, which are also important in larval fish food webs, precludes realistic understanding of pelagic ecosystem dynamics.

NOAA Technical Report NMFS 8. Prince, Eric D. (convener and editor), and Lynn M. Poulos (editor). **"Proceedings of the international workshop on age determination of oceanic pelagic fishes: Tunas, billfishes, and sharks."** December 1983, 211 p. (27 papers, no abstract).

NOAA Technical Report NMFS 9. Chester, Alexander J. **"Sampling statistics in the Atlantic menhaden fishery."** August 1984, 16 p.

ABSTRACT

Atlantic menhaden, *Brevoortia tyrannus,* the object of a major purse-seine fishery along the U.S. east coast, are landed at plants from northern Florida to central Maine. The National Marine Fisheries Service has sampled these landings since 1955 for length, weight, and age. Together with records of landings at each plant, the samples are used to estimate numbers of fish landed at each age. This report analyzes its sampling design in terms of probability sampling theory. The design is classified as two-stage cluster sampling, the first stage consisting of purse-seine sets randomly selected from the population of all sets landed, and the second stage consisting of fish randomly selected from each sampled set. Implicit assumptions of this design are discussed with special attention to current sampling procedures. Methods are developed for estimating mean fish weight, numbers of fish landed, and age composition of the catch, with approximate 95 percent confidence intervals. Based on specific results from three ports (Port Monmouth, N.J.; Reedville, Va.; Beaufort, N.C.) for the 1979 fishing season, recommendations are made for improving sampling procedures to comply more exactly with assumptions of the sampling design. These recommendations include adopting more formal methods for randomizing set and fish selection, increasing the number of sets sampled, considering the bias introduced by unequal set sizes, and developing methods to optimize the use of funds and personnel.

Problems in the Atlantic Fisheries resulted in special investigations by the Canadian government and the IRPP by Weeks and Mazzany. This book is the result of the latter and contains a review of Canada's Atlantic fishery, an analysis of its problems, and the authors' conclusions and recommendations for government policy. The authors state categorically that "economic viability must be the overriding long-term objective for the industry (which) must become self-supporting." Among their recommendations are that: 1) Industry, labor, and capital be reduced and brought into line with expected resources and markets, 2) in the first 1-2 years reduce the number of fishermen by attrition and continuation of limited entry to the major fisheries (and "more actively" reduce fishermen and capital in the next 3-5 years), 3) provide quasi-property rights through a systems of transferable quotas (which would be divisible and saleable), introduce a self-funding scheme for vessel buy-back, and others. The volume presents, a very concise look at Canada's Atlantic fisheries, its problems, the authors' recommendations as well as those of the Canadian government's Task Force on the Atlantic Fisheries, plus a comparative analysis of both. The paperbound 112-page booklet is available from the Brookfield Publishing Company for $9.50.

The Tilapias and Their Culture

The tilapias are a group of freshwater cichlids of Africa and the Levant which have been introduced and farmed in many parts of the world. Some species make nests; others, the mouthbrooders, are widely used in warmwater aquaculture programs, and genetic research is expected to enhance their production.

"Tilapiine Fishes of the Genera *Sarotherodon, Oreochromis,* and *Danakilia*" by Ethelwynn Trewavas, published by the British Museum (Natural History), Cromwell Road, London, England SW7 5BD, describes 41 of the species that carry the eggs and embryos in the mouth of one or both parents. One genus, *Danakilia*, is limited in size and range and not cultured. *Sarotherodon* (9 species) and *Oreochromis* (31 species) are distinguished primarily by their breeding habits, biogeography, and structural features, and several of them are very important to fish culturists. *Tilapia*, once used for most of the well-known species, is now restricted to those which make and guard nests.

While this authoritative and extensive review is primarily taxonomic, the author also provides well-written and thorough overviews of each species' natural history and other data useful to aquaculturists, such as ecology, distribution (natural and dispersal by man), zoogeography, reproduction, and habitats. Data is also provided on the species' foods, temperatures and salinity tolerances, and breeding and hybridization, as well as on their growth, distinguishing characteristics, and, for some, general physiology, behavior, predators and parasites, etc. The volume is illustrated with many fine drawings and photographs.

The author, who retired in 1961 from the Museum as curator of fishes, has studied the cichlids (since 1928) for over 50 years, and her voluminous book will likely be of in-

terest and value to many of those involved in tilapia biology, fisheries, research, and culture. The 583-page hardbound volume is available from the publisher for £50.

"The Biology and Culture of Tilapias," edited by R. S. V. Pullin and R. H. Lowe-McConnell, published by the International Center for Living Aquatic Resources Management (ICLARM), MCC P.O. Box 1501, Makati, Metro Manila, Philippines, as ICLARM Conference Proceedings 7, constitutes the Proceedings of the International Conference on the Biology and Culture of Tilapias held 2-5 September 1980 in Bellagio, Italy.

Once limited mostly to Africa, tilapias have been widely distributed, primarily since the 1950's, to tropical and subtropical areas, and their farming systems range from Asian ricefield culture to experimental farms using heated water from power plants. This volume presents an excellent and useful series of reviews by biologists and fish culturists, as well as an outline of future research needs. It is divided into four sections: Biology, physiology, culture, and culture-related topics. Papers in the first part discuss tilapia taxonomy and speciation, ecology and distribution, tilapias in fish communities, and provide an evolutionary perspective on tilapia life histories.

Part 2 reviews environmental physiology of tilapias, their reproductive physiology and feeding, digestion, and growth (both qualitative and quantitative considerations). The session on culture presents reviews of cage culture, diseases of tilapias, and pond culture of tilapias under controlled conditions. Other papers discuss genetic markers in *Sarotherodon* and their use for sex and species identification, tilapia hybridization, control of tilapia reproduction, and problems of mass production of hybrid tilapia fry. The volume also includes a statement on research requirements, extensive references, and indexes to genera, species, and water bodies. The 432-page volume is available from ICLARM for $13 (paper, surface mail), $17.50 (cloth, surface mail), $25 (paper, airmail), or $29.50 (cloth, airmail).

"A Bibliography of Important Tilapias (Pisces: Cichlidae) for Aquaculture," by Peter Schoenen, was published in 1982 by the International Center for Living Aquatic Resources Management (ICLARM),

A Guide to World Fishes

Publication of the Second Edition of Joseph S. Nelson's **"Fishes of the World"** has been announced by John Wiley & Sons, Inc., 605 Third Ave., New York, NY 10158. This useful reference for fisheries personnel and researchers has been enlarged and considerably updated to reflect research accomplished during the last decade. An introductory chapter outlines various aspects of systematics and zoogeography, and a discussion of fish diversity and abundance includes a table showing the numbers of recognized families, genera, and total number of species and freshwater varieties in the 50 orders of the world's living fishes. The author also reviews the classification of lower chordates.

Typical family descriptions consist of a common name and spelling of the taxonomic group, distribution data, a line drawing illustrating morphological characteristics, a brief description of the group, biological, ecological, and systematic notes, subfamilies, estimated number of genera and species, plus recent references to major systematic studies. Included are 452 illustrations, 45 updated distribution maps, a checklist of extant classes, orders, suborders, and families, and an extensive bibliography. The 523-page hardbound volume is a good up-to-date introduction to the world's major fish groups, and is available from the publisher for $44.95.

Technology of Tropical and Subtropical Fishes

Publication of the **"Proceedings of the Eighth Annual Tropical and Subtropical Fisheries Conference of the Americas,"** compiled by Ranzell Nickelson II, has been published by the Sea Grant College Program, Texas A&M University, College Station, TX 77843. It consists of 25 papers, edited by their respective authors, on a wide variety of topics of interest to the fisheries industry and fishery technologists.

