The Sperm Whale

Introduction

The sperm whale, *Physeter macrocephalus* Linnaeus, 1758[85], is the largest and most sexually dimorphic member of the odontoceti or toothed whales. Males reach a maximum length of 18.5 m, while the maximum length of females is 12.5 m (Odell, 1992). Calves at birth have an average length of 4 m. The most distinctive physical feature of the sperm whale is the exceptionally large head to body ratio: about one-third of the total body length. The enormous head contains a reservoir of spermaceti oil produced by the spermaceti organ. And a black or grayish fatty substance, known as ambergris, is produced in the sperm whale's intestines. Near the anterior of the head and to the left is a single blow hole (Fig. 34). The narrow bottom jaw holds 17–29 pairs of functional teeth that align with indentations in the upper jaw (Rice, 1989).

These toothed whales are rarely found in waters less than 300 m deep. They are often concentrated around oceanic islands in areas of upwelling and along the outer continental shelf and mid ocean waters (Rice, 1989).

Sperm whales are deep divers. Solitary adult males can stay submerged for over 60 minutes at recorded depths of over 2,000 m (Watkins et al., 1993). Mixed groups of females and young whales with calves have an average dive time of 8 minutes, while mixed groups without calves average 25 minutes (Leatherwood et al., 1982; Mano, 1990; Gordon and Steiner, 1992). Body size, degree of social cohesion, oceanographic features or bottom topography, and prey species availability are all factors that may affect variation in dive behavior between individuals and areas.

Distribution and Migration

Sperm whales inhabit all ocean basins, from equatorial waters to the polar regions. In general, their distribution varies by gender and age composition of groups and is related to prey availability and certain oceanic conditions (Fig. 35). Mature females, calves, and immature whales of both sexes are found in social groups in temperate and tropical waters year round. Very rarely are female/immature groups found higher than lat. 50°N and lat. 50°S (Reeves and Whitehead, 1997). Male sperm whales lead a mostly solitary life after reaching sexual maturity between 9 and 20 years of age and travel into regions as high as lat. 70°N in the North Atlantic and lat. 70°S in the Southern Ocean (Reeves and Whitehead, 1997).

General migration patterns vary between males and females. In summer, all sperm whales can be found at the highest latitudes of their range. In winter, female/immature groups migrate closer to equatorial waters in both hemispheres, possibly following warmer sea-surface temperatures (Kasuya and Miyashita, 1988; Waring et al., 1993). Sexually mature males join these female/immature groups throughout the winter. The genetic homogeneity of sperm whales worldwide, suggests that genetic exchange occurred between Northern and Southern Hemisphere populations at some time in their evolutionary history (Dufault et al.[86]).

Large-scale oceanographic events, such as El Niño, also seem to affect the distribution and movements of sperm whales (Whitehead et al.[87]), creating annual and seasonal geographic variability.

North Pacific

In 1981, the IWC's Scientific Committee designated two sperm whale stocks in the North Pacific, western and eastern, based on whaling records, the results of Discovery tagging[38], and the intermingling of males in the northern latitudes (Donovan, 1991). The boundary delineating western and eastern North Pacific stocks became known as the "Cambridge Line" (Fig. 36), and has been much debated since its acceptance by the IWC's Scientific Committee. There is evidence from historical whaling data, ship-based surveys, and oceanographic features, that three or more North Pacific stocks of sperm whales should be recognized for management purposes (Bannister and Mitchell, 1980; Kasuya, 1991).

Sperm whales occur throughout the North Pacific. Female and immature whales are found year round in temperate and tropical waters from the Equator to around lat. 45% N. During summer, mature male sperm whales are thought to move north into waters off the Aleutian Islands, Gulf of Alaska, and

[85] Both *Physeter macrocephalus* and *Physeter catodon* are scientific names used in the literature to refer to the sperm whale. However, *P. macrocephalus* has been designated as the preferred name by the International Code of Zoological Nomenclature's Article 24(a) naming procedure (Rice, 1998). *P. macrocephalus* has never been used to refer to another species, while *P. catadon* has been used in reference to other cetaceans (e.g. pilot whales) (see Husson and Holthius,1974).

[86] Dufault, S., H. Whitehead, and M. Dillon. 1997. An examination of current knowledge on the stock structure of sperm whales (*Physeter macrocephalus*) world-wide. Unpubl. doc. SC/49/07 submitted to Rep. Int. Whal. Comm., 19 p.

[87] Whitehead, H., V. Papastavrou, and S. Smith. 1990. Sperm whales and El Niño off the Galapagos Islands. Unpubl. doc. SC/40/Sp4 submitted to Rep. Int. Whal. Comm., 6 p.

the southern Bering Sea (Fig. 4). However, Discovery tag[38] data revealed considerable east-west movement between Alaska and the western North Pacific, with little evidence of north-south movement in the eastern North Pacific (Ohsumi and Masaki, 1977; Wada, 1980; Taylor[88]).

In the U.S. EEZ of the North Pacific, three discrete population "centers" have been identified for stock assessment purposes: 1) Alaska, 2) California/Oregon/Washington, and 3) Hawaii (Barlow et al., 1997; Hill et al., 1997). These stock designations are based on distributional data from sightings and catches only, and there are no reliable phenotypic or genotypic data available for any of the sperm whale "centers" in U.S. waters (Small and DeMaster, 1995; Hill et al., 1997).

