DRAFT

RECOVERY PLAN FOR THE SPERM WHALE

(*PHYSETER MACROCEPHALUS*)

Office of Protected Resources
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
Silver Spring, Maryland

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PREFACE

Congress passed the Endangered Species Act of 1973 (16 USC 1531 et seq) (ESA) to protect species of plants and animals endangered or threatened with extinction. NMFS and the U.S. Fish and Wildlife Service share responsibility for the administration of the Act. NMFS is responsible for most marine mammals including the sperm whale. This Plan was prepared at the request of the Assistant Administrator for Fisheries to promote the conservation of sperm whales.

The goals and objectives of the Plan can be achieved only if a long-term commitment is made to support the actions recommended here. Achievement of these goals and objectives will require the continued cooperation of the governments of the United States and other nations. Within the United States, the shared resources and cooperative involvement of federal, state, and local governments, industry, academia, non-governmental organizations, and individuals will be required throughout the recovery period.

DISCLAIMER

Recovery Plans identify reasonable actions that the best available science indicates are required to recover and/or protect listed species. Plans are prepared by the NOAA's National Marine Fisheries Service, sometimes with the assistance of recovery teams, contractors, state agencies, and others. This plan was originally prepared by Randall R. Reeves and Gregory K. Silber for the National Marine Fisheries Service. Objectives will be attained and any necessary funds made available subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities or existing authorities. Nothing in this plan should be construed as a commitment or requirement that any federal agency obligate or pay funds in contravention of the Anti-Deficiency Act, 31 U.S.C. 1341, or any other law or regulation. Recovery plans do not necessarily represent the view or the official positions or approvals of any individuals or agencies involved in the plan formulation, other than those of the National Marine Fisheries Service. They represent the view of the National Marine Fisheries Service only after they have been approved by the Assistant Administrator for Fisheries. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery actions.

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http://www.nmfs.noaa.gov/pr/recovery/plans.htm

Cover photograph by Shannon Rankin (SWFSC) shows Southwest Fisheries Science Center Researchers approaching a sperm whale for biopsy and identification photos (authorized under a Marine Mammal Protection Act permit).

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EXECUTIVE SUMMARY

Current Species Status: Sperm whales, Physeter macrocephalus, are currently listed as "endangered" under the Endangered Species Act (ESA). Sperm whales were subject to commercial whaling for more than two and a half centuries and in all parts the world. Sperm whale harvest was essentially unregulated until 1970, when quotas were introduced in the North Pacific Ocean; in 1971 quotas were introduced in the Southern Ocean. The International Whaling Commission (IWC) accorded sperm whales complete protection from commercial whaling by member states beginning with the 1981/82 pelagic season and subsequently with the 1986 coastal season (IWC 1982). Currently, Japan takes a small number of sperm whales each year under an exemption for scientific research. Norway and Iceland have formally objected to the IWC ban on commercial whaling and are therefore free to resume whaling of sperm whales under IWC rules, but neither country has expressed an interest in taking sperm whales.

The impacts of whaling and the complex social structure and reproductive behavior of sperm whales have confounded assessments of population status and structure. In addition, historical catch records are sparse or nonexistent in some areas of the world and over long periods of time, and gross under-reporting or mis-reporting of modern catch data has taken place on a large scale. The wide-ranging, generally offshore distribution of sperm whales, and their long submergence times, complicate efforts to estimate abundance. Although the aggregate abundance worldwide is probably at least several hundred thousand individuals, the extent of depletion and degree of recovery of populations are uncertain.

Currently, the population structure of sperm whales has not been adequately defined. Most models have assigned arbitrary boundaries, often based on patterns of historic whaling activity and catch reports, rather than on biological evidence. This Recovery Plan is organized, for convenience, by ocean basin. Thus, sperm whales are discussed in three sections, those in the North Atlantic Ocean, including the Caribbean Sea and Gulf of Mexico, those in the North Pacific Ocean and its adjoining seas and gulfs, and those in the Southern Hemisphere. Clearly, an improved understanding of the genetic differences among and between populations is a major information need for the determination of distinct population units.

Habitat Requirements and Limiting Factors: There is always the possibility of illegal whaling or a resumption of legal commercial whaling for sperm whales. In addition, sperm whales are susceptible to entanglement in fishing gear (including "ghost nets") and collisions with ships. Their demonstrated responsiveness to loud, unfamiliar underwater sounds makes it likely that they are adversely affected, at least transiently, by anthropogenic noise in the marine environment. Also, levels of some contaminants in sperm whale tissue (e.g., mercury, cadmium, and organochlorine compounds) are high enough to raise concerns about toxicity and reproductive impairment.

Recovery Strategy: This plan identifies measures that need to be taken to ensure the recovery of sperm whales in the North Atlantic, North Pacific, and Southern Hemisphere oceans. The key features of the proposed recovery program for the sperm whale are to: (1) coordinate state, federal, and international actions to implement recovery efforts; (2) determine population discreteness and stock structure; (3) develop and apply methods to estimate population size and monitor trends in abundance; (4) identify and protect habitat essential to sperm whale survival and recovery; (5) identify causes and minimize human-caused injury and mortality; (6) determine and minimize any detrimental effects of anthropogenic noise in the oceans; (7) maximize efforts to acquire scientific information from dead, stranded, and entangled or entrapped sperm whales; and (8) develop a post-delisting monitoring plan.