Terrance Leary describes the activities of the Gulf of Mexico Fishery Management Council while Fred Prochaska et al. review the world production trends and U.S. imports of shrimp and spiny lobsters. Hector Lupin addresses communication problems between fisheries institutes and the fisheries industry in Latin America. Two articles outline experimental gear for and on-board handling of deep-sea red crabs (*Geryon* sp.) in the Gulf of Mexico, while Charles Roithmayr reports on purse-seine fishing for coastal pelagic fishes (thread herring, Spanish sardine, round scad, scaled sardine, and round herring) in the northern Gulf.

Other articles discuss salmonellae in oysters, clams, crabs, and mullet; TDT of *Vibrio cholerae* in shrimp; problems with adductor muscle parasites, *Sulcascaris sulcata*, in calico scallops in the southeastern U.S.; closed system shedding of blue crabs; measuring texture to evaluate fish freshness; texture variation in cooked fish fillets, pasteurization methods for flaked fish by Melvin Waters; electronic candling to detect bones in white fish fillets; menhaden use for surimi production; texture analysis of *Macrobrachium* tails; using osmoregulation in Penaeid shrimps to

MCC P.O. Box 1501, Makati, Metro Manila, Philippines, as ICLARM Bibliographies 3. While several other bibliographies have been published on the tilapias, this is the first to deal comprehensively with cultured tilapias, and the author has sought to make available all references on these fishes for libraries, researchers, and biologists. Species included in this bibliography include: *Oreochromis macrochir, O. aureus, O. hornorum, O. mossambicus, O. niloticus, Sarotherodon galilaeus, Tilapia rendalli*, and *T. zilli*. Each species is introduced with a "List of Synonyms," followed by its bibliography, arranged alphabetically by author, and ending with a subject index and a geographic index for the species. The 336-page paperbound volume is available for $18.00 (airmail $32.50).

"ICLARM Bibliographies 3, Supplement 1" by Peter Schoenen includes additional references discovered since publication of the original work, and covers *Oreochromis macrochir, O. aureus, O. hornorum, O. mossambicus, O. niloticus, Sarotherodon galilaeus, Tilapia rendalli*, and *T. zilli*. The references are all those published on those species as of the end of 1983. Reference numbers are consecutive from the first volume, and as before, subject and geographic indexes are included. The 191-page paperbound volume is available from ICLARM and ISBS (price not listed).

"**Applied Genetics of Tilapias**" by Giora W. Wohlfarth and Gideon Hulata has also been published by ICLARM as Studies and Reviews 6. The review was commissioned by ICLARM to collate existing information on the applied genetics of tilapias to assess the usefulness of previous work and to suggest future research directions. The review also summarizes much of the information on the biology and distribution of tilapias which is useful in approaching genetic manipulation. Discussed are variations between species, interspecific hybridization, sex determination, variation within species, population control, use of electrophoretic markers, and future breeding research needs. The 26-page paperbound volume is available from ICLARM for $3.00 (surface) and $5.28 (airmail). U.S. orders should be sent to the ICLARM Distributor, International Scholarly Book Services, Inc., P.O. Box 1632, Beaverton, OR 97075, using the airmail price.

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enhance flavors; and others. The volume is available from the publisher for $10.

A Review of Fish Aggregating Devices

"**Review of Experiences With and Present Knowledge About Fish Aggregating Devices,**" by M. Bergstrom has been published as BOBP/WP/23 by the FAO's Bay of Bengal Programme, Post Bag No. 1054, Madras 600 018 India. To prepare it the author contacted many experts and has thus provided a selective yet excellent review of a wide range of FAD's, their construction, placement, and how they are fished.

The author presents many examples of artificial reef types and materials from auto tires to concrete, FRP, wood bundles, vessel hulls, and much more, as well as FAD's anchored or drifting at the surface. A more extensive section reviews traditional, modern, and experimental mid-water FAD's. Other sections review site selection for anchoring modern FAD's and harvesting methods for the various devices. Finally, the author discusses such considerations as FAD maintenance, ownership and access rights, legal aspects, anchor design and size, corrosion, chafing, etc. The large format, paperbound 57-page report is available from the BOBP (price not listed).

Basic Marine Ecology

"**An Introduction to Marine Ecology**," by R. S. K. Barnes and R. N. Hughes, has been published by Blackwell Scientific Publications, Inc., The Downing House, 706 Cowper Street, Palo Alto, CA 94301. Barnes is a Lecturer in Aquatic Ecology, University of Cambridge, and Hughes is Lecturer in Ecology, University College of North Wales, U.K.

The first 10 chapters review such subjects as the nature and global distribution of marine organisms, marine habitats and productivity, planktonic systems of surface (< 1,000 m) waters, benthos of continental shelves and littoral sediments, salt marshes and mangrove swamps, rocky shores and kelp forests, coral reefs, pelagic and benthic systems of the deep sea; fish and other nekton, life history patterns and natural selection, and speciation and biogeography. Chapter 11 reviews the overall marine ecosystem and Chapter 12 discusses human uses of the sea for food, waste disposal, and development.

Thus, the volume presents a broad look at marine ecology and the function of marine ecosystems, for students who already possess some basic knowledge of general ecology. Well illustrated and indexed, the 339-page paperbound volume is available from the publisher for $23.50.

Studies of a Large Marine Wetland Ecosystem

The Wadden Sea, the shallow coastal area from the Netherlands to Denmark, is Europe's largest estuarine area (~8,000 km^2) and most important nursery for North Sea fish and shrimp and hosts several

million migratory water birds. Its more than 30 barrier islands shelter wide tidal flats and salt marshes. The area also faces many conflicting human interests and demands. The fishing fleet was halved between 1960 and 1980, and the number of fishermen was reduced even more. Shrimp, *Crangon crangon*, now dominates the landings (~75 percent).

An International Wadden Sea Working Group was set up in 1965, with studies coordinated by the Nature Management Department of the Agricultural University at Wageningen, to collect baseline data upon which to base conservation and management decisions for the area. Included were studies of 1) Geomorphology (Dijkema et al., 1980), 2) Hydrography (Postma, 1982), 3) Marine Botany (Wolff, 1979), 4) Marine Zoology (Dankers et al., 1981), 5) Fishes and Fisheries (Dankers et al., 1979), 6) Wadden Sea Birds (Smit and Wolff, 1980), 7) Marine Mammals (Reijnders and Wolff, 1982), 8) Pollution (Essink and Wolff, 1978), 9) Flora and Vegetation (Dijkema and Wolff, 1983), 10) Terrestrial and Freshwater Fauna (Smit et al., 1981), and 11) Physical Planning and Nature Management (Bruyns and Wolff, 1983).

The invertebrates volume (No. 4) presents reviews of the species of zooplankton, zoobenthos, and nekton of the Wadden Sea and its river estuaries, and their relationships with their environment. Life histories of such other important invertebrates as copepods, jellyfish, lugworms, blue mussel, cockle, shore crab, shrimp, etc., are also reviewed.

Of the 102 Wadden Sea fishes, 22 are common, 26 are fairly common, 16 are scarce, 12 are rare, and 22 are extremely rare. The fish and fisheries volume (No. 5) reviews the species present, data on their abundance and long- and short-term population changes, and the region's fisheries. It explains the Sea's importance for juvenile fishes and recommends studies of the effect of shrimping on fish recruitment, and on the role of shellfish culture in the Sea's ecosystem.