A survey conducted by the NMFS in the winter of 1997 (Sperm Whale Abundance and Population Structure, or SWAPS) was designed to census these three "centers" and the area south of the U.S./Mexican border to more clearly determine sperm whale distribution and abundance in this region. Preliminary results of this survey (new abundance estimates are still being determined) along with the results of previous surveys in the same area, suggest that seasonal sperm whale distribution in these waters varies annually, and brings into question the belief that sperm whales are abundant during February off central California (Bannister and Mitchell, 1980). More work is necessary in the temperate eastern Pacific before reliable stock structure designations can be made (Taylor[88]; Taylor et al.[89]).

Sperm whales in the western North Pacific stock occur from the Equator, along the Philippines, and up to the Kuril Islands and Kamchatka Peninsula, Russia (Fig. 5) (Kasuya and Miyashita, 1988; Shuntov, 1994). Based on Japanese coastal whaling data, tag returns, blood typing, and whale distribution associated with oceanographic current systems (i.e. Kuroshio Current and Oyashio Front), Kasuya (1991) proposed that there are three distinct sperm whale stocks in the North Pacific: 1) northwest North Pacific, 2) southwest North Pacific, and 3) eastern North Pacific. However, distinction between the three is confounded by the overlap in male distribution in northern latitudes (Kasuya and Miyashita, 1988).

North Atlantic

There is evidence from the harvest of Discovery tagged[38] individuals that North Atlantic sperm whales are one geographically continuous stock. One sperm whale tagged on the Scotian Shelf was killed over 7 years later off Spain (Mitchell, 1975c). From five to six handheld harpoons from the Azore sperm whale fishery were recovered from whales killed off northwest Spain (Donovan, 1991), with an additional Azorean harpoon recovered from a male sperm whale killed off Iceland (Fig. 7) (Martin, 1982). Consequently, the IWC recognized the North Atlantic sperm whale population as one management stock.

[88] Taylor, B. 1997. Appendix 3. *In* D. P. DeMaster (Editor), Minutes from fifth meeting of the Alaska Scientific Review Group, 7-9 May 1997, Seattle, Wash., 21 p. Avail. from D. P. DeMaster, Director, Natl. Mar. Mammal Lab., 7600 Sand Point Way, N.E., Seattle, WA 98115.

Figure 34.—Aerial view of an adult sperm whale. Note the angled blow. NMML Collection.

[89] Taylor, B. L., S. L. Mesnick, and A. E. Dizon. 1998. Progress report and suggested future research on using genetic data to define sperm whale stock structure in the North Pacific. Unpubl. doc. SC/50/CAWS19 submitted to Rep. Int. Whal. Comm.

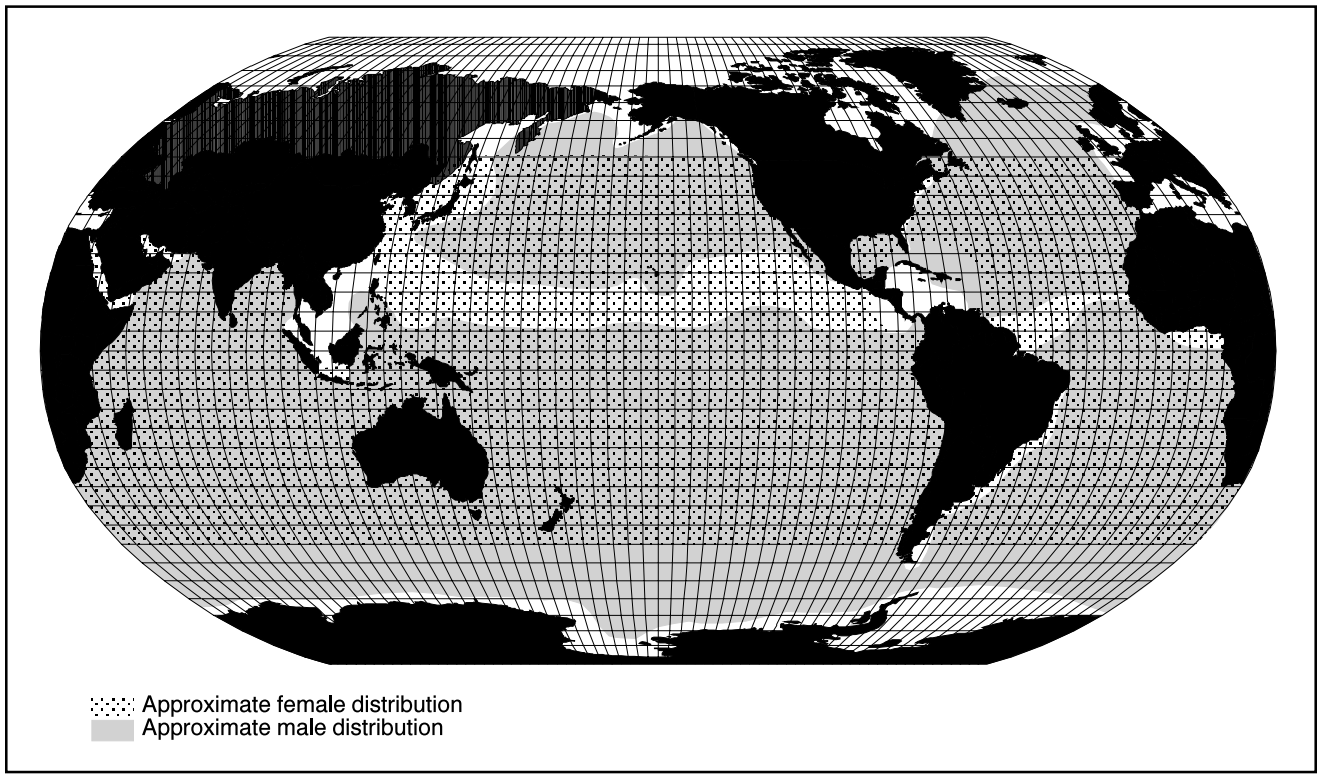

Figure 35.—Worldwide sperm whale distribution by gender. Adapted from Gosho et al. (1984).

