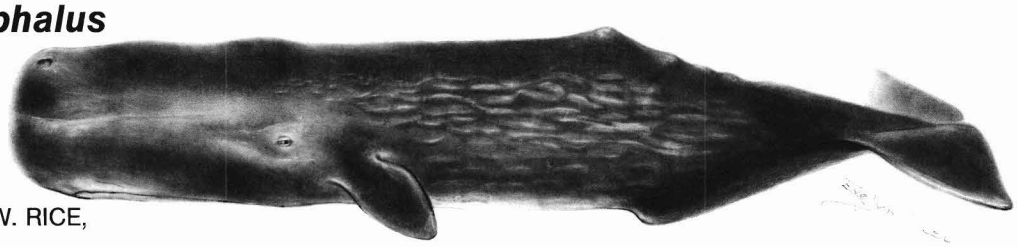
# The Sperm Whale, *Physeter macrocephalus*



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

## Introduction

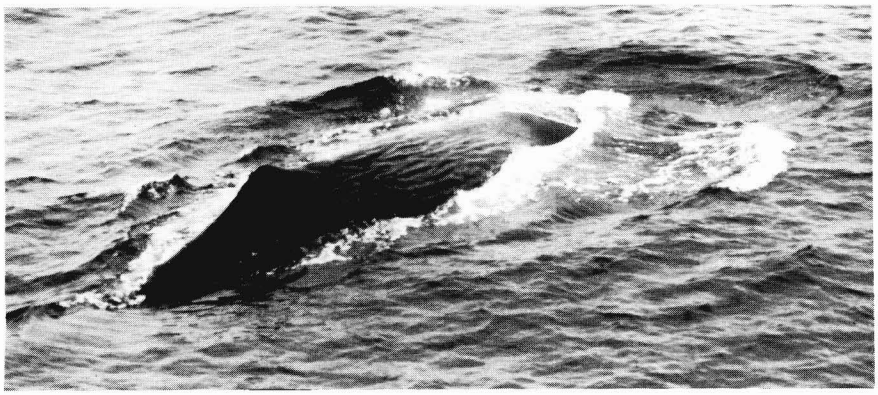
The sperm whale *Physeter macrocephalus* Linnaeus, 1758[1], is the largest of the toothed whales (Odontoceti). In the past, males as large as 20 m (65 feet) in length have been recorded; today, however, males larger than 18 m (60 feet) are rare. The maximum length of female sperm whales is 12 m (40 feet) (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.

The authors are with the National Marine Mammal Laboratory, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115.

[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.