Of the 25 marine mammals recorded in the Wadden Sea, only the harbor seal, gray seal, common or harbor porpoise, and bottlenose dolphin have been regular inhabitants, though the last two have virtually disappeared. Authors of this report (No. 7) consider pollution, particularly PCB's to be the main threat to seals and recommend studies on juvenile survival, the role of disturbance in reduced recruitment, and why the harbor porpoise and bottlenose dolphin have virtually disappeared. Also presented is data on the status and life histories of those four marine mammals.

Second largest of the reports, "Birds of the Wadden Sea," No. 6 presents extensive ecological data on the area's waterfowl, their habitat selection and competition, invertebrate consumption, and threats to them; almost 3.5 million birds may be present in late summer congregations.

Finally, Report No. 11, sums up the political and administrative organizations in the region, the status of planning and management systems, reviews conservation in the area as well as exploitation and use of the area, international conventions pertinent to the area, and the major areas of conflict between conservation and utilization interests. It further presents a model for the region's protection and management, and recommends a formalized Wadden Sea Convention and establishment of a professional management organization in the three nations to coordinate protection and management of the region.

The eleven initial reports, bound into four volumes, are available at $85.00 from A. A. Balkema, 99 Main Street, Salem NH 03079. The separate paperbound reports are available at prices ranging from $4.75 (No. 8, Pollution) to $28.00 (No. 9, Flora and Vegetation).

This statement is required by The Act of August 12, 1970, Section 3685, Title 39, U.S. Code, showing ownership, management, and circulation of the Marine Fisheries Review, publication number 366-630, and was filed on 1 October 1984. The Review is published quarterly (four issues annually) with an annual subscription price of $8.75 (sold by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402). The complete mailing address of the office of publication is: Scientific Publications Office, F/NR1, NMFS, NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115. The complete mailing address of the headquarters of the publishing agency is: National Marine Fisheries Service, NOAA, Department of Commerce, 2001 Wisconsin Ave., N.W., Washington, DC 20235. The name of the publisher is Jack McCormick and the editor and managing editor is Willis Hobart; their mailing address is: NMFS Scientific Publications Office, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115. The owner is the U.S. Department of Commerce, 14th St., N.W., Washington, DC 20230; there are no bondholders, mortgagees, or other security holders. The purpose, function, and nonprofit status of the organization (agency) and the exempt status for Federal income tax purposes has not changed during the preceding 12 months. The extent and nature of circulation is as follows: Total number of copies (A) (average number of copies of each issue during the preceding 12 months) was 2501 and the actual number of copies of the single issue published nearest to the filing date was 2501. Paid circulation (B) is handled by the U.S. Government Printing Office, Washington, DC 20402, and (C) the total number printed for their sales (mail subscriptions and individual sales) was 750 for both the average number of copies each issue during the preceding 12 months and the actual number of copies of the single issue published nearest to the filing date. Free distribution (D) by mail, carrier, or other means; samples, complimentary, and other free copies (average number of copies each issue during the preceding 12 months) was 1751 and the actual number of copies of the single issue published nearest to the filing date was 1751. The total distribution (E: sum of C and D) (average number of copies each issue during the preceding 12 months) was 2501 and the actual number of copies of the single issue published nearest to the filing date was 2501. There were no copies not distributed or returned from new agents (F). The total (G: sum of E and F) is equal to the net press run figures shown in item A: 2501 copies. I certify that the statements made by me above are correct and complete: (Signed) Jack McCormick, Publisher.

A Basic Guide to the Study of Algae

"Algal Biology: A Physiological Approach," by W. Marshall Darley, has been published by Blackwell Scientific Publications, Inc., The Downing House, 706 Cowper Street, Palo Alto, CA 94301, as volume 9 in their Basic Microbiology Series. The author is with the University of Georgia's Department of Botany, and his book is intended as a supplemental text for courses in phycology, aquatic ecology, limnology, and marine biology.

The volume provides a handy introduction to the field of algal physiological ecology and emphasizes the individual organism and how it functions in its environment. The author gives an overview of the various classes of algae, relates concepts in algal physiological ecology, and reviews environmental factors affecting phytoplankton growth and population dynamics. Also discussed are seaweeds; benthic algae; algae in snow, soil, and hot springs; human and algal interactions; and symbiotic associations of algae. Indexed, the 168-page paperbound book is available from the publisher for $15.60.

Authors, Titles, and Subjects in the *Marine Fisheries Review* 46(1-4), 1984

A

Acanthophora, 1:16
Acanthuridae, 3:71
Albacore, Thunnus alalunga, 1:1, 3:8, 4:65
Alfonsin, 2:15
  distribution, 2:15
  fisheries, 2:15
  life history, 2:15-16
Amberjack, Seriola dumerilli, 2:11
American oyster, Crassostrea virginica, 3:15
American sand lance, Ammodytes americanus, 2:44
Ammodytes americanus, American sand lance, 2:44
Antarctic fur seals, Arctocephalus gazella, 3:59
Anthias bicolor, 2:11
Archaeogastropods, 4:78-79
  Trochus incrassatus, 4:79
  T. maculatus, 4:79
  T. pyramis, 4:78
  Turbo argyrostoma, 4:79
Artificial propagation, coho salmon, mid-Columbia River system, 3:34
"Assessing the accuracy of a method to determine the amount of minced fish in mixed mince-fillet fish blocks," by J. Perry Lane, John J. Ryan, and Robert J. Learson, 3:76
Atlantic croaker, Micropogonias undulatus, 2:45
Atlantic salmon, Salmo salar, 3:44
Atlantic thread herring, Opisthonema oglinum, 1:19

B

Bailey, Jack E.--see Jaenicke et al.
Balaena glacialis, right whale, 4:2
Balaena mysticetus, bowhead whale, 3:7, 4:2
Balaenoptera borealis, sei whale, 4:2
Balaenoptera musculus, blue whale, 4:2
Balaenoptera physalus, fin whale, 4:2
Balistidae, 3:71
Basham, Larry--see Slatick and Basham
Bearded seal, Erignathus barbatus, 3:7
Beluga whale, Delphinapterus leucas, 3:7
Bigeye tuna, Thunnus obesus, 1:1, 4:65
Bivalve mollusks, ageing, 2:27
Blackfin tuna, Thunnus atlanticus, 4:65
Blahm, Theodore H.--see Durkin et al.
"(The) blue whale, Balaenoptera musculus," by Sally A. Mizroch, Dale W. Rice, and Jeffrey M. Breiwick, 4:15
Blue whale, Balaenoptera musculus, 4:2
  distribution, 4:16
  exploitation, 4:18
  management, 4:18-19
  migration, 4:15
  mortality, natural, 4:18
  reproduction, 4:17, 18
  stocks, 4:16, 17
Bluefin tuna, Thunnus thynnus, 1:1, 4:65
Bluefin tuna, Thunnus thynnus orientalis, 3:5
Bluegill, Lepomis macrochirus, 3:15
Blueline surgeonfish, Acanthurus lineatus, 4:78
"(The) bowhead whale, Balaena mysticetus," by Howard W. Braham, 4:45
Bowhead whale, Balaena mysticetus, 3:7, 4:2, 45
  distribution, 4:45
  exploitation, 4:49-51
  management, 4:51-52
  migration, 4:45, 47
  mortality, natural, 4:49
  population, 4:51
  reproduction, 4:49
  stocks, 4:47-48
Box crab, Calappa sp., 2:13
Braham, Howard W., "The bowhead whale, Balaena mysticetus," 4:45
Braham, Howard W., "The status of endangered whales: An overview," 4:2
Braham, Howard W., and Dale W. Rice, "The right whale, Balaena glacialis," 4:38
Braham, Howard W.--see Rice et al.
Breiwick, Jeffrey M.--see Gosho et al., Mizroch et al.
Brigham's snapper, Pristipomoides zonatus, 2:11
Brook trout, Salvelinus fontinalis, 3:15
Brown shrimp, Penaeus aztecus, 2:53
Brusher, Harold A., Mark L. Williams, Lee Trent, and Barbara J. Palko, "Using charterboat catch records for fisheries management," 3:48
Buchanan, Kurt D.--see Durkin et al.
Butler, Richard W.--see Coe et al.
Butterfish, Hyperoglyphe japonica, 2:11