Female and immature animals stay in Atlantic temperate or tropical waters year round. In the western North Atlantic, concentrations of female/immature groups are found in the Caribbean Sea (Gosho et al., 1984) and south of New England in continental-slope and deep-ocean waters along the eastern United States (Blaylock et al., 1995). In eastern Atlantic waters, female/immature groups aggregate in waters off the Azores, Madeira, Canary, and Cape Verde Islands (Fig. 7) (Tomilin, 1967). Mature male sperm whales have been recorded as far north as Spitsbergen (Fig. 18) (Øien, 1990). All recent sightings and strandings from the eastern North Atlantic suggest a predominance of solitary and paired mature male sperm whales in waters off Iceland, the Faroe Islands, and the Norwegian Sea (Gunnlaugsson and Sigurjónsson, 1990; Øien,1990; Christensen et al., 1992a). Nine southern cephalopod species (known only from south of lat. 45°N) have been found in stomachs of male sperm whales killed off the coast of Iceland (Martin and Clarke, 1986). This suggests that these male whales are feeding in low latitudes of the North Atlantic before traveling to high latitudes. In the western North Atlantic, the Scotian Shelf's Gully and Shortland Canyon regions are frequented by male sperm whales during

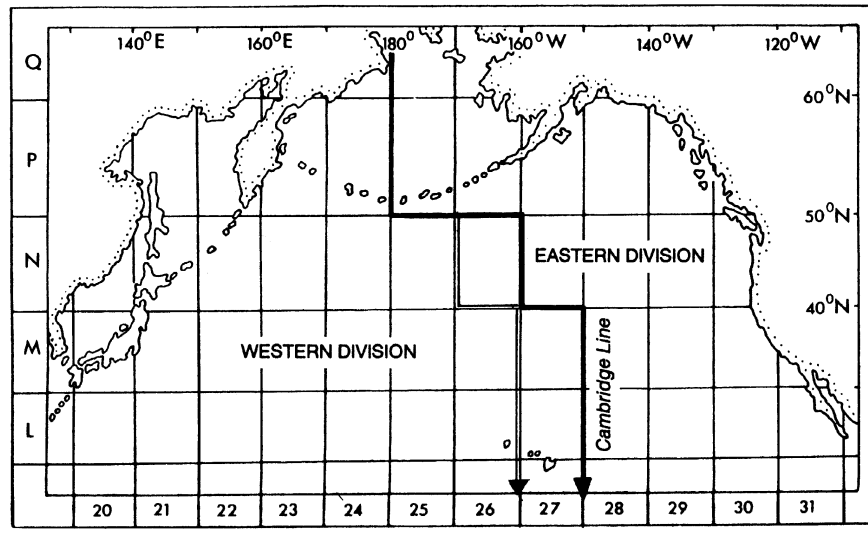

Figure 36.—The "Cambridge Line"; North Pacific sperm whale stock boundary recognized by the IWC (Donovan, 1991).

summer (Whitehead et al., 1992; Mullins et al.[90]).

Schmidly (1981), Fritts[91], and Hansen et al.[92] suggested that there is a distinct stock of sperm whales in the northern Gulf of Mexico. The NMFS recognizes these Gulf of Mexico sperm whales as one distinct stock (Waring et al., 1998). However, these whales are currently recognized as part of the entire North Atlantic stock by the IWC (IWC, 1980c).

In U.S. waters of the Atlantic Ocean, sperm whales occur over the continental shelf edge (CeTAP[70]) and well into the continental slope and mid ocean regions during all seasons (Waring et al., 1998). The NMFS has recognized these western North Atlantic whales as one stock (Waring et al., 1998). There is seasonal variability in the latitudinal distribution of sperm whale concentrations in this area. In winter, concentrations exist east and northeast of Cape Hatteras (Fig. 6), and as spring approaches, these concentrations shift northward to waters off Delaware, Maryland, and Virginia, across the central portion of the Mid Atlantic Bight, and into southern Georges Bank. Throughout summer these concentrations are distributed as in the spring, but also include areas east and north of Georges Bank, the Northeast Channel, and the continental shelf south of New England. In fall, the highest concentrations occur over the continental shelf south of New England with some groups found in the Mid Atlantic Bight (Winn et al., 1987; Waring et al., 1998). Waring et al. (1993) reported significantly more sperm whales in areas where warm core rings of the Gulf Stream interact with continental shelf-edge bathymetric features than where either the warm core ring or the shelf-edge exists alone. This suggests that the interaction of variables such as sea surface temperature (SST), bottom topography, and associated primary productivity are all important to sperm whale distribution in the Atlantic Ocean.