Recovery Goals and Criteria: The goal of this Plan is to promote recovery of sperm whales to the point at which it becomes appropriate to downlist them from endangered to threatened status, and ultimately to remove them from the list of Endangered and Threatened Wildlife and Plants, under the provisions of the ESA.

Downlisting Criteria

Sperm whales may be considered for delisting when the following criteria are met:

1a. The overall population in each ocean basin (Atlantic, Pacific, and Indian Oceans) has remained stable or increased for at least 40 years (1.5 generations assuming 26.5 years/generation); or

1b. Given current and projected threats and environmental conditions, the overall sperm whale population in each ocean basin in which it occurs (Atlantic, Pacific, and Indian Ocean) satisfies the risk analysis standard for threatened status (has no more than a 1% chance of quasi-extinction in 100 years);

and

2. Factors that may limit population growth have been identified and are being or have been addressed to the extent that they allow for continued growth of populations. Specifically, the factors in 4(a)(1) of the ESA are being or have been addressed:

Factor A: The present or threatened destruction, modification or curtailment of a species' habitat or range.

- Fishing gear interactions have been identified and action is being taken to address problems, where necessary. Fishing gear interactions to be investigates include interactions with drift gillnet, longline, and any other gear determined to have an effect on sperm whale populations.
- Effects of reduced prey abundance are identified and action is being taken to address the issue, if necessary.
- Effects of vessel interactions (ship collisions, noise, pollution, disturbance) have been identified and actions are being or have been taken to address the issues, where necessary.

- Effects of anthropogenic noise have been investigated and actions taken to minimize potential effects.

Factor B: Overutilization for commercial, recreational or educational purposes.
- Directed human kills (commercial, subsistence and scientific) are being managed on a sustainable basis by the IWC.

Factor C: Disease or Predation.
- Disease and predation have been investigated and determined not to be appreciably affecting the recovery of the species.

Factor D: The inadequacy of existing regulatory mechanisms.
- The IWC is continuing to regulate directed take of whales on a sustainable basis.
- The ESA, MMPA and other applicable laws (e.g., other U.S. laws and laws of other nations that regulate take within their EEZ) are adequately regulating takes of whales through vessel collisions and fishing interactions.

Factor E: Other natural or manmade [sic] factors affecting its continued existence.
- Other natural or anthropogenic factors have been investigated and determined not to be limiting the recovery of the species.

Delisting Criteria

Sperm whales shall be considered for delisting when the following criteria are met:

1a. The overall population in each ocean basin (North Atlantic, North Pacific, and Southern Hemisphere Oceans) is determined to have been stable or increased for at least 80 years (3 generations); or

1b. Given current and projected threats and environmental conditions, the overall sperm whale population in each ocean basin in which it occurs (North Atlantic, North Pacific, and Southern Hemisphere Oceans) satisfies the risk analysis standard for unlisted status (has less than a 10% probability of becoming endangered in 20 years); and

2. Factors that may limit population growth have been identified and are being or have been addressed to the extent that they allow for continued growth of populations. Specifically, the factors in 4(a)(1) of the ESA are being or have been addressed:

Factor A: The present or threatened destruction, modification or curtailment of a species' habitat or range.
- Fishing gear interactions have been identified and actions taken to address the problems have been proven effective, in that they allow for continued growth of the population. Fishing gear interactions to be investigated include interactions with drift gillnet, longline, and any other gear determined to have an effect on sperm whale populations.
- Effects of reduced prey abundance have been identified, and actions taken to address

prey abundance are shown to be effective, i.e., reduced prey abundance is determined not to affect sperm whale populations.
- Effects of vessel interactions (ship collisions, noise, pollution, and disturbance) have been identified and actions being or having been taken to address the issues shown to be effective, i.e., have been determined not to have an effect on sperm whale populations.
- Effects of anthropogenic noise have been investigated and actions taken to minimize potential effects have proven effective, allowing for the continued growth of the population.

Factor B: Overutilization for commercial, recreational or educational purposes
- Whaling and subsistence take is managed on a sustainable basis by the IWC and directed take in U.S. waters is in accordance with the MMPA, i.e., managed for Optimum Sustainable Populations.

Factor C: Disease or Predation
- Disease and predation have been investigated and determined not to be appreciably affecting the recovery of the species.

Factor D: The inadequacy of existing regulatory mechanisms
- The IWC is continuing to regulate directed take of whales on a sustainable basis.
- The MMPA and other applicable laws (e.g., other U.S. laws and laws of other nations that regulate take within their EEZ) are adequately regulating takes of whales through vessel collisions and fishing interactions.

Factor E: Other natural or manmade [sic] factors affecting its continued existence.
- Other natural or anthropogenic factors have been investigated and determined not to be limiting to the recovery of the species.