C

Callorhinus ursinus, northern fur seal, 3:9
Cape fur seals, Arctocephalus pusillus, 3:59
Carangidae, 2:11
Caridean shrimps, 2:18-25
  Heterocarpus ensifer, 2:18
  Heterocarpus laevigatus, 2:18
Caridean shrimps, N.W. Hawaiian Islands, 2:18-26
  catch rate, 2:20
  distribution, 2:20-22
  peak abundance, 2:25
  seasonal abundance, 2:23-24
  size/depth, 2:23
Celewycz, Adrian G.--see Jaenicke et al.
Cetaceans, 4:2
"Characteristics of the Texas shrimp fleet," by Judith T. Krauthamer, William E. Grant, and Wade L. Griffin, 2:53
Charterboat catch records, fishery management
  catch and effort data, 3:48
  catch per boat hour (CBH), 3:53
  effort distribution, 3:52
  fishing method, 3:49
  fishing zones, definition, 3:48
  species caught, 3:50
Chinook salmon, Oncorhynchus tshawytscha, 3:5, 36
Chub mackerel, Scomber japonicus, 2:11
Chum salmon, Oncorhynchus keta, 3:5, 35
Chum salmon virus (CSV), 3:15
Ciguatera fish poisoning, eastern Caribbean
  fish involved, 1:16-17
  frequency/incidence, 1:13
  hazardous (high risk) species, 1:17
  toxic areas, 1:15-16
"Ciguatera in the eastern Caribbean," by David A. Olsen, David A., David W. Nellis, and Richard S. Wood, 1:13
Clupea harengus pallasi, Pacific herring, 3:5
Coastal herrings, Atlantic and Gulf, 1:19-20
  proximate composition, 1:19-21
  proximate composition analyses, 1:20
    fatty acids, 1:20
    oil, 1:19-20
    protein, 1:20
Coded wire tags (CWT), internal magnetic, 3:68
Coe, James M., David B. Holts, and Richard W. Butler, "The 'tuna-porpoise' problem: NMFS dolphin mortality reduction research, 1970-81," 3:18
Coho salmon, artificial propagation in mid-Columbia River system, 3:35
  egg production, 3:37
  fisheries, 3:36
  life history, 3:35-37
  return rates, 3:40
  seasonal runs, 3:37
  spawning, 3:35-36
  survival rates, 3:40-41
Coho salmon, Oncorhynchus kisutch, 3:5, 34, 64
Collagen, content in tuna, 2:40
Conger eels
  Ariosoma bowersi, 2:12
  Conger wilksoni, 2:12
  Congerellus aequoreus, 2:12
Connors, Thomas J.--see Lane and Connors
"Coral reef sanctuaries for trochus shells," by Gerald A. Heslinga, Obichang Orak, and Marcus Ngiramengior, 4:73
Coral reef snail, Trochus niloticus
  abundance, 4:75
  demand, 4:73-74
  depletion, 4:74
  distribution, 4:76
  fisheries, 4:73
  habitat, 4:76
  harvest, 4:73
  products, 4:73
  resource management, 4:74
  sanctuary program, 4:74-75
Crab, Dungeness--see Dungeness crab
Crassotrea virginica, American oyster, 3:15

D

Delphinapterus leucas, beluga whale, 3:7
Dictyota, 1:16
Dolly varden, Salvelinus malma, 3:64
Dolphins, incidental mortality reduction, 3:18
  behavior patterns, 3:20
  management recommendations, 3:32
  mortality, 3:20-23
  net configuration, 3:21-22
  regulations, 3:18, 23-31
  research, behavioral, 3:29-32
  research, mechanical, 3:22-29
    handling methods/gear, 3:25-28
    net design/improvements, 3:25-28
    net/vessel handling, 3:23-25
"Dungeness crab leg loss in the Columbia River estuary," by Joseph T. Durkin, Kurt D. Buchanan, and Theodore H. Blahm, 1:22
Dungeness crab, Columbia River
  causes of injury, 1:24
  composition by sex, 1:22-24
  leg loss, 1:22
  regeneration, 1:22-24
Durkin, Joseph T., Kurt D. Buchanan, and Theodore H. Blahm, "Dungeness crab leg loss in the Columbia River estuary," 1:22

E

Eastern Pacific Ocean Tuna Fishing Agreement, 4:72
Eicosapentaenoic acid, 2:60-61
El Niño, 1:7-12
El Niño, effects on tuna resources, 4:65
El Niño, Pacific Northwest, 1:7-12
  Kelvin waves, 1:7-8
  oceanographic observations, 1:7-12
  sea surface temperature anomolies, 1:7-8
  sigma-t density, 1:9-10
  subsurface conditions, 1:8-10
"Encounters of Hawaiian monk seals with fishing gear at Lisianski Island, 1982," by John R. Henderson, 3:59
Endangered Species Act (ESA), 4:2
Endangered whales, 4:2, 4
  Endangered Species Act (ESA), 4:2, 4
    listed whales' status, 4:2
    listing factors, 4:2
  populations, 4:5, 6
  status review, 4:2, 4, 5
Eschrichtius robustus, gray whale, 3:9, 4:2
European flat oyster, Ostrea edulis, 3:15
"Evaluation of methods to determine the proportions of fillets and minced fish flesh in mixed fish blocks," by J. Perry Lane and Thomas J. Connors, 2:36

F

Far East mussel, Crenomytilus graynus, 2:33
Fiedler, Paul C., Gary B. Smith, and R. Michael Laurs, "Fisheries applications of satellite data in the eastern North Pacific," 3:1
"(The) fin whale, Balaenoptera physalus," by Sally Mizroch, Dale W. Rice, and Jeffrey M. Breiwick, 4:20
Fin whale, Balaenoptera physalus, 4:2, 20
  distribution, 4:20-21
  exploitation, 4:22-23
  feeding, 4:22
  management, 4:24
  migration, 4:20
  population, 4:23-24
  reproduction, 4:22
  stocks, 4:21-22
Finfish pathogens, 3:14
Finfish resources, Gulf of Mexico, 1:19
Fish Block Technical Working Group, 2:38
Fish blocks, composition, 2:36, 3:76
  determination, 2:36, 3:77
  minced fish, amount, 3:76
  recommendations, 2:39, 3:77-78
Fish farming, salmon, 3:44
Fish farming, trout, 3:44
Fish oil, dietary, 2:61-62
  consumption, 2:62

docosahexaenoic acid (DHA), 2:61
eicosapentaenoic acid (EPA), 2:61
heart attack, effects on, 2:62
high-, low-oil fishes, 2:62
Omega-3 long-chain fatty acid, 2:62
Fish oil concentrates, 2:61
"Fish or fish oil in the diet and heart attacks," by Maurice E. Stansby, 2:60
Fish poisoning--see ciguatera fish poisoning
Fish spoilage, honeycombing, 2:40
"Fisheries applications of satellite data in the eastern North Pacific," by Paul C. Fiedler, Gary B. Smith, and R. Michael Laurs, 3:1
Fisheries, eastern Caribbean, 1:13-17
Fishery Conservation Zone (FCZ), 3:48
Fishery research, remote sensing data, 3:1
Fishes, Red Sea
proximate composition, 3:71
seasonal variations, 3:74
Ford, Robert J., "Norwegian salmon and trout farming," 3:44
Frank, Hilmer A., Mitchel E. Rosenfeld, Derrick H. Yoshinaga, and Wai-Kit Nip, "Relationship between honeycombing and collagen breakdown in skipjack tuna, Katsuwonus pelamis," 2:40
Freshwater mussel, Margaritana margaritana, 2:33