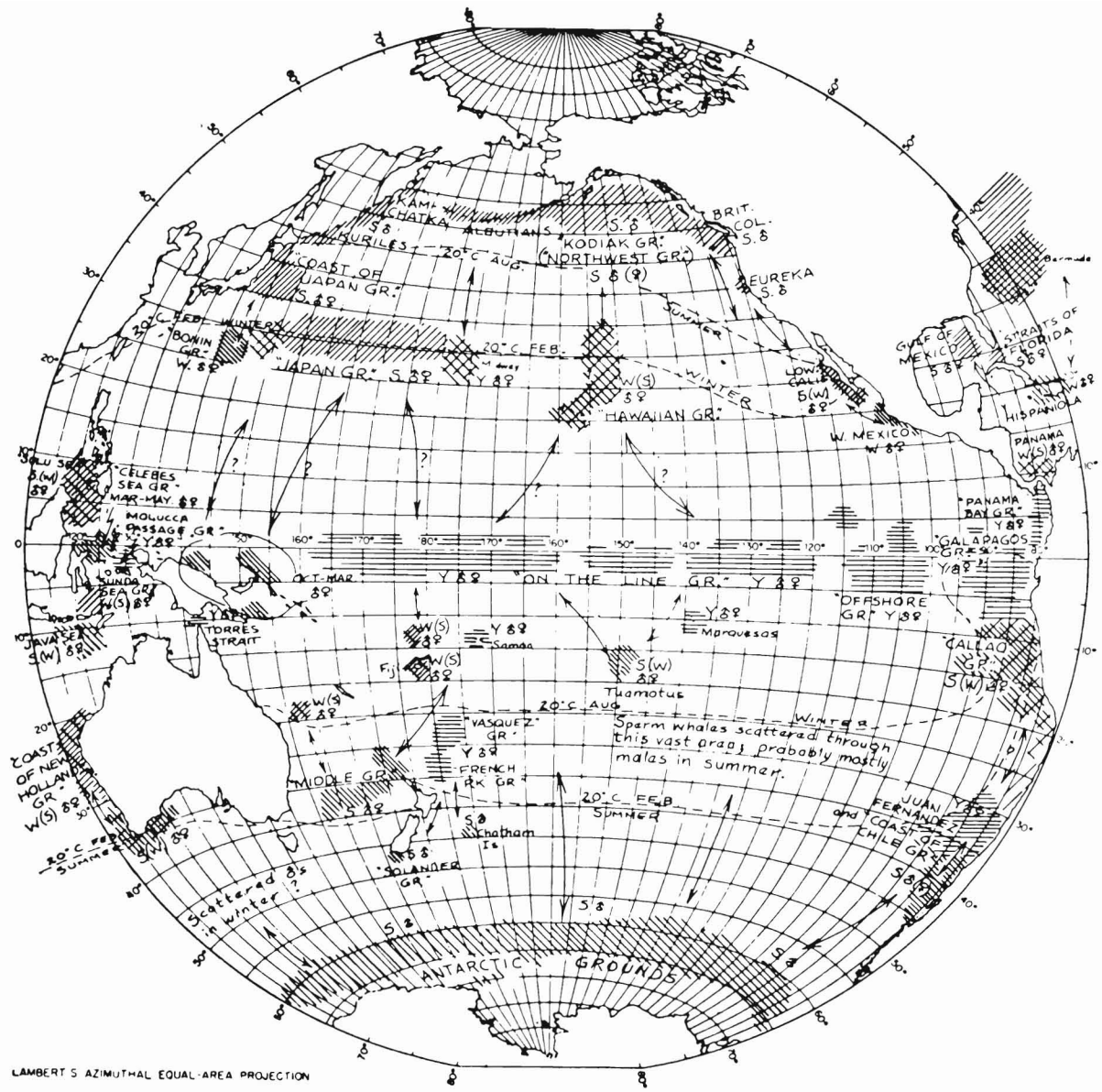



Figure 1a.—Pacific Ocean distribution of sperm whales based on past commercial catches (Gilmore, 1959).