Estimated cost of recovery efforts:

The cost of actions necessary to achieve recovery, as identified in the previous section, are estimated in the following table. (Estimates are in thousands of dollars.)

Year	Action 1	Action 2	Action 3	Action 4	Action 5	Action 6	Action 7	Action 8	Action 9	Total
N. Atl. (2012)	220	500	9,000	100	525	385	520	2,625	75	13,950
N. Pac. (2012)	220	500	13,500	100	525	385	520	2,625	75	18,450
S. Ocean (2026)	220	250	3,000	200	475	180	410			4,735
Totals	**660**	**1,250**	**25,500**	**400**	**1,525**	**950**	**1,450**	**5,250**	**150**	**37,135**

Date of Recovery: The exact date of recovery cannot be determined but will likely take decades. The effectiveness of many management activities are not known and currently it is impossible to predict when such measures will bring the species to a point at which the protections of the ESA are no longer warranted. As more information is obtained on the threats, their impacts on sperm whales, and how they can be effectively mitigated, more robust projections about the time to recovery, and its expense, will be developed. We can, however, estimate the minimum time it would take to meet the delisting criteria above if sperm whales were recovering at a conservative expected rate for a large toothed whale.

For criterion 1a) if we assume recovery at 3%/year and the precision achieved in coastal Pacific waters (coefficient of variation = 0.4), then approximately 40 years would be needed to detect the increase (assuming $\alpha = \beta = 0.1$). Downlisting criterion 1a) requires 80 years (3 generations). In both the North Pacific and North Atlantic there are approximately 20 years worth of data in hand. The only data in hand for the South Atlantic and South Pacific are from high latitude areas (containing only adult males) and an area in the eastern tropical Pacific. The only data available for the Indian Ocean originate from Japanese surveys of the southernmost portion to the south of 20 degrees South. Obtaining data that are suitable for criterion 1a) would therefore require a minimum of 80 additional years at which point trends and population structure should be documented. The date of recovery for sperm whales would therefore be 2086.

Criterion 1b) is likely to be reached in substantially less time. This criterion would require population structure work and ocean-basin wide surveys, which are estimated to take an additional 15 years from now (date of recovery of 2021). Were it possible to delineate ESA “species” within the North Atlantic and North Pacific, the timeframe would be much shorter (approximately 6 years) and approximate costs for these ocean basins assuming recovery has been occurring, would be $3 million dollars per ocean basin, with a minimum time to recovery in 6 years (2012) using criterion 1b). The substantial abundance of sperm whales combined with trend data are very likely to result in a probability of extinction much less than 1% in 100 years.

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I. BACKGROUND

A. Brief Overview

Sperm whales, Physeter macrocephalus, have been listed as “endangered” since 1970 (35 FR 8495, June 2, 1970), under the precursor to the Endangered Species Act (ESA) and remained on the list of threatened and endangered species after the passage of the ESA in 1973. Sperm whales are widely distributed throughout the world’s oceans. Although most populations were depleted by modern whaling, the sperm whale remains the most abundant of the large whale species. Commercial whaling for this species ended in 1988, with the implementation of a moratorium against whaling by the International Whaling Commission (IWC). Sperm whales are still being targeted in a few areas: there is a small catch by primitive methods in Lamalera, Indonesia, and Japan takes sperm whales for scientific purposes. There is also some evidence to suggest that sperm whales are being hunted illegally in some parts of the world, but the impact of this take is unknown. Currently, there is no good estimate for the total number of sperm whales worldwide. The best estimate is that there are between 200,000 and 1,500,000 sperm whales, based on extrapolations from only a few areas that have useful estimates. Status of populations throughout the world’s oceans, stated in terms of present population size relative to “initial” (pre-whaling or carrying capacity) level, is close to 18th and 19th century concentrations. However, a large area in the South Pacific appears to have a low density of sperm whales.

Although the main direct threat to sperm whales was addressed by the IWC whaling moratorium, several potential threats remain. Among the current potential threats are collisions with vessels, entanglement in fishing gear, reduced prey due to overfishing, habitat degradation, disturbance from high-frequency noise, and the possibility of illegal or resumed legal whaling at biologically unsustainable rates. The possible effects of pollution on sperm whales remain poorly understood. Although published evidence indicates that levels of mercury, cadmium, and certain organochlorines in sperm whale’s tissue were high enough to cause concern about toxicity, no clear link between contamination and strandings has been found. The sperm whale’s principle prey is large squid, but they will also eat large demersal and mesopelagic sharks, skates, and fishes. Thus, trends in fish populations, whether driven by fishery operations, human-caused environmental deterioration, or natural processes, may strongly affect the size and distribution of sperm whale populations.

B. Species Description and Taxonomy

The sperm whale (Physeter macrocephalus (Linnaeus, 1758)) is a truly cosmopolitan species, whose distribution is thought to be more extensive than that of any other marine mammal, except the killer whale (Orcinus orca) (Rice 1989). Male sperm whales can reach lengths of more than 18 meters (m), while females can reach lengths of up to 12.5 m. They can weigh up to 57 and 24 metric tons, respectively (Rice 1989).