G

Gambierdiscus toxicus--see ciguatera fish poisoning
Gammaridean amphipods: Ampelisca A. eschrichti, A. macrocephala, A. nugax, Nototropis brueggeni, N. ekmani, Pontoporeia affinis, P. femorata, 4:9
Golden sardine, Sardinella aurita, 1:19
Gooding, Reginald M., "Trapping surveys for the deepwater caridean shrimps, Heterocarpus laevigatus and H. ensifer, in the northwest Hawaiian Islands," 2:18
Gosho, Merrill E., Dale W. Rice, and Jeffrey M. Breiwick, "The sperm whale, Physeter macrocephalus," 4:54
Grant, William E.--see Krauthamer et al.
"(The) gray whale, Eschrichtius robustus," by Dale W. Rice, Allen A. Wolman, and Howard W. Braham, 4:7
Gray whale, Eschrichtius robustus, 3:9, 4:2, 7-14
distribution, 4:7
exploitation, 4:10-12
feeding, 4:9
identification, 4:7
management, 4:12-13
migrations, 4:8
natural mortality, 4:10
reproduction, 4:10
stocks, 4:7
Great whales--Special Section, 4:1
Green turtle, Chelonia mydas, 3:57
Griffin, Wade L.--see Krauthamer et al., Tettey and Griffin
Groundfish, 2:11
"Groundfish fisheries and research in the vicinity of seamounts in the North Pacific Ocean," by Richard N. Uchida and Darryl T. Tagami, 2:1
Groundfish fisheries, Hawaiian Archipelago, 2:1
commercial exploitation, 2:2
preliminary management plan, 2:1
species biology
Alfonsin, 2:15
pelagic armorhead, 2:13
Grouper, Caprodon schlegelii, 2:11
Grouper, Epinephelus quernus, 2:11
Growth lines, bivalve mollusks, 2:27

H

Hake, red and silver, surimi
commercial processing, 2:44
gel-forming ability, 2:44
laboratory processing, 2:46
Hale, Malcolm B., "Proximate chemical composition and fatty acids of three small coastal pelagic species," 1:19
Hanna, Rifaat G. M., "Proximate composition of certain Red Sea fishes," 3:71
Harbor seal, Phoca vitulina, 3:7
Hard clams, Mercenaria mercenaria, 2:33, 3:15
Hawaiian Archipelago, seamount survey, 2:7-13
bottom topography, 2:7-8
sampling, 2:8-9
seamounts, 2:1
Hawaiian monk seals, Monachus schauinslandi, 3:59,
Hemirhamphidae, 3:71
Henderson, John R., "Encounters of Hawaiian monk seals with fishing gear at Lisianski Island, 1982," 3:59
Hermit crabs, Dardanus spp., 2:12, 4:76
Herrick, Samuel F., Jr., "U.S. tuna trade summary, 1982," 1:1
Herrick, Samuel F., Jr., and Steven Koplin, "U.S. tuna trade summary, 1983," 4:65
Heslinga, Gerald A., Obichang Orak, and Marcus Ngiramengior, "Coral reef sanctuaries for trochus shells," 4:73
"History of artificial propagation of coho salmon, Oncorhynchus kisutch, in the mid-Columbia River system," by Roy J. Wahle and Roger E. Pearson, 3:34
Holts, David B.--see Coe et al.
Honeycombing, skipjack tuna
analysis, 2:41
definition, 2:40
evaluation, 2:40
"(The) humpback whale, Megaptera novaeangliae," by James H. Johnson, and Allen A. Wolman, 4:30
Humpback whale, Megaptera novaeangliae, 3:9, 4:30
distribution, 4:31
exploitation, 4:35
feeding, 4:33-34
habitat protection, 4:36
identification, 4:30
management, 4:35-36
migration, 4:31
mortality, 4:34-36
population, 4:35
recruitment, 4:34
reproduction, 4:34
stocks, 4:31-32

I-J

"(The) incidental capture of sea turtles in the Atlantic U.S. Fishery Conservation Zone by the Japanese tuna longline fleet," by W. N. Witzell, 3:56
Infectious hematopoietic necrosis virus (IHNV), 3:14
International Whaling Commission (IWC), 4:21, 26, 35, 39, 47, 59
"Investment in Gulf of Mexico shrimp vessels, 1965-77," by Ernest O. Tettey and Wade L. Griffin, 2:49
Jack mackerel, Trachurus symmetricus, 3:5
Jaenicke, Herbert W., Adrian G. Celewycz, Jack E. Bailey, and Joseph A. Orsi, "Paired open beach seines to study estuarine migrations of juvenile salmon," 3:62
Johnson, James H., and Allen A. Wolman, "The humpback whale, Megaptera novaeangliae," 4:30

K-L

Kemp's ridley turtle, Lepidochelys kempi, 3:57
Killer whale, Orcinus orca, 4:34
King crab, Paralithodes spp., 3:7
Koplin, Steven--see Herrick and Koplin
Krauthamer, Judith T., William E. Grant, and Wade L. Griffin, "Characteristics of the Texas shrimp fleet," 2:53
Labridae, 2:11, 3:71
Lane, J. Perry and Thomas J. Connors, "Evaluation of methods to determine the proportions of fillets and minced fish flesh in mixed fish blocks," 2:36
Lane, J. Perry, John J. Ryan, and Robert J. Learson, "Assessing the accuracy of a method to determine the amount of minced fish in mixed mince-fillet fish blocks," 3:76
Lanier, Tyre C., "Suitability of red hake, Urophycis chuss, and silver hake, Merluccius bilinearis, for processing into surimi," 2:43
Laurs, R. Michael--see Fiedler et al.
Learson, Robert J.--see Lane et al.
Leatherback turtle, Dermochelys coriacea, 3:57
Lethrinidae, 3:71
Loggerhead turtle, Caretta caretta, 3:57
Lutjanidae, 2:11, 3:71

M

Mackerel scad, Decapterus tabl, 2:11
Magnuson Fishery Conservation and Management Act (MFCMA), 2:1, 3:48
"Marine bivalve mollusks as reservoirs of viral finfish pathogens: Significance to marine and anadromous finfish aquaculture," by Theodore R. Meyers, 3:14
Marine fish farms, Norwegian
Atlantic salmon, 3:44-46
rainbow trout, 3:46
Marine Mammal Protection Act (MMPA) of 1972, 3:18, 4:2
Megaptera novaeangliae, humpback whale, 3:9, 4:2
Mercenaria mercenaria, hard clams, 3:15
Merluccius productus, Pacific whiting, 3:5
Meyers, Theodore R., "Marine bivalve mollusks as reservoirs of viral finfish pathogens: Significance to marine and anadromous finfish aquaculture," 3:14
Micropogonias undulatus, Atlantic croaker, 2:45
Minced fish, amount in fish blocks, 3:76
Mizroch, Sally A., Dale W. Rice, and Jeffrey M. Breiwick, "The blue whale, Balaenoptera musculus," 4:15
Mizroch, Sally, Dale W. Rice, and Jeffrey M. Breiwick, "The fin whale, Balaenoptera physalus," 4:20
Mizroch, Sally, Dale W. Rice, and Jeffrey M. Breiwick, "The sei whale, Balaenoptera borealis," 4:25
Monk seals, entanglement with fishing gear, 3:59
incidence, 3:60-61
response, 3:60-61
Moray eels: Gymnothorax berndti, G. steindachneri, G. undulatus, 2:12
Mullidae, 3:71