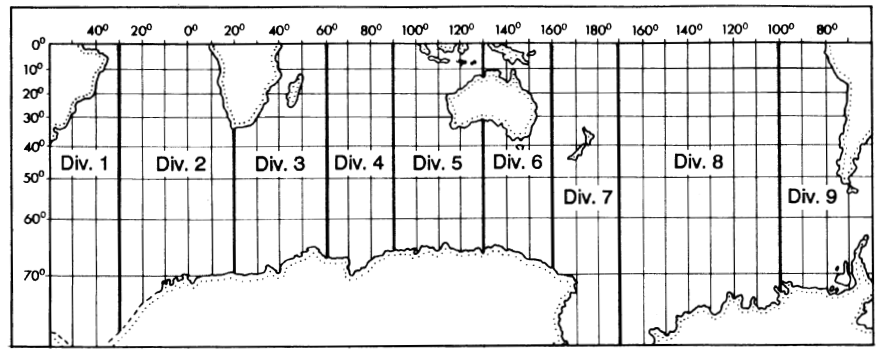

Figure 37.—IWC Southern Hemisphere stock "Division" designations for sperm whales (Donovan, 1991).

Northern Indian Ocean

There is no biological evidence to suggest genetic interchange between sperm whales in the northern Indian Ocean and sperm whales south of the Equator. This has led the IWC's Scientific Committee to assign separate stock identity to Northern and Southern Hemisphere populations in the Indian Ocean (IWC, 1995b). Little is known of the northern Indian Ocean sperm whale; however, distinct concentrations of whales have been documented off the coast of Somalia and in Sri Lanka's Gulf of Mannar (Fig. 12, 14) (James and Soundararajan, 1979; Gordon, 1991; Eyre, 1995). These concentrations are usually females and immature whales, male sightings being rare in the northern Indian Ocean (Gordon, 1991). Stranding reports are uncommon along the Indian coast for all whale species; the five sperm whale strandings reported between 1748 and 1980, were all males (James and Soundararajan, 1979).

Southern Hemisphere

For the purposes of worldwide population assessment and management, the IWC recognizes the area south of the Equator as one biogeographical region, the Southern Hemisphere. The Commission has divided this circumpolar region into nine sperm whale "Divisions" (Fig. 37). Donovan (1991) noted that these divisions are based more on manipulating available data from commercial whaling than on actual biological information. They are:

Division 1	Western Atlantic (long. 60°W–30°W),
Division 2	Eastern Atlantic (long. 30°W–20°E),
Division 3	Western Indian (long. 20°E–60°E),
Division 4	Central Indian (long. 60°E–90°E),
Division 5	Eastern Indian (long. 90°E–130°E),
Division 6	Eastern Australia (long. 130°E–160°E),
Division 7	New Zealand (long. 160°E–170°W),
Division 8	Central Pacific (long. 170°W–100°W), and
Division 9	Eastern Pacific (long. 100°W–60°W).

Male sperm whales are widely dispersed along the Antarctic ice edge from December to March (austral summer) (Gosho et al., 1984). In contrast, mixed groups of females and immature whales have a southern limit in the South Atlantic of lat. 50–54°S (Gosho et al., 1984; Tynan, 1998).

The Indian Ocean Sanctuary was created in 1979, under Article v(1)(c) of the ICRW, and all commercial whaling was prohibited within its boundaries. This boundary extends from the Antarctic continent to lat. 55°S and from long. 20°E to long. 130°E. In the western In-

[90] Mullins, J., H. Whitehead, and L. S. Weilgart. In press. Behaviour and vocalizations of two single sperm whales, *Physeter macrocephalus*, off Nova Scotia, 15 p. Can. J. Fish. Aquat. Sci.

[91] Fritts, T. H. 1983. Turtles, birds, and mammals in the northern Gulf of Mexico and nearby Atlantic waters. Rep. prep. for U.S. Dep. Inter., FWS/OBS-82/65, 455 p.

[92] Hansen, L. J., K. D. Mullin, and C. L. Roden. 1995. Estimates of cetacean abundance in the northern Gulf of Mexico from vessel surveys. Contrib. MIA-94/95-25, NMFS Southeast Fisheries Science Center, Miami, Fla., 9 p.

dian Ocean (Division 3), there is evidence that concentrations of mixed female/immature whale groups exist south of the Seychelles (Fig. 12) (James and Soundararajan, 1979; Kasuya and Wada, 1991; Kahn et al., 1993; Eyre, 1995). In the central Indian Ocean (Division 4), concentrations of sperm whales have been recorded to the north of St. Paul and Amsterdam Islands in the austral summer (Fig. 14) (Gosho et al., 1984).

Rice (1977b), Wade and Gerrodette (1993), and Dufault and Whitehead (1995) suggested that a separate equatorial Pacific sperm whale population exists. Photo-identification studies off the Galapagos Islands and mainland Ecuador and North Peru indicate that there may also be a geographical separation between Galapagos and Ecuador/North Peru whales, although their genetic discreteness has yet to be verified (Fig. 13) (Dufault and Whitehead, 1995).

Current and Historical Abundance

North Pacific

All current abundance estimates for the number of sperm whales in the entire North Pacific are considered unreliable. As a result, caution should be used when interpreting published estimates. Rice (1989) estimated 930,000 (no CV) sperm whales in the North Pacific Ocean. Gosho et al. (1984) estimated a total North Pacific population of 472,100 (no CV). Both of these estimates are statistically unreliable because they are based primarily on CPUE[22] data collected during whaling operations and do not take into account any possible decline in abundance that occurred after whaling ceased (IWC, 1988).