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

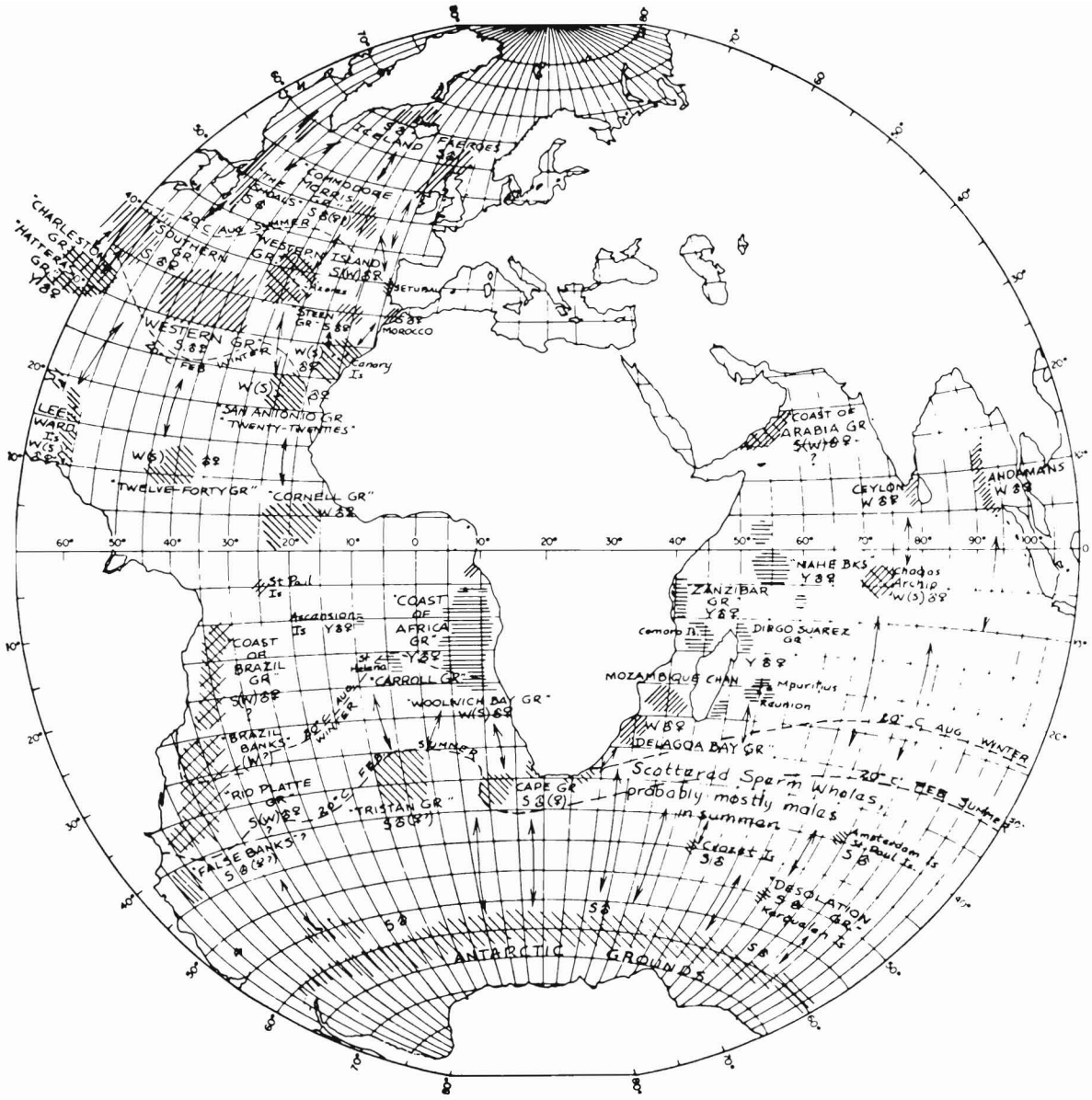



Figure 1b. — Atlantic and Indian Ocean distribution of sperm whales based on past commercial catches (Gilmore, 1959).