N-O

Narwhal, Monodon monoceros, 3:7
National Aeronautics and Space Administration (NASA), satellites, 3:1
Nellis, David W.--see Olsen et al.
Ngiramengior, Marcus--see Heslinga et al.
Nip, Wai-Kit--see Frank et al.
"Nonselectivity of gillnet fishery on jaw-tagged adult steelhead, Salmo gairdneri," by Emil Slatick and Larry Basham, 3:68
Northern fur seal, Callorhinus ursinus, 3:9, 59
"Norwegian salmon and trout farming," by Robert J. Ford, 3:44
Observer program, voluntary/mandatory, 3:20-21
Ocean condition research, remote sensing data, 3:1
Ocean quahog, Arctica islandica,
age and growth studies, 2:28-29
sex determination, 2:32-33
validation of annual periodicity, 2:29-30
"Oceanographic observations off the Pacific Northwest following the 1982 El Niño event," by R. K. Reed, 1:7
Octopus sp., 2:13
Olsen, David A., David W. Nellis, and Richard S. Wood, "Ciguatera in the eastern Caribbean," 1:13
Omega-3 long chain fatty acid, 2:60-62
fish oil concentrates, in, 2:61
serum cholestrol effects, 2:61
Oncorhynchus gorbuscha, pink salmon, 3:5, 35
O. keta, chum salmon, 3:5, 35
O. kisutch, coho salmon, 3:5, 34
O. nerka, sockeye salmon, 3:5, 14
O. tshawytscha, chinook salmon, 3:5, 36
Orak, Obichang--see Heslinga et al.
Orcinus orca, killer whale, 4:34
Orsi, Joseph A.--see Jaenicke et al.

P-Q

Pacific herring, Clupea harengus pallasi, 3:5
Pacific mackerel, Scomber japonicus, 3:5
Pacific salmon, see Oncorhynchus spp.
Pacific salmon migrations, S.E. Alaska, 3:62
analysis, 3:65
direction, 3:63
timing, 3:63
Pacific whiting, Merluccius productus, 3:5
"Paired open beach seines to study estuarine migrations of juvenile salmon," by Herbert W. Jaenicke, Adrian G. Celewycz, Jack E. Bailey, and Joseph A. Orsi, 3:62
Palko, Barbara J.--see Brusher et al.
Pathogens, finfish, 3:14
bioaccumulation, 3:14-16
depuration, 3:14
epizootics, 3:14
infectious hematopoietic necrosis, 3:14
IPN molluscabirnaviruses, 3:15
JOV-1, 3:15
management implications, 3:16
potential infections, bivalves, 3:15
chum salmon virus (CSV), 3:15
infectious hematopoietic necrosis virus (IHNV), 3:16
salmonid IPN piscibirnaviruses, 3:16
13p2 reovirus, 3:15
Pearson, Roger E.--see Wahle and Pearson
Pelagic armorhead, Pentaceros richardsoni, 2:2
distribution, 2:13
feeding behavior, 2:13

fisheries, 2:14
life history, 2:13-14
migration, 2:13
morphological differences, 2:14
population, 2:13
Penaeid shrimp, Penaeus marginatus, 2:19
Phoca vitulina, harbor seal, 3:7
Physeter macrocephalus, sperm whale, 4:2
Pink salmon, Oncorhynchus gorbuscha, 3:5, 35, 62, 64
Pink shrimp, Penaeus duorarum, 2:53
Pink snapper, Pristipomoides sieboldii, 2:11
Plectranthias kelloggi, 2:11
Poisons--see Ciguatera fish poisoning
Polar bear, Ursus maritimus, 3:7
Pollock, Theragra chalcogramma, 2:45
Polyunsaturates, 2:60-61
"Procedures for preparing acetate peels and evidence validating the annual periodicity of growth lines formed in the shells of ocean quahogs, Arctica islandica," by John W. Ropes, 2:27
"Proximate chemical composition and fatty acids of three small coastal pelagic species," by Malcolm B. Hale, 1:19
Proximate composition
coastal (S.E. U.S.) herrings, 2:20
Red Sea fishes, 3:71
"Proximate composition of certain Red Sea fishes," by Rifaat G. M. Hanna, 3:71
Purse-seining, tuna, 3:18

R

Rainbow trout, Salmo gairdneri, 3:15, 44
Red bigeye, Cookeolus boops, 2:10
Red hake, Urophycis chuss, 2:43
Red snapper, Epinephelus quernus, 2:11
Reed, R. K., "Oceanographic observations off the Pacific Northwest following the 1982 El Nino event," 1:7
"Relationship between honeycombing and collagen breakdown in skipjack tuna, Katsuwonus pelamis," by Hilmer A. Frank, Mitchel E. Rosenfeld, Derrick H. Yoshinaga, and Wai-Kit Nip, 2:40
Remote sensing, satellite, 3:1
Ribbon seal, Phoca fasciata, 3:7
Rice, Dale W., Allen A. Wolman, and Howard W. Braham, "The grey whale, Eschrichtius robustus," 4:7
Rice, Dale W.--see Braham and Rice, Gosho et al., Mizroch et al.
"(The) right whale, Balaena glacialis," by Howard W. Braham and Dale W. Rice, 4:38
Right whale, Balaenoptera glacialis, 4:2, 38
distribution, 4:38
exploitation, 4:42-43
feeding, 4:41
identification, 4:38-39
management, 4:43-44
migration, 4:38
mortality, 4:42
population, 4:43
reproduction, 4:41-42
stocks, 4:39-41
Ringed seal, P. hispida, 3:7
Rockfish, Sebastes matsubari, 2:4
Ropes, John W., "Procedures for preparing acetate peels and evidence validating the annual periodicity of growth lines formed in the shells of ocean quahogs, Arctica islandica," 2:27
Rosenfeld, Mitchel E.--see Frank et al.
Round scad, Decapterus punctatus, 1:19
Ryan, John J.--see Lane et al.