Barlow (1994a) provided a current sperm whale abundance estimate for U.S. waters off central California of 756 individuals (CV = 0.49, 95% C.I. 303–1,886). Limited trend data from 1979 to 1991 showed a relatively stable abundance of sperm whales in California coastal waters (Barlow, 1994b). Preliminary results from the winter of 1997 SWAPS survey indicated that the estimate of 756 whales may have actually been an overestimate (Taylor[88]). Using line transect data from 1991 to 1993 and 1996 ship-based surveys off California, Oregon, and Washington, Barlow[74] estimated a weighted average of 1,191 (CV = 0.22) and a minimum population estimate (N_{min}) of 995 sperm whales for those years.

From a ship-based line transect survey in the eastern tropical Pacific between lat. 10°N and 10°S, Wade and Gerrodette (1993) provided a sperm whale abundance estimate of 22,700 (CV = 0.22, 95% C.I. 14,800–34,600); although, as noted earlier, this estimate of abundance may include animals from more than one stock. No current abundance estimates are available for the entire western North Pacific.

Historical abundance estimates for the western and eastern North Pacific stocks are provided in Table 4. An abundance estimate of 620,400 animals was calculated for the entire North Pacific in 1910 (Gosho et al., 1984), although this estimate is no longer considered reliable by the IWC Scientific Committee.

North Atlantic

Based on historical whaling records and CPUE[22] data from modern whaling operations, there are an estimated 190,000 (no CV) sperm whales inhabiting the entire North Atlantic (Odell, 1992). However, this estimate is considered unreliable by the IWC's Scientific Commitee (IWC, 1988).

Recent regional abundance estimates have been calculated for both the western and eastern North Atlantic (Table 17). These numbers, from ship-based and aerial surveys conducted over several seasons, are much smaller than those summarized by Gosho et al. (1984). The small sample sizes, limited coverage, and probable undercounting of whales in the areas result in statistical biases within these estimates (Barlow and Sexton[93]).

Historical abundance estimates for Icelandic, Azorean, and Spanish North Atlantic stocks are provided in Table 4. An initial abundance estimate of 224,800 animals was calculated for all North Atlantic stocks in 1905 (Gosho et al., 1984), although this estimate is no longer considered reliable by the IWC Scientific Committee.

Northern Indian Ocean

There are no current population abundance estimates available for the northern half of the Indian Ocean.

Southern Hemisphere

The current estimate of 299,400 (no CV) sperm whales from the Equator to lat. 70°S dates from 1977 and is statistically unreliable (IWC, 1988). This estimate was calculated on the basis of historical whaling records and CPUE[22] data from whaling operations (Odell, 1992).

Utilizing JSV and IWC/IDCR survey data, Butterworth et al.[47] estimated sperm whale abundances south of lat. 60°S (3,200–14,000; CV = 0.39–0.19) and south of lat. 30°S (128,000–290,000;

Table 17.—Recent abundance estimates for North Atlantic sperm whales.

Area	Population estimate	Coefficient of variation	Source[1]
Western North Atlantic			
U.S. EEZ[2] (1991)	337	0.50	Blaylock et al., 1995
Summer 1995	2,698	0.67	Waring et al., 1998
Spring and summer 1982	219	0.36	CeTAP[70]
Northern Gulf of Mexico			
Spring and summer 1991–94	530	0.31	Hansen et al.[92]
Eastern North Atlantic			
Iceland	1,234	0.17	Gunnlaugsson and Sigurjonsson, 1990
Faroe Islands	308	0.38	Gunnlaugsson and Sigurjonsson, 1990
Norwegian Sea	5,231	0.31	Christensen et al., 1992a
Northern Norway to Spitsbergen	2,548	0.27	Øien, 1990

[1] Source footnote numbers refer to text footnote numbers.

[2] U.S. EEZ = United States Exclusive Economic Zone (200 n.mi from nearest land).

[93] Barlow, J., and S. Sexton. 1996. The effect of diving and searching behavior on the probability of detecting track-line groups, g_0, of long-diving whales during line-transect surveys. NMFS Southwest Fisheries Science Center, La Jolla, Calif., Admin Rep. LJ-96-14.

CV = 0.44–0.46), respectively (Table 18). Given the Antarctic latitudes surveyed, these numbers most likely represent a large proportion of male whales.

In South Pacific waters, Childerhouse et al. (1995) determined, using photo-identification and an "open" mark-recapture model, that between 60 and 180 (no CV) male sperm whales occur off Kaikoura, New Zealand (Division 7), each winter. In the equatorial Pacific, the total population of sperm whales between the Galapagos and Ecuador and North Peru was estimated at 3,891 (95% C.I. 2,600–5,300) (Whitehead et al., 1992).

Historical abundance estimates for the nine Southern Hemisphere divisions are provided in Table 19. An abundance estimate for the year 1946 of 547,600 sperm whales (no CV) for the entire Southern Hemisphere was calculated from these division-based estimates. All of these estimates are statistically unreliable due to their use of historical whaling catch data and CPUE[22] from whaling operations. It is important to note that sperm whale catches from the early 19th century through the early 20th century were calculated on barrels of oil produced per whale rather than the actual number of whales caught. Extrapolation from these types of data has led to only rough estimates of the number of whales killed per year (Gosho et al., 1984). In addition, newly revealed Soviet whaling catch data from Southern Hemisphere factory ships indicate considerable underreporting of sperm whale catches (Zemsky et al., 1995; Zemsky et al., 1996). According to these "new" catch data, approximately 14,700 harvested sperm whales went unreported in the original Soviet catch data between 1947 and 1987. As more of these Soviet data are made available, catch-based population estimates will need to be revised.