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

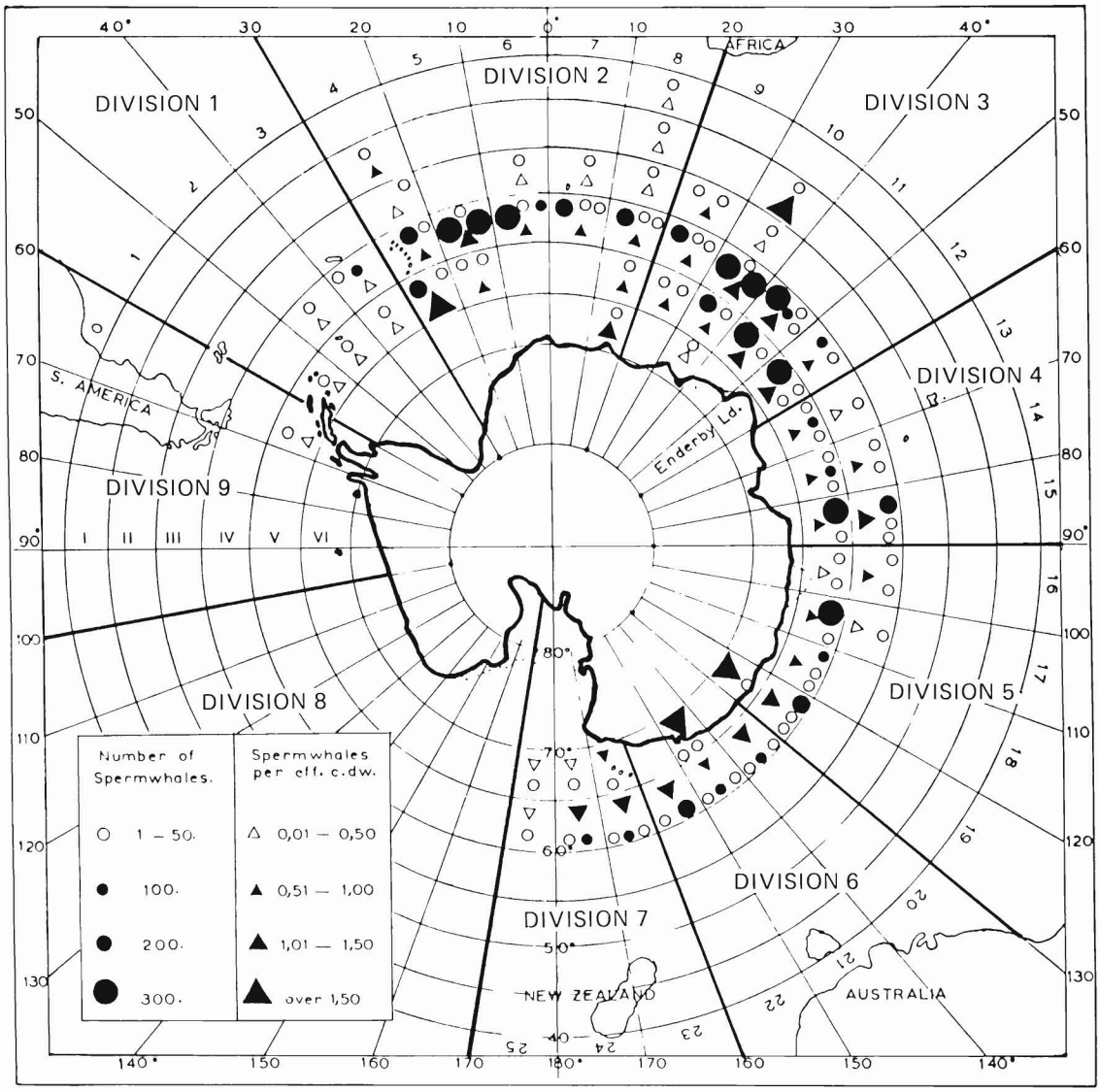



Figure 2. – Total catch of sperm whales in the Antarctic and average yield of sperm whales per effective catcher's day's work (c.d.w.) for seasons 1950-51, 1951-52, 1954-55, and 1955-56 apportioned between squares of 5 degrees latitude and 10 degrees longitude (Holm and Jonsgård, 1959).

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).

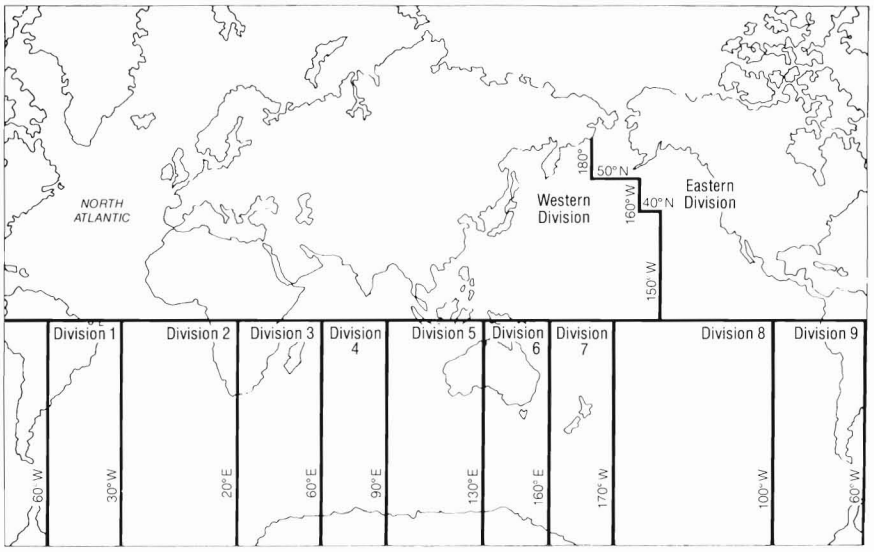



Figure 3.—Sperm whale stock divisions of the International Whaling Commission.

### 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.

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 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.

**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).

## Literature Cited


Akimushkin, I. I. 1963. Golovonogie mollyuski morei SSSR (Cephalopods of the seas of the U.S.S.R.). Izd. Akad. Nauk SSSR, Moscow. [In Russ., transl. by Isr. Program Sci. Transl., 1965, 223 p.; avail. U.S. Dep. Commer., Natl. Tech. Inf. Serv., Springfield, Va., as TT65-50013.]

Allen, K. R. 1980. Conservation and management of whales. Butterworth and Co., Lond., 107 p.

_____, and G. Kirkwood. 1977. A sperm whale population model based on cohorts (SPCOH). Rep. Int. Whaling Comm. 27:268-271.

Bannister, J. L. 1968. An aerial survey for sperm whales off the coast of Western Australia 1963-65. Aust. J. Mar. Freshwater Res. 19:31-51.

_____. 1969. The biology and status of the sperm whale off Western Australia—an extended summary of results of recent work. Appendix 7. Rep. Int. Whaling Comm. 19:70-76.

_____, and R. Gambell. 1965. The succession and abundance of fin, sei, and other whales off Durban. Nor. Hvalfangst-Tidende 54(3):45-60.