The sperm whale has a disproportionately large head, one quarter to one third of its total body length (Rice 1989). Its rod-shaped lower jaw is narrow and underslung, with 20-26 pairs of well-developed teeth in the mandibles, but the maxillary teeth are vestigial. Its dorsal fin is low in profile, thick, and not pointed or recurved. Sperm whales are generally dark gray in color, with white lips and often white areas on the belly and flanks. Photographs of distinctive markings on the dorsal fins and flukes of sperm whales are used in studies of life history and behavior (Whitehead and Gordon 1986; Whitehead 1990).

There is a firm and long-standing scientific consensus that only one species of sperm whale exists. However, scientists have disputed the species' nomenclature and systematics. With regard to nomenclature, Schevill (1986, 1987) and Holthuis (1987) debated the relative merits of two Linnaean names for the sperm whale - catodon vs. macrocephalus. The higher-level taxonomy was subsequently reviewed extensively by Milinkovitch et al. (1993, 1994, 1995) and Milinkovitch (1995), who used molecular data to argue that sperm whales (family Physeteridae) are the sister group to baleen whales (sub-order Mysticeti), and therefore, the toothed whales (sub-order Odontoceti) are not monophyletic but rather comprise a paraphyletic group. Heyning's (1997) rebuttal of that hypothesis, using cladistic analysis, has gained wide acceptance among cetologists (Rice 1998).

From a U.S. perspective, sperm whales are managed under three constructs, all with different objectives and therefore, different resolutions of population structure: the MMPA, the IWC, and the ESA. Roughly, the MMPA protects marine mammal species with a goal of maintaining marine mammal populations stocks as a functioning element of their ecosystem, the IWC manages whales with a goal of maintaining healthy stocks while authorizing harvest to meet aboriginal needs, scientific research and related purposes, and the ESA seeks to avoid extinction and recover depleted species to a point at which they no longer need ESA protections. The level of population structure appropriate to meet the objectives of these three constructs is roughly hierarchical with the finest structure needed to meet MMPA goals, that level or larger to meet IWC goals, and the largest resolution to meet ESA goals (Taylor 2005). Both the MMPA and the IWC use the term "stocks" to refer to these units to conserve. We reserve the use of the term "stocks" in the context of MMPA or IWC stocks and instead use the more generic term "populations" in other contexts.

The stock concept has been the subject of much discussion among biologists and natural resource managers. A recent working definition of “stock” under the MMPA is a “demographically isolated biological population” (Wade and Angliss 1997) where internal dynamics (births and deaths) are far more important than external dynamics (immigration and emigration) to maintaining the population. The IWC continues to waver somewhere between two types of stock definitions: biological stocks based on genetic separation and management stocks referring to population units defined in functional terms of some kind (Donovan 1991). Although considerable effort has been expended to tighten the definition of stocks, current IWC practice continues to define on a case-by-case basis and only on stocks in need of current management. Thus, stock definition for areas with no aboriginal whaling or anticipated commercial whaling, as would be the case for sperm whales, has not been considered for decades.

C. Zoogeography

The distribution of sperm whales extends to all deep ice-free marine waters from the Equator to the edges of polar pack ice (Rice 1989). Sperm whales are present in many warm-water areas throughout the year, and such areas may have discrete "resident" populations (Watkins et al. 1985; Gordon et al. 1998, Drout 2003, Engelhaupt 2004, Jaquet et al. 2003). While their aggregate distribution is certainly influenced by the patchiness of global marine productivity (Jaquet and Whitehead 1996), no physical barriers, apart from land masses, appear to obstruct their dispersal (Berzin 1972; Jaquet 1996). Rice (1989) suggested that it was reasonable to expect some inter-basin movement around the Cape of Good Hope (Atlantic Ocean-Indian Ocean) and through the passages between the Lesser Sunda Islands or round the south coast of Tasmania (Indian Ocean-Pacific Ocean), but he considered exchange via Cape Horn (Pacific Ocean-Atlantic Ocean) to be "almost entirely restricted, except possibly for a few males."

A striking feature of the sperm whale's life history is the difference in migratory behavior between adult males and females. Only adult males move into high latitudes, while all age classes and both sexes range throughout tropical and temperate seas. At least some individuals are present year-round in the higher latitudes (Mellinger et al. 2004). A combination of factors, including wide dispersal by males, ontogenetic changes in association patterns, and female pod fidelity and cohesion complicates any evaluation of population structure. An initial examination of global matrilineal population structure suggests that interoceanic dispersal of female lineages is limited (Dillon 1996, Lyrholm and Gyllensten 1998). However, studies of allelic variation in nuclear markers are needed to reveal the extent to which male dispersal might cause genetic mixing between oceanic populations (Lyrholm et al. 1999, Bond 1999).

Intensive whaling may have fragmented the world population of sperm whales. While present-day concentration areas generally match those of the 18th and 19th centuries, at least one large area of the South Pacific (the "Offshore" and "On the Line" whaling grounds between the Galápagos and Marquesas) appears to have a relatively low density of sperm whales today (Jaquet and Whitehead 1996). Further research is needed to verify that the density is in fact low, and if it is, to determine the reason(s).