Table 18.—Ship-based line transect abundance estimates of Antarctic circumpolar sperm whales (Butterworth et al., text footnote 47).

Area by year	Population estimates	CV
South of lat. 60°S		
1978/79–1983/84	3,200	0.39
1985/86–1990/91	14,000	0.19
South of lat. 30°S		
1965/66–1977/78	290,000[1]	0.46
1978/79–1987/88	128,000[1]	0.44

[1] Extrapolated from Japanese Survey Vessel (JSV) data (Jan.–Feb. only).

Table 19.—Estimated historical abundance of sperm whales in the Southern Hemisphere for the year 1946 (Gosho et al., 1984) based on 1978 and 1980 IWC catch data.

IWC stock division	Population estimate
1	32,700
2	72,100
3	80,700
4	49,700
5	49,600
6	29,800
7	42,000
8	96,200
9	94,800
Total	547,600

Historic Exploitation Patterns

North Pacific

Large-scale pelagic whaling in the North Pacific Ocean ceased in 1980, but U.S. fleets found few whales and therefore had stopped whaling by 1979 (Tønnessen and Johnsen, 1982). In 1988, the IWC banned the killing of sperm whales. Table 20 summarizes current estimates of sperm whale catches from the North Pacific stocks by whaling operations from 1911 to 1987[94]. It must be noted that these numbers, especially those from Japanese whaling operations, may lead to underestimation of historic abundance due to underreporting to the IWC (Kasuya and Miyashita, 1988). The total estimated post World War II take from the entire North Pacific is 258,000 animals. Not specifically indicated in Table 20, but of significance to North Pacific stocks, are the number of whales (mostly males) taken from the Bering Sea (Fig. 38). Although there were no estimates of whales caught in this region, a significant decline in CPUE[22] north of lat. 50°N led Kasuya (1991) to conclude that the Bering Sea sperm whale population had been greatly depleted.

[94] Based on barrels of oil produced per whale.

North Atlantic

In the North Atlantic, the hunting of sperm whales occurred off the west coast of Iceland, Norway (coastal and pelagic), the Faeroe Islands, Britain (coastal), West Greenland, Nova Scotia, Newfoundland/Labrador, New England, the Azores, Madeira, Spain, and Spanish Morocco (Waring et al., 1998) (Fig. 6, 7). Some whales were taken off the U.S. Mid Atlantic coast, although the number of whales actually caught is unclear in the literature (Townsend, 1935; Reeves and Mitchell, 1988). Commercial whaling operations for sperm whales were also conducted in the northern Gulf of Mexico during the late 1700's to the early 1900's (Townsend, 1935). There are no catch estimates available for the number of sperm whales caught during the U.S. operations. The numbers caught in Norway and off Canada are summarized in Table 20.

Southern Hemisphere

The average annual catch of sperm whales in the Southern Hemisphere from 1956 to 1976 was over 20,000 whales. Gosho et al. (1984) provided summaries of those and worldwide sperm whale catch levels.

Current Exploitation

IWC worldwide catch limits (quotas) for all sperm whale stocks are currently set at zero (IWC, 1995b). As a result of

Table 20.—Recorded sperm whale catch numbers from North Pacific and North Atlantic whaling operations.

Area	Years	No. of animals	Source
North Pacific			
Western North Pacific (Kurils, Hokkaido, Sanriku, central & south Japan)	1911–45	19,989	Kasuya, 1991
Eastern North Pacific	pre-WWII	3,699	Kasuya, 1991
Total from Japanese operations	1955–86	62,033	Kasuya and Miyashita, 1988
Total North Pacific	1947–87	258,000	Barlow et al., 1995b
North Atlantic			
Western Norway	1925–69	374	Christensen et al., 1992a
Western Norway	1948–71	1,088	Christensen et al., 1992a
Newfoundland/Labrador	1904–72	424	Blaylock et al., 1995
Nova Scotia	1964–72	109	Blaylock et al., 1995

Figure 38.—Three sperm whales on a flensing platform in Alaska. The right animal's spermaceti organ has been removed. University of Washington Special Collections, Lagen Collection, negative UW17505.

this prohibition on whaling, the number of reported sperm whale kills for either commercial or aboriginal harvest has been zero in recent years (IWC, 1995a). The only known subsistence harvest of sperm whales occurs in Lomlem, Indonesia, where a few whales are taken per year using primitive methods (Barnes, 1991). Today the threat of commercial overharvest is greatly reduced compared to the potentially more long-term threats of habitat degradation, marine pollution, human exploitation of potential prey, and commercial fisheries interactions.

Life History and Ecology

Feeding

In general, the sperm whale's primary prey consists of larger mesopelagic cephalopod and fish species, including the giant squid, *Architeuthis* sp. Approximately 40 species of cephalopods are consumed by sperm whales worldwide. In the North Pacific, the four most common prey items of sperm whales off central California are all cephalopod species (i.e. *Moroteuthis*, *Gonatopsis*, *Histioteuthis*, and *Galiteuthis*) (Fiscus et al., 1989). In the Indian Ocean, the cephalopod species most commonly eaten by sperm whales are of the Histioteuthid family (Gordon, 1991). Sperm

Figure 39.—Showing its square-shaped head, a sperm whale breaches in the distance. S. Leatherwood, NMML Collection.

whales in the high latitudes of the North Atlantic (i.e. Norwegian Sea and Iceland) feed on deep-dwelling fish species of the genus *Cyclopterus* (lumpsuckers) and *Sebastes* (redfishes). Fish prey comprises almost half of the total biomass eaten by sperm whales in this region, while the other half is comprised of cephalopods (Martin and Clarke, 1986; Christensen et al., 1992b).