Beddington, J. R., and J. G. Cooke. 1981. Development of an assessment technique for male sperm whales based on the use of length data from the catches, with special reference


**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.

to the North-west Pacific stock. Rep. Int. Whaling Comm. 31:747-760.

Berzin, A. A. 1971. Kashalot (The sperm whale). Izd. "Pishchevaya Promyshlennost", Moscow. [In Russ., transl. by Isr. Program Sci. Transl., 1972, 394 p., avail. U.S. Dep. Commer., Natl. Tech. Inf. Serv., Springfield, Va., as TT71-50152.]

_____, and A. A. Rovnin. 1966. Raspredelenie i migratsii kitov v severo-vostochnoi chasti Tikhojgo okeana, v Beringovom i Chukotskom moryakh (Distribution and migration of whales in the northeastern part of the Pacific Ocean, Bering and Chukchee Seas). Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr. (TINRO) 58:179-207. [In Russ., transl. by U.S. Dep. Inter., Bur. Commer. Fish., Seattle, Wash., 1966, p. 103-136 *In* K. I. Panin (editor), Soviet research on marine mammals of the Far East.]

Best, P. B. 1969. The sperm whale (*Physeter catodon*) off the west coast of South Africa. (4) Distribution and movements. S. Afr. Div. Sea Fish. Invest. Rep. 78:1-12.

_____. 1979. Social organization in sperm whales, *Physeter macrocephalus*. *In* H. E. Winn and B. L. Olla (editors), Behavior of marine animals, volume 3: cetaceans, p. 227-289. Plenum Press, N.Y.

Clark, A. H. 1887. The American whale-fishery. Science (Wash., D.C.) 9(217): 321-324.

Clarke, M. R. 1976. Observation on sperm whale diving. J. Mar. Biol. Assoc. U.K. 56:809-810.

_____. 1980. Cephalopoda in the diet of sperm whales of the Southern Hemisphere and their bearing on sperm whale biology. Discovery Rep. 37:1-324.

Clarke, R. 1954. Open boat whaling in the Azores. Discovery Rep. 26:281-354.

_____. 1956. Sperm whales of the Azores. Discovery Rep. 28:237-98.

Committee for Whaling Statistics. 1959-1983. International whaling statistics, volumes 41-91. Comm. Whaling Stat., Oslo, Nor., var. pagin.

Frost, S. 1978. Volume I. Report of the independent inquiry. Whales and whaling. Aust. Gov. Publ. Serv., Canberra, 342 p.

Gambell, R. 1967. Seasonal movements of sperm whales. Symp. Zool. Soc. Lond. 19:237-254.

_____. 1972. Sperm whales off Durban. Discovery Rep. 35:199-358.

Gaskin, D. E. 1972. Whales, dolphins, and seals. St. Martins Press, Inc., N.Y., 200 p.

Gilmore, R. 1959. On mass strandings of sperm whales. Pac. Nat. 1(10):9-16.

Harmer, S. F. 1928. The history of whaling. Proc. Linn. Soc. Lond. 140:51-95.

Hegarty, R. B. 1959. Returns of whaling vessels sailing from American ports—A continuation of Alexander Starbuck's "History of the American whale fishery" 1876-1928. Reynolds Print., Inc., New Bedford, Mass., 58 p.

Holm, J. L., and A. Jonsgård. 1959. Occurrence of the sperm whale in the Antarctic and the possible influence of the moon. Nor. Hvalfangst-Tidende 48(4):161-182.

Husson, A. M., and L. B. Holthius. 1974. *Physeter macrocephalus* Linnaeus, 1758, the valid name for the sperm whale. Zool. Meded. (Leiden) 48:205-217.

IWC. 1969. Appendix VI: Report of the IWC-FAO working group on sperm whale stock assessment. Rep. Int. Whaling Comm. 19:39-84.

_____. 1971. Report of the Special Meeting on Sperm Whale Biology and Stock Assessments. Rep. Int. Whaling Comm. 21:40-50.

_____. 1978. Report of Scientific Committee: Sperm whales. Rep. Int. Whaling Comm. 28:57-62.

_____. 1979. Annex E: Report of the subcommittee on sperm whales. Rep. Int. Whaling Comm. 29:65-74.

_____. 1980a. Report of the special meeting on sperm whale assessments 27 November to 8 December 1978. Rep. Int. Whaling Comm., Spec. Issue 2:107-136.