In this Plan we separate description of the data into three sections: North Atlantic, North Pacific, and Southern Oceans. This organization follows the way sperm whales have been treated by both IWC and MMPA management regimes and the way that data are often gathered. There is no biological reason, however, to use the equator as a boundary and well-known populations are found on both sides of this artifical line. It is recognized that our understanding of population structure for this nearly continuously distributed species, with complex social structure, remains poor and that further work is needed to identify units that are both discrete and significant to the survival of the species. Although sperm whales are found throughout the world's waters, only males penetrate to truly arctic waters and there are seasonal movements towards colder waters in the summer feeding seasons, by at least the males. Therefore, while no firm boundaries can be drawn, there is likely very limited movement between the Atlantic, the Pacific, and the Indian Ocean. The criteria in this plan, therefore, use these three large oceanic regions. The criteria for the global listing, therefore, mean that all three of these oceanic regions must meet the criteria and that careful consideration should be given to the meaning of "significant," as used in the phrase "significant portion of its range", in light of our poor understanding of population structure.

D. Life History-North Atlantic Population

D.1 Population Structure

Information regarding the broad movements of sperm whales has been collected from years of tagging studies and analyses of commercial whaling data. For instance, a tag that was shot into a male sperm whale off Nova Scotia in 1966, was recovered when the whale was killed off Spain in 1973 (Mitchell 1975). This observation provided direct evidence of movement by male sperm whales across the North Atlantic basin. Harpoons or harpoon fragments from the Azores were found in the bodies of whales killed off Iceland and Spain, indicating movement across large parts of the eastern North Atlantic as well (Martin 1982; Sigurjónsson 1985; Aguilar 1985). Tagging data have also shown that sperm whales make substantial latitudinal movements across the equator (Ivashin 1967).

In U.S. waters two management units are recognized: a western North Atlantic stock and a northern Gulf of Mexico stock (Waring et al. 2005). Two recent PhD. dissertations examined structure within the North Atlantic using genetic markers. Drout (2003) found mtDNA variation between samples collected in the Mediterranean and North Atlantic Ocean. Engelhaupt (2004) examined genetic variation among samples collected in the Gulf of Mexico, Mediterranean, North Sea, and North Atlantic Ocean using both mtDNA and nuclear genetic markers. Both studies found that all Mediterranean samples were represented by a single mtDNA haplotype and Englehaupt (2004) found two unique haplotypes in the Gulf of Mexico. Both studies found significant genetic subdivision between isolated ocean basins (the Gulf of Mexico and the Mediterranean) and the North Atlantic. It is important to recognize that further analyses of population structure of sperm whales in the North Atlantic have not been attempted, and any current designation of stocks or management units must be regarded as preliminary (Donovan 1991; Taylor and Dizon 1996).

D.2 Distribution and Habitat Use

Sperm whales inhabit the entire North Atlantic basin (Rice 1989). Two of the major 19th century whaling grounds for sperm whales, the Southern Ground and the Charleston Ground, are situated directly off the eastern United States (Townsend 1935). The northern Gulf of Mexico and the West Indies were also visited regularly by the sperm whalers.

In Mitchell's (1972) extensive cruises covering much of the western and central North Atlantic Ocean, he found the highest densities of sperm whales, by far, in the "North Sargasso Sea Region" (30-40°N, 50-70°W) and the "Gulf Stream Region" (two discrete offshore areas between 40°N and 50°N - one over the Grand Banks of Newfoundland and the other over the North Atlantic Ridge). This result is consistent with the observation by Townsend (1935) and Waring et al. (1993), that the Gulf Stream has an important influence on sperm whale distribution.

The sperm whale is the most common large cetacean in the northern Gulf of Mexico, where it occurs in greatest density along and seaward of the 1000 m contour (Mullin et al. 1991, 1994; Jefferson and Schiro 1997; Davis et al. 1998; Weller et al. 2000; Würsig et al. 2000; Mullin and Fulling 2004). They appear to prefer steep rather than shallow depth gradients (Davis et al. 1998). The spatial distribution of sperm whales within the Gulf is strongly correlated with mesoscale physical features such as loop current eddies that locally increase primary production and prey availability (Biggs et al. 2005). In the north-central Gulf, sperm whales are especially common near the Mississippi Canyon, where they are present year-round (Davis et al. 1998). Although they are not common near DeSoto Canyon to the east in the Gulf, their total range includes much of the wider Caribbean region (Townsend 1935; Watkins and Moore 1982). There has recently been extensive work on the movements and habitat use of sperm whales in the Northern Gulf of Mexico, by the Sperm Whale Seismic Study (SWSS). These studies include habitat cruises, physical oceanographic analysis, and long term satellite tag deployments. Several satellite tags have operated for over 12 months and indicate movements generally along the shelf break (700-1000 m depth) throughout the Gulf, with some animals using deeper oceanic waters. There has also been some evidence of large scale movements of individuals out of the Gulf of Mexico from satellite tag deployments. The ongoing SWSS studies continue to provide detailed information on the habitat preferences and population structure of Gulf of Mexico sperm whales (Jochens and Biggs 2004).