Reproduction

One of the most recognizable features of sperm whale social structure is the "nursery school" that contains between 20 and 30 individuals, including females, calves, and juveniles (Whitehead and Arnbom, 1987; Whitehead, 1996; Richard et al., 1996). At around 6 years of age, juvenile males (and possibly females) leave these nursery schools to form juvenile or bachelor schools (Richard et al., 1996). Juvenile schools contain individuals between 4 and 20 years of age and are less cohesive and smaller than the nursery schools (Whitehead and Arnbom, 1987). By the time males reach 30 years of age, they are mostly solitary.

Breeding among sperm whales takes place in spring and early summer in both hemispheres (from April to August in the Northern Hemisphere and from October to February in the Southern Hemisphere). Pairings take place in the lower latitudes, where males join nursery schools for days at a time. However, photo-identification studies suggest that not all males breed each year (Martin, 1980; Whitehead and Arnbom, 1987).

Females reach sexual maturity at 9 years of age and a length of approximately 9 m. The calving interval is one of the longest for mammals, between 4.8 and 6 years (Kasuya, 1991). Gestation lasts from 14 to 16 months, and lactation is between 1 and 2 years (Kasuya, 1991). Males reach sexual maturity at 20 years of age and a length of 12 m. At around 30 years of age, males reach "social" maturity and begin living the previously mentioned solitary life.

Pregnancy rates vary between exploited and unexploited stocks. Exploitation of sperm whale stocks may have caused a density-dependent response, which increased the average pregnancy rate of 20% in unexploited populations to 25% in exploited populations (IWC, 1980c).

Natural Mortality

Serological studies on North Pacific and North Atlantic sperm whales indicate that these whales are carriers of and are infected by calciviruses and papillomavirus (Smith and Latham, 1978; Lambertsen et al., 1987). For example, there was evidence of papillomavirus-associated disease in 10% of a population sample taken from Iceland (Lambertsen et al., 1987).

Killer whales, false killer whales, *Pseudorca crassidens;* and short-finned pilot whales, *Globicephala melana,* have all been observed in what appears to be harassment of sperm whale groups (Arnbom et al., 1987; Palacios and Mate, 1996; Weller et al., 1996). Sperm whale defensive maneuvers in these interactions seem to be based on protection of the youngest and most vulnerable of the group (Nishiwaki, 1962; Weller et al., 1996). Bleeding wounds have been observed on sperm whale heads and tail flukes after such events (Arnbom et al., 1987; Dufault and Whitehead, 1995). The most recent documented incident of killer whales attacking sperm whales occurred off Point Conception, Calif., in October 1997 (Roberts[95]). During the attack, approximately 25 killer whales mortally wounded at least one of nine sperm whales. The incident was unusual because it apparently involved only large, mature sperm whales. The attacked whales showed no defensive actions except in protecting injured members of their pod.

Estimated natural mortality rates for sperm whales are age-specific. Juveniles (age 0–2) have an estimated annual mortality of 0.09, while mature (age 2 and above) whales have an estimated annual mortality of 0.05 (IWC, 1971). Because of the lack of information on the causes of natural mortality in sperm whales, these rates are no longer considered statistically reliable by the IWC (IWC, 1980c).

[95] Roberts, K. 1998. NOAA Corps Officer, Pacific Marine Environmental Laboratory-EDD, 7600 Sand Point Way, N.E., Seattle, WA 98115. Personal commun.

Human-related Mortality

Fisheries Interactions

In U.S. waters of the Pacific, incidental take of sperm whales has been documented in drift gillnet operations. The average annual rate of mortality and serious injury from the offshore California drift gillnet fishery from 1991 to 1995 is nine sperm whales (Barlow et al., 1997). Observers aboard Alaska sablefish, *Anoplopoma fimbria*; and Pacific halibut, *Hippoglossus stenolepis*, longline vessels have documented sperm whales feeding on longline-caught fish in the Gulf of Alaska (Hill and Mitchell[96]). In 1997, the first entanglement of a sperm whale in Alaska's longline fishery was recorded, although the whale was not seriously injured (Hill and DeMaster[97]). There is no evidence that mortality or serious injury occurs as a result of interactions with this fishery; however, the nature and extent of these longline fishery-sperm whale interactions is not yet clear.

The first observed incidental take of a sperm whale in U.S. waters of the North Atlantic was in 1989 in a drift gillnet. The estimated fishery-related mortality and serious injury rate was 2.2 sperm whales in 1989, 4.4 in 1990, and zero from 1991 to 1996 (Waring et al., 1998), although in 1995 one sperm whale was observed entangled in a pelagic drift gillnet. This entangled whale was released alive, although gear remained wrapped around several body parts. Waring et al. (1998) describe three known instances of sperm whale entanglements in the northwest Atlantic; two in net gear and one in longline gear.

There is little information available regarding fishery interactions with sperm whales outside U.S. waters. However, behavior similar to that observed in the Alaska longline fishery has also been documented during longline operations off South America (South Georgia, Kerguelen, and southern

[96] Hill, P. S., and E. Mitchell. 1998. Sperm whale interactions with longline vessels in Alaska waters during 1997. Unpubl. rep. presented at 6th Pacific Scientific Review Group Meeting, March 30, 1998, Honolulu, Hawaii. Avail. from National Marine Mammal Laboratory, 7600 Sand Point Way, N.E., Seattle, WA 98115.