S

Salmo gairdneri, 3:15, 35
Satellite, remote sensing, 3:1
Satellite sensors, 3:1-10
applications, 3:3-7
charts, 3:7
coastal zone monitoring, 3:6-7
ocean/surface conditions, 3:3-6
prediction, stock recruitment, 3:5
sea-ice monitoring, 3:7
Saturated fatty acids, 2:60-61
Scomber japonicus, Pacific mackerel, 3:5
Scombridae, 2:11
Scorpaenidae, 2:11
Scrod cod, Gadus morhua, 3:76
Scyphomedusidae, 3:57
Sea turtles, incidental tuna-trawl catch, 3:57
Atlantic longline fishery, in, 3:57
catch, 3:56-58
catch permits, 3:49
distribution, 3:57
Sea urchin, Echinometridae, 2:13
Sea-ice, remote sensing monitoring, 3:7
SEASAT satellite, 3:6
"(The) sei whale, Balaenoptera borealis," by Sally Mizroch, Dale W. Rice, and Jeffrey M. Breiwick, 4:25
Sei whale, Balaenoptera borealis, 4:2, 25
distribution, 4:25-26
exploitation, 4:27-28
feeding, 4:27
identification, 4:25
management, 4:28-29
migration, 4:25
mortality, 4:27
population, 4:28
reproduction, 4:27
stocks, 4:26-27
Serranidae, 3:71
Shrimp fishery, Texas, 2:53
commercial, 2:53
costs, 2:53
economic impacts, 2:53
fishing areas, 2:53
fleet, 2:54
legislation, 2:58-59
licensing, 2:53
management, 2:53
recreational, 2:53
total landings/value, 2:53
vessels, 2:53
Shrimp landings, Gulf of Mexico, 2:51
Shrimp vessels, Gulf of Mexico, 2:49
Signidae, 3:71
Silver hake, Merluccius bilinearis, 2:43
Skipjack tuna, Euthynnus pelamis, 1:1, 2:40, 4:65
Slatick, Emil and Larry Basham, "Nonselectivity of gillnet fishery on jaw-tagged adult steelhead, Salmo gairdneri," 3:68
Slipper lobster, Scyllarides squammosus, 2:13
Smith, Gary B.--see Fiedler et al.
Snake mackerel, Promethichthys promethus, 2:9
Snow (tanner) crab, Chionoecetes spp., 3:7
Sockeye salmon, Oncorhynchus nerka, 3:5, 14, 35
Spanish sardine, Sardinella aurita, 1:19
Sparidae, 3:71
"(The) sperm whale, Physeter macrocephalus," by Merrill E. Gosho, Merrill E., Dale W. Rice, and Jeffrey M. Breiwick, 4:54
Sperm whale, Physeter macrocephalus, 4:2, 54
distribution, 4:54-59
exploitation, 4:60-62
feeding, 4:59-60
identification, 4:54
management, 4:63
population, 4:60
reproduction, 4:60
stocks, 4:59, 62-63
stocks, 4:59
Spyridia, 1:16
Stansby, Maurice E., "Fish or fish oil in the diet and heart attacks," 2:60
Starfish, Astropectinidae, 2:12
"(The) status of endangered whales: An overview," by Howard W. Braham, 4:2
Steelhead, Salmo gairdneri, 3:35, 68-69
Stock recruitment, remote sensing predictions, 3:5
"Suitability of red hake, Urophycis chuss, and silver hake, Merluccius bilinearis, for processing into surimi," by Tyre C. Lanier, 2:43
Surf clam, Spisula solidissima, 2:27
Surimi, red and silver hake, 2:43

T

Tagami, Darryl T.--see Uchida and Tagami
Tetraodontidae, 2:11
Tettey, Ernest O., and Wade L. Griffin, "Investment in Gulf of Mexico shrimp vessels, 1965-77," 2:49
Theragra chalcogramma, pollock, 2:45
Thunnus alalunga, albacore, 3:8
T. albacares, yellowfin tuna, 3:18
T. thynnus orientalis, bluefin tuna, 3:5
Toxins--see ciguatera fish poisoning
Trachurus symmetricus, jack mackerel, 3:5
"Trapping surveys for the deepwater caridean shrimps, Heterocarpus laevigatus and H. ensifer, in the Northwest Hawaiian Islands," by Reginald M. Gooding, 2:18
Trent, Lee--see Brusher et al.
Trochus niloticus, 4:73
Trochus pyramis, 4:76
Tunas--see individual species
"(The) 'tuna-porpoise' problem: NMFS dolphin mortality reduction research, 1970-81," by James M. Coe, David B. Holts, and Richard W. Butler, 3:18
Tuna trade, U.S., 1:1-7, 4:65, 71
albacore production, white meat tuna, 4:66
Atlantic catch, 1:3-4
canned tuna imports, 4:65, 70-71
canned white meat tuna, 4:67
cannery receipts, 1:1-4
domestic production, 4:65
fleet characteristics, 4:65
foreign processors, 4:65
markets, 4:71
Pacific catch, 1:2
production, 1:4-5
resource limitations, 4:71
retail sales, 4:71
tropical light meat tuna processing, 4:68
U.S. consumption of canned tuna, 4:71
Turbinaria, 1:16

U-V

U.S. Department of Commerce Voluntary Fishery Product Inspection Program, 3:76
U.S. fisheries, regulatory guidelines, 3:49
U.S. Grade Standards for Fishery Products, 3:76
U.S. Standards for Grades of Frozen Fish Blocks, 2:38, 3:76
"U.S. tuna trade summary, 1982," by Samuel F. Herrick, Jr., 1:1
"U.S. tuna trade summary, 1983," by Samuel F., Herrick, Jr., and Steven Koplin, 4:65
Uchida, Richard N., and Darryl T. Tagami, "Groundfish fisheries and research in the vicinity of seamounts in the North Pacific Ocean," 2:1
"Using charterboat catch records for fisheries management," by Harold A. Brusher, Mark L. Williams, Lee Trent, and Barbara J. Palko, 3:48

W-Z

Wahle, Roy J., and Roger E. Pearson, "History of artificial propagation of coho salmon, Oncorhynchus kisutch, in the mid-Columbia River system," 3:34
Walrus, Odobenus rosmarus, 3:7
White shrimp, Penaeus setiferus, 2:53
Williams, Mark L.--see Brusher et al.
Witzell, W. N., "The incidental capture of sea turtles in the Atlantic U.S. Fishery Conservation Zone by the Japanese tuna longline fleet," 3:56
Wolman, A. A.--see Johnson and Wolman, Rice et al.
Wood, Richard S.--see Olsen et al.
Yellowfin tuna, Thunnus albacares, 1:1, 3:18
Yoshinaga, Derrick H.--see Frank et al.

Papers in the *Marine Fisheries Review* 46(1-4), 1984

46(1)

"U.S. Tuna Trade Summary, 1982," Samuel F. Herrick, Jr., 1:1-6.
"Oceanographic Observations Off the Pacific Northwest Following the 1982 El Nino Event," R. K. Reed, 1:7-12.
"Ciguatera in the Eastern Caribbean," David A. Olsen, David W. Nellis, and Richard S. Wood, 1:13-18.
"Proximate Chemical Composition and Fatty Acids of Three Small Coastal Pelagic Species," Malcolm B. Hale, 1:19-21.
"Dungeness Crab Leg Loss in the Columbia River Estuary," Joseph T. Durkin, Kurt D. Buchanan, and Theodore H. Blahm, 1:22-24.

46(2)

"Groundfish Fisheries and Research in the Vicinity of Seamounts in the North Pacific Ocean," Richard N. Uchida and Darryl T. Tagami, 2:1-17.
"Trapping Surveys for the Deepwater Caridean Shrimps, Heterocarpus laevigatus and H. ensifer, in the Northwest Hawaiian Islands," Reginald M. Gooding, 2:18-26.
"Procedures for Preparing Acetate Peels and Evidence Validating the Annual Periodicity of Growth Lines Formed in the Shells of Ocean Quahogs, Arctica islandica," John W. Ropes, 2:27-35.
"Evaluation of Methods to Determine the Proportions of Fillets and Minced Fish Flesh in Mixed Fish Blocks," J. Perry Lane and Thomas J. Connors, 2:36-39.
"Relationship Between Honeycombing and Collagen Breakdown in Skipjack Tuna, Katsuwonus pelamis," Hilmer A. Frank, Mitchel E. Rosenfeld, Derrick H. Yoshinaga, and Wai-Kit Nip, 2:40-42.
"Suitability of Red Hake, Urophycis chuss, and Silver Hake, Merluccius bilinearis, for Processing into Surimi," Tyre C. Lanier, 2:43-48.
"Investment in Gulf of Mexico Shrimp Vessels, 1965-77," Ernest O. Tettey and Wade L. Griffin, 2:49-52.
"Characteristics of the Texas Shrimp Fleet," Judith T. Krauthamer, William E. Grant, and Wade L. Griffin, 2:53-59.
"Fish or Fish Oil in the Diet and Heart Attacks," Maurice E. Stansby, 2:60-63.