Off Nova Scotia, sperm whales were found by coastal whalers mainly in continental slope waters 50-1000 fathoms deep, especially in submarine canyons and around the edges of banks (Mitchell 1975). Similarly, the overall distribution along the U.S. east coast is centered along the shelf break and over the slope (CETAP 1982; Waring et al. 2005). Very high densities occur in inner slope waters north of Cape Hatteras, North Carolina seaward of the 1000-m isobath during summer months (Mullin and Fulling 2003; Southeast Fisheries Science Center unpublished data; Waring et al. 2005). Sperm whales are also known to move onto the continental shelf in waters less than 100 m deep on the southern Scotian Shelf and south of New England, particularly between late spring and autumn (Whitehead et al. 1992a,b; Waring et al. 1997; Scott and Sadove 1997).

D.3 Feeding and Prey Selection

Sperm whales are deep and prolonged divers and can therefore use the entire water column, even in very deep areas. However, they seem to forage mainly on or near the bottom, often ingesting stones, sand, sponges, and other non-food items (Rice 1989; Whitehead et al. 1992a,b). As far as is known, sperm whales feed regularly throughout the year. Lockyer (1981) estimated that they consumed about 3.0-3.5% of their body weight per day.

A large proportion of the sperm whale’s diet consists of low-fat, ammoniacal, luminescent squids (Clarke 1980, 1996; Martin and Clarke 1986). In some areas of the North Atlantic, however, males prey heavily on the oil-rich squid Gonatus fabricii, a species frequently also eaten by bottlenose whales (Hyperoodon ampullatus) (Clarke

1997). A giant squid (Architeuthis sp.) as large as 12 m long and weighing 200 kg has been found in a sperm whale's stomach (Berzin 1972). While sperm whales feed primarily on large and medium-sized squids, the list of documented food items is fairly long and diverse. Prey items include other cephalopods, such as octopuses, and medium- and large-sized demersal fishes, such as rays, sharks, and many teleosts (Berzin 1972; Clarke 1977, 1980; Rice 1989). The diet of large males in some areas, especially in high northern latitudes, is dominated by fish (Rice 1989). Lumpsuckers (Cyclopterus lumpus), for example, are frequently taken in Denmark Strait (Martin and Clarke 1986).

D.4 Competition

In a review of the evidence for interspecific competition in baleen whales, Clapham and Brownell (1996) found it to be extremely difficult to prove that inter-specific competition comprises an important factor in the population dynamics of large whales. May et al. (1979) used a relatively simple example, using male sperm whales, squid, and krill in the Antarctic, to show how complex the dynamics could be. According to their model, yield in the krill fishery is a function of both fishing effort on krill and the abundance of sperm whales. Sperm whales prey on cephalopods, which in turn, prey on krill. According to the model, the largest sustainable krill fishery in the Southern Ocean would be attained when sperm whales were not exploited there.

There is no evidence that competition for prey resources is a factor limiting the abundance of sperm whales in the North Atlantic. Adult male sperm whales have been observed to aggregate near trawl nets targeting Greenland halibut (Reinhardtius hippoglossoides) in one area of the western North Atlantic, but they are not known to take fish from the nets (Leaper and Karpouzli 1998). Two of the squid species eaten by sperm whales in the North Atlantic - Gonatus fabricii and Todarodes sagittatus - are known to be important in the diets of northern bottlenose whales (Gonatus only), long-finned pilot whales (Globicephala melas, both subspecies recognized in the North Atlantic and Southern Hemisphere), and short-finned pilot whales (G. macroryhncus); (Clarke 1997). However, there is no basis for assuming that competition for food among these three cetacean species is a factor in determining their population trend and abundance.

D.5 Reproduction

Comprehensive information on the reproduction of sperm whales, obtained mainly from whaling specimens and observations made aboard catcher boats, has been reviewed by several authors (Best 1979; Best et al. 1984; Rice 1989). Observational studies of sperm whales during the 1980s and 1990s, independent of the whaling industry, have improved understanding of the complex social behavior and population dynamics of sperm whales.

Sperm whales mature slowly. Females usually begin ovulating at 7-13 years of age. Maturation in males usually begins in this same age interval, but most individuals do not become fully mature until their twenties. Prime bulls, in their late twenties and older, rove among groups of females on the tropical breeding grounds. A male's association with a female group can be as brief as several hours. Since females within a group often come into estrus synchronously, the male need not remain with them for an entire season to achieve maximal breeding success (Best and Butterworth 1980).

The peak breeding season for sperm whales in the North Atlantic occurs during the spring (March/April to May), with some mating activity taking place earlier or later, from December to August. Gestation lasts well over a year, with credible estimates of the normal duration ranging from 15 months to more than a year and a half. Lactation lasts at least two years, and the inter-birth interval is 4-6 years for prime-aged females and apparently, much longer for 40+-year-olds.