[97] Citation updated in proof: see Hill and DeMaster, 1999 in literature cited.

Table 21.—Factors possibly influencing the recovery of sperm whale stocks under the ESA (1973) §4(a)(1)1992 Amend.

Factor	North Pacific	North Atlantic	Gulf of Mexico	Indian Ocean	Southern Hemisphere
1. Present or threatened destruction or modification of habitat	Pollution	Pollution (e.g. plastics, heavy metals)	Oil and gas development (e.g. noise disturbance, oil spills)	Pollution	Pollution
2. Overutilization for commercial, recreational, scientific, or educational purposes	Unknown	Whale watching and associated vessel traffic	Scientific research and associated vessel traffic	Unknown	Whale watching, scientific research, photography, and associated vessel traffic
3. Disease or predation	Papilloma and calcivirus; *Orcinus* attacks	Papilloma and calcivirus	Papilloma and calcivirus; *Orcinus*, *Pseudorca*, and *Globicephala* attacks	Papilloma and calcivirus	*Orcinus* and *Pseudorca* attacks
4. Other natural or man-made factors	Entanglement in fishing gear (e.g. longline, drift gillnets)	Entanglement in fishing gear (e.g. drift gillnets)	Unknown	Unknown	Entanglement in fishing gear (e.g. longline)

Chile) where sperm whales have become entangled in longline gear, have been observed feeding on fish caught in the gear, and have been reported following longline vessels for days (CCAMLR, 1994; Ashford et al., 1996; Capdeville, 1997). These observations, combined with anecdotal reports suggest that interactions between sperm whales and longline operations may be widespread in the waters off South America (Hill and Mitchell[96]).

Noise Disturbance

In recent years, many studies on the effect of noise on the behavior of whales have been done (Richardson et al., 1995). A resident population of sperm whales occurs in the northern Gulf of Mexico, an area of intensive oil and gas exploration and development activities. Oil production platforms and their associated vessels have unknown effects on sperm whales (Odell, 1992). Studies of whale reactions to seismic surveys in the Gulf of Mexico indicated that sperm whales reacted to seismic pulses by moving away 50 km or more (Mate et al., 1994). In the southern Indian Ocean, most sperm whales stopped vocalizing when exposed to seismic pulses as much as 300 km away (Bowles et al., 1994). Sperm whales have also been observed exhibiting startle responses to a closely approaching vessel (Whitehead et al., 1990). Observed reactions of sperm whales in the presence of vessels include more erratic surface movements, reduced surface time, fewer blows per surfacing, shorter intervals between successive blows, and increased frequency of dives without raised flukes (Cawthorn, 1992; Gordon et al., 1992). It is unknown whether anthropogenic noise has biological significance for sperm whales.

Pollution

Relatively high mercury levels have been found in breeding females captured off southern Australia. It is unclear whether these mercury levels affect the whale's health (Cannella and Kitchener, 1992). Plastic debris is probably ingested quite frequently by sperm whales at sea. For example, a 15 m male sperm whale captured in nearshore waters off Iceland had a 3-gal plastic bucket lodged in his intestinal tract (Lambertsen and Kohn, 1987).

Classification Status

The sperm whale was listed as endangered under the ESA in 1973 and is protected under the MMPA. Endangered status is applied to all sperm whale stocks utilizing U.S. waters (Anonymous, 1994b). The western North Pacific stock is the only sperm whale stock designated as a "Protected Stock" by the IWC. Under this designation, the IWC recognizes that these whales are 10% or more below their maximum sustainable yield (MSY) level, or 54% of carrying capacity (*K*) (IWC, 1995b). Although without trend data or information on status relative to *K* for this stock, the validity of this designation is questionable.

Since Braham's 1991 status review[3], there has been little new information to improve the accuracy of population estimates or stock identity. One of the major difficulties in identifying distinct sperm whale stocks is their heterogenous and widespread distribution, which is apparently gender- and age-related. Table 21 summarizes information on potential threats affecting the status of sperm whales. Therefore, any reevaluation of sperm whale classification status awaits the collection of more reliable information on distribution, migration patterns, abundance, and trends in abundance on a stock-specific basis, as well as the development of objective delisting criteria. Nonetheless, if the accuracy of abundance estimates and stock determinations for North Atlantic and North Pacific sperm whale populations can be made more reliable with additional survey data, and if human-related sources of mortality and serious injury remain low, some stocks might be candidates for downlisting.

Acknowledgments

Thanks to those who took the time to comment on earlier drafts (Willis Hobart, Jim Carretta, Kim Shelden, Leah Gerber, Paul Wade, Michael Payne, Dave Rugh, and Scott Hill) and to those who commented on later drafts (Phillip Clapham, Jay Barlow, Robert Brownell, Kevin Chu, Katherine Wang, and Jeffrey Breiwick). Thanks also go to Kristin Laidre for her attention to detail and map-making skills. And, many thanks to Pieter Folkens for permission to use his illustrations. This manuscript was supported in part by the NMFS National Marine Mammal Laboratory (Contracts 40ABNF80 0705, 40ABNF701925, and 43ABNF 701085) and through ESA/MMPA funds from the NMFS Office of Protected Resources.

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