_____. 1980b. Annex F: Report of the sub-committee on sperm whales. Rep. Int. Whaling Comm. 30:79-96.

_____. 1981. Annex D: Report of the sub-committee on sperm whales. Rep. Int. Whaling Comm. 31:78-102.

_____. 1982. Annex D. Report of the sub-committee on sperm whales. Rep. Int. Whaling Comm. 32:68-86.

_____. 1983. Annex D. Report of the sub-committee on sperm whales. Rep. Int. Whaling Comm. 33:74-90.

Kirpichnikov, A. A. 1950. O sovremennom rasprostranenii kashalotov v mirovom okeane po promyslovym dannym (Present-day distribution of sperm whales in the world ocean according to commercial data.) Byull. Mosk. Ova. Inspyt. Prir. Otd. Biol. 55(5):11-25. [In Russ.]

Kugler, R. C. 1981. Historical records of American sperm whaling. *In* Mammals in the seas, volume 3, general papers and large cetaceans, p. 321-326. Food Agric. Organ. U.N., Rome, FAO Fish. Ser. 5, Vol. 3.

Mackintosh, N. A. 1965. The stocks of whales. Fishing News (Books) Ltd., Lond. 232 p.

Martin, A. R. 1982. A link between the sperm whales occurring off Iceland and the Azores. Mammalia 46:259-260.

Matthews, L. H. 1938. The sperm whales, *Physeter catodon*. Discovery Rep. 17:93-168.

McClung, R. M. 1978. Hunted mammals of the sea. William Morrow and Co., N.Y., 192 p.

Mitchell, E. 1975. Preliminary report on Nova Scotia fishery for sperm whales (*Physeter catodon*). Rep. Int. Whaling Comm. 25:226-235.

Nishiwaki, M. 1967. Distribution and migration of marine mammals in the North Pacific area. Bull. Ocean Res. Inst. Univ. Tokyo 1, 64 p.

Ohsumi, S. 1965. Reproduction of the sperm whale in the North Pacific. Sci. Rep. Whales Res. Inst., Tokyo 19:1-35.

_____. 1966. Sexual segregation of the sperm whale in the North Pacific. Sci. Rep. Whales Res. Inst., Tokyo 20:1-16.

_____, and Y. Masaki. 1977. Stocks and trends of abundance of the sperm whale in the North Pacific. Rep. Int. Whaling Comm. 27:167-175.

Omura, H. 1955. Whales in the northern part of the North Pacific. Nor. Hvalfangst-Tidende 44(6):323-345.

Rice, D. 1974. Whales and whale research in the eastern North Pacific. *In* W. E. Schevill (editor), The whale problem; a status report, p. 170-195. Harvard Univ. Press, Cambridge, Mass.

_____. 1978. Sperm whales. *In* D. Haley (editor), Marine mammals of the eastern North Pacific and Arctic waters, p. 82-87. Pac. Search Press., Seattle.

Scammon, C. M. 1874. The marine mammals of the north-western coast of North America together with an account of the American whale-fishery. John H. Carmany and Co., San Franc. (Republ. in 1968 by Dover Publ., Inc., N.Y., 319 p.)

Slijper, E. J. 1962. Whales. [Transl. from Dutch by A. J. Pomerans.] Basic Books, Inc., N.Y., 475 p.

Starbuck, A. 1878. History of the American whale fishery from its earliest inception to the year 1876. U.S. Comm. Fish Fish., Part 4, Rep. Comm. 1875-1876, append. A, 779 p. (Reprinted in two volumes in 1964 by Argosy-Antiquarian Ltd., N.Y., 768 p.)

Tomilin, A. G. 1957. Zveri SSSR i prilezhashehikh stran (Mammals of the U.S.S.R. and adjacent countries). Volume 9. Kitoobroznye (Cetacea). Izd. Akad. Nauk. SSSR, Moscow, 756 p. [In Russ., transl. by Isr. Program Sci. Transl., 1967, 717 p., avail. U.S. Dep. Commer., Natl. Tech. Inf. Serv., Springfield, Va., as TT65-50086.]

Tønnessen, J. N., and A. O. Johnsen. 1982. The history of modern whaling. (Transl. from Norwegian by R. I. Christophersen.) Univ. Calif. Press, Berkeley, 798 p.

Townsend, C. H. 1935. The distribution of certain whales as shown by logbook records of American whaleships. Zoologica (N.Y.) 19(1):1-50.

Watkins, W. A. 1977. Acoustic behavior of sperm whales. Oceanus 20(2):50-58.