Stable, long-term associations among related and unrelated females (Christal 1998) form the core units of sperm whale societies (Christal et al. 1998). Up to about a dozen females usually live in such groups, accompanied by their female and young male offspring. Males start leaving these family groups at about six years of age, after which they live in "bachelor schools." The cohesion among males within a bachelor school declines as the animals age. During their breeding prime and old age, male sperm whales are essentially solitary (Christal and Whitehead 1997).

Two particular aspects of the sperm whale's reproductive biology are relevant to management. First, the maximal rate of increase in reproduction is very low, perhaps no more than one or two percent per year. Second, selective killing of large males by whalers could have had the residual effect of reducing reproductive rates (Whitehead et al. 1997).

D.6 Natural Mortality

Sperm whales can live to ages in excess of 60 years (Rice 1989). Known non-anthropogenic threats include predation, competition, and disease; however, there are many documented cases of strandings for which the cause of the stranding is unknown. Sperm whale calves are subject to predation by killer whales (Arnbom et al. 1987) and possibly large sharks (Best et al. 1984). Although the long-standing opinion has been that adult sperm whales are essentially free from the threat of natural predators (Rice 1989;

Dufault and Whitehead 1995), an observation off California showed a prolonged and sustained attack by killer whales on a pod of sperm whales (mainly adult females and juveniles) resulting in the severe wounding and death of some of the individuals (Pitman and Chivers 1998). Sperm whales are also "harassed" by pilot whales (Globicephala spp.) and false killer whales (Pseudorca crassidens), but most "attacks" by these species do not result in the death of sperm whales (Weller et al. 1996; Palacios and Mate 1996). Fighting also occurs between adult male sperm whales (Caldwell et al. 1966; Best 1979; Kato 1984; Clarke and Paliza 1988; Whitehead 1993).

Entire schools of sperm whales occasionally strand, but the causes of this phenomenon are uncertain (Rice 1989). In fact, the causes of strandings of cetaceans in general are not well known. However, there is some evidence that sperm whale strandings may be linked to celestial cycles, although the precise mechanisms are not clear. Lunar cycles appear to influence strandings, possible as a result of the effects that light levels have on the vertical migration of their prey species (Wright 2005). Solar cycles also seem to play a role, possibly by creating variations in the Earth's magnetic field (Vanselow and Ricklefs, 2005). Fighting also occurs between adult male sperm whales (Caldwell et al. 1966; Best 1979; Kato 1984; Clarke and Paliza 1988; Whitehead 1993).

Little is known about the role of disease in determining sperm whale natural mortality rates (Lambertsen 1997). Only two naturally occurring diseases that are likely to be lethal have been identified in sperm whales: myocardial infarction associated with coronary atherosclerosis, and gastric ulceration associated with nematode infection (Lambertsen 1997). Recently, Moore and Early (2005) identified a type of cumulative bone necrosis in sperm whales that might be caused by the formation of nitrogen bubbles following deep dives and subsequent ascents, essentially decompression sickness, or what is called the "bends" in humans

D.7 Abundance and Trends

Whitehead (2002) estimated current sperm whale abundance to be approximately 300,000-450,000 worldwide. Although his estimates are based on extrapolating surveyed areas to unsurveyed areas, without a systematic survey design, these are probably the best available and most current estimates of global sperm whale abundance.

No attempt has been made to estimate the total abundance of sperm whales in the North Atlantic Ocean. Instead, researchers have provided estimates of small populations of sperm whales within a relatively narrow portion of their range. All estimates from sighting surveys are negatively biased due to the long submergence times of sperm whales (i.e., dives lasting up to 2 hours . Furthermore, the bias associated with a given estimate can be highly variable, depending on the survey platform. Barlow and Sexton (1996) concluded that availability bias for ship surveys, may be relatively small because of the substantial distance at which sperm whale blows can be detected. Abundance estimates from aerial surveys, in contrast, could be low by a factor of three to eight (Barlow 1994).

The most extensive sperm whale surveys were shipboard surveys conducted in the western and central North Atlantic, during the period 1966-69, which provided a very crude estimate of approximately 22,000 sperm whales in the area bounded by 10-70°N and 20-80°W (Mitchell 1972).

Currently, the best estimate for the northeastern United States is 4,804 (CV=0.38) based upon two vessel surveys and an aerial survey conducted during the summer of 2004 (Waring et al. 2005). The estimate pertains to waters from Florida to the Gulf of Maine within the U.S. EEZ and Canadian portions of the Gulf of Maine, but does not include the Nova Scotian shelf and Gulf of St. Lawrence. Thus, it does not apply to the entire range of sperm whales in the western North Atlantic, which extends across the Scotian Shelf and into the Labrador Sea and Davis Strait (Reeves and Whitehead 1997). The density of sperm whales along the U.S. east coast (17.04 per 1000 km2) is the highest reported in a recent survey of sperm whale densities worldwide (Whitehead 2002). Shipboard surveys in the northern Gulf of Mexico between 1991 and 1995 resulted in estimates of 530 (CV=0.31) (Waring et al. 1997) and 442 (CV=0.36) sperm whales (Jefferson 1996). More recent vessel surveys conducted during 1996-2001, resulted in a combined estimate of 1,349 (CV 0.23) for the oceanic northern Gulf of Mexico (Mullin and Fulling 2004). The survey estimates for the Gulf of Mexico are negatively biased, as they do not account for the long submergence time of sperm whales.