46(3)

"Fisheries Applications of Satellite Data in the Eastern North Pacific," Paul C. Fiedler, Gary B. Smith, and R. Michael Laurs, 3:1-13.
"Marine Bivalve Mollusks as Reservoirs of Viral Finfish Pathogens: Significance to Marine and Anadromous Finfish Aquaculture," Theodore R. Meyers, 3:14-17.
"The 'Tuna-Porpoise' Problem: NMFS Dolphin Mortality Reduction Research, 1970-81," James M. Coe, David B. Holts, and Richard W. Butler, 3:18-33.
"History of Artificial Propagation of Coho Salmon, Oncorhynchus kisutch, in the Mid-Columbia River System," Roy J. Wahle and Roger E. Pearson, 3:34-43.
"Norwegian Salmon and Trout Farming," Robert J. Ford, 3:44-47.
"Using Charterboat Catch Records for Fisheries Management," Harold A. Brusher, Mark L. Williams, Lee Trent, and Barbara J. Palko, 3:48-55.
"The Incidental Capture of Sea Turtles in the Atlantic U.S. Fishery Conservation Zone by the Japanese Tuna Longline Fleet," W. N. Witzell, 3:56-58.
"Encounters of Hawaiian Monk Seals With Fishing Gear at Lisianski Island, 1982," John R. Henderson, 3:59-61.
"Paired Open Beach Seines to Study Estuarine Migrations of Juvenile Salmon," Herbert W. Jaenicke, Adrian G. Celewycz, Jack E. Bailey, and Joseph A. Orsi," 3:62-67.
"Nonselectivity of Gillnet Fishery on Jaw-tagged Adult Steelhead, Salmo gairdneri," Emil Slatick and Larry Basham, 3:68-70.
"Proximate Composition of Certain Red Sea Fishes," Rifaat G. M. Hanna, 3:71-75.
"Assessing the Accuracy of a Method to Determine the Amount of Minced Fish in Mixed Mince-Fillet Fish Blocks," J. Perry Lane, John J. Ryan, and Robert J. Learson, 3:76-79.

46(4)

"The Status of Endangered Whales: An Overview," Howard W. Braham, 4:2-6.
"The Gray Whale, Eschrichtius robustus," Dale W. Rice, Allen A. Wolman, and Howard W. Braham, 4:7-14.
"The Blue Whale, Balaenoptera musculus," Sally A. Mizroch, Dale W. Rice, and Jeffrey M. Breiwick, 4:15-19.
"The Fin Whale, Balaenoptera physalus," Sally Mizroch, Dale W. Rice, and Jeffrey M. Breiwick, 4:20-24.
"The Sei Whale, Balaenoptera borealis," Sally Mizroch, Dale W. Rice, and Jeffrey M. Breiwick, 4:25-29.
"The Humpback Whale, Megaptera novaeangliae," James H. Johnson and Allen A. Wolman, 4:30-37.
"The Right Whale, Balaena glacialis," Howard W. Braham and Dale W. Rice, 4:38-44.
"The Bowhead Whale, Balaena mysticetus," Howard W. Braham, 4:45-53.
"The Sperm Whale, Physeter macrocephalus," Merrill E. Gosho, Dale W. Rice, and Jeffrey M. Breiwick, 4:54-64.
"U.S. Tuna Trade Summary, 1983," Samuel F. Herrick, Jr. and Steven Koplin, 4:65-72.
"Coral Reef Sanctuaries for Trochus Shells," Gerald A. Heslinga, Obichang Orak, and Marcus Ngiramengior, 4:73-80.

Editorial Guidelines for the *Marine Fisheries Review*

The *Marine Fisheries Review* publishes review articles, original research reports, significant progress reports, technical notes, and news articles on fisheries science, engineering, and economics, commercial and recreational fisheries, marine mammal studies, aquaculture, and U.S. and foreign fisheries developments. Emphasis, however, is on in-depth review articles and practical or applied aspects of marine fisheries rather than pure research.

Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

The Manuscript

Submission of a manuscript to *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under a completed NOAA Form 25-700.

Manuscripts must be typed (double-spaced) on high-quality white bond paper and submitted with two duplicate (but not carbon) copies. The complete manuscript normally includes a title page, a short abstract (if needed), text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). Manuscript pages should be numbered and have 1½-inch margins on all sides. Running heads are not used. An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

Abstract and Headings

Keep titles, heading, subheadings, and the abstract short and clear. Abstracts should be short (one-half page or less) and double-spaced. Paper titles should be no longer than 60 characters; a four- to five-word (40 to 45 characters) title is ideal. Use heads sparingly, if at all. Heads should contain only 2-5 words; do not stack heads of different sizes.

Style

In style, the *Marine Fisheries Review* follows the "U.S. Government Printing Office Style Manual." Fish names follow the American Fisheries Society's Special Publication No. 12, "A List of Common and Scientific Names of Fishes from the United States and Canada," fourth edition, 1980. The "Merriam-Webster Third New International Dictionary" is used as the authority for correct spelling and word division. Only journal titles and scientific names (genera and species) should be italicized (underscored). Dates should be written as 3 November 1976. In text, literature is cited as Lynn and Reid (1968) or as (Lynn and Reid, 1968). Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. Measurements are preferred in metric units; other equivalent units (i.e., fathoms, °F) may also be listed in parentheses.

Tables and Footnotes

Tables and footnotes should be typed separately and double-spaced. Tables should be numbered and referenced in text. Table headings and format should be consistent; do not use vertical rules.

Literature Cited

Title the list of references "Literature Cited" and include only published works or those actually in press. Citations must contain the complete title of the work, inclusive pagination, full journal title, and the year, month, volume, and issue numbers of the publication. Unpublished reports or manuscripts and personal communications must be footnoted. Include the title, author, pagination of the manuscript or report, and the address where it is on file. For personal communications, list the name, affiliation, and address of the communicator.

Citations should be double-spaced and listed alphabetically by the senior author's surname and initials. Co-authors should be listed by initials and surname. Where two or more citations have the same author(s), list them chronologically; where both author and year match on two or more, use lowercase alphabet to distinguish them (1969a, 1969b, 1969c, etc.).

Authors must double-check all literature cited; they alone are responsible for its accuracy.

Figures

All figures should be clearly identified with the author's name and figure number, if used. Figure legends should be brief and a copy may be taped to the back of the figure. Figures may or may not be numbered. Do not write on the back of photographs. Photographs should be black and white, 8 × 10 inches, sharply focused glossies of strong contrast. Potential cover photos are welcome, but their return cannot be guaranteed. Magnification listed for photomicrographs must match the figure submitted (a scale bar may be preferred).

Line art should be drawn with black India ink on white paper. Design, symbols, and lettering should be neat, legible, and simple. Avoid freehand lettering and heavy lettering and shading that could fill in when the figure is reduced. Consider column and page sizes when designing figures.

Finally

First-rate, professional papers are neat, accurate, and complete. Authors should proofread the manuscript for typographical errors and double-check its contents and appearance before submission. Mail the manuscript flat, first-class mail, to: Editor, *Marine Fisheries Review*, Scientific Publications Office, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115.

The senior author will receive 50 reprints (no cover) of his paper free of charge and 50 free copies are supplied to his organization. Cost estimates for additional reprints can be supplied upon request.

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