Estimates of sperm whale abundance from surveys in the eastern North Atlantic were 2,500 (CV=0.27) in July 1988 (Øien 1990). In the central North Atlantic, vessel surveys in June-August 1987, yielded abundance estimates of 4,925 (CV=0.16) and 902 (CV=0.45) sperm whales in Icelandic and Faroese waters, respectively (Gunnlaugsson and Sigurjónsson 1990).

Best (1983) claimed that 19th century whalers took “a disproportionately large number” of sperm whales in the North Atlantic relative to other ocean basins. Thus, “if signs of overexploitation by the primitive fishery are to be detected, these might be most obvious in this region” (Best 1983). On the other hand, for most of the 20th century, sperm whales in the North Atlantic Ocean were subjected to much less intensive whaling than those in the North Pacific and Southern Oceans. Moreover, post-World War II whaling for sperm whales in the North Atlantic occurred primarily in areas where females were either absent or substantially less available than males (Avila de Melo and Martin 1985). Thus, one could argue that if signs of recovery from historical overexploitation were to be detected, they would most likely be found in the North Atlantic. No time series of survey data is available to address questions of population trend in the North Atlantic in a meaningful way, but several other types of analyses have been at least suggestive of trends. Length frequency data on catches at Iceland suggest that males larger than 35 ft (10.5 m) and mature females in the North Atlantic declined progressively between 1905 and 1979, with the greatest decline occurring in males from the 1940s onward (Hiby and Harwood 1981).

Trends in length frequency of males in the catches at Madeira and the Azores have been interpreted as suggesting (1) that the population of large, reproductively-active males at the Azores was over-exploited in the 1940s and 1950s, but was recovering by the 1970s; and (2) that this component of the population remained depleted at Madeira from the 1960s until the hunt's closure there in 1981 (Avila de Melo and Martin 1985).

Analyses of temporal trends in sperm whale strandings in the North Sea and British Isles have been interpreted as suggesting an increase in the whale population since the 1970s (Smeenk 1997). However, Goold et al. (2005) reported that stranding of sperm whales in the North Atlantic have been increasing at a rate higher than would be expected from a simple increase in sperm whale population size alone. It is possible that the increased strandings frequency could be related to fishery bycatch (whales having drowned in gear) or to decreased individual health as a result of chemical contamination (Evans 1997).

E. Life History-North Pacific Population

E.1 Population Structure

The question of stock structure in the North Pacific was a focus of intense discussion in the IWC Scientific Committee during the 1970s, a time when sperm whales were being heavily exploited by Japanese and Soviet pelagic whalers (IWC 1980). Masaki (1970) used tagging results, blood types, catch distributions, sighting patterns, and size compositions to establish the concept of three stocks: one west of 170°E (Asian stock), one between 180° and 160°W (mixed or Central stock), and one east of 150°W (American stock) (Tillman 1977). Ohsumi and Masaki (1977) emphasized that the "mixing" area in the central North Pacific was used primarily by males, and they proposed a two-stock scheme (east and west) for females, while retaining the previous three-stock scheme for males.

Two attempts have been made to analyze historical whaling and tag-return data for insights about population separation in the North Pacific. Bannister and Mitchell (1980) evaluated Townsend's (1935) monthly plots of catch positions and Maury's (1852) whale charts showing effort-corrected indices of whale distribution. Both sets of documents were based on 19th century American whaling logbook records. The Maury and Townsend depictions were judged to be consistent with Masaki's (1970) hypothesis of three reasonably well-defined populations. Kasuya and Miyashita (1988) evaluated biological, bio-chemical, oceanographic, whaling, tagging, and sighting data and concluded that there were three populations, but with boundaries different from those suggested by earlier authors. Their analysis suggested that the eastern North Pacific (or American) population is widely distributed north of 20°N, with breeding schools circulating between Mexican waters in the southeast, the historical whaling grounds centered around the Hawaiian Islands, the Alaskan Gyre, and waters on the south side of the Aleutian Chain. The boundaries for this population are approximately the Aleutians in the north, the North American coast in the east, and a line connecting 52°30'N, 175°E and 20°N, 160°W. Adult males of this population tend to be segregated longitudinally (toward the west) rather than latitudinally (toward the north) from the females and juveniles. For the western North Pacific population, Kasuya and Miyashita (1988) proposed northwestern and southwestern populations, with the boundary shifting seasonally (Donovan 1991).

In U.S. waters, three management units are recognized in U.S. EEZ waters in the Pacific - California/Oregon/Washington, Hawaiian, and Alaskan stocks (Carretta et al. 2006). Sperm whales in the eastern tropical Pacific are thought to belong to another population. Tag returns indicate that whales move between southern California and British Columbia (Rice 1974) and therefore, suggest that the California/Oregon/Washington population is separate from the Hawaiian population. Currently, studies of population structure using modern methods have not yet been completed for North Pacific sperm whales; therefore, any current designation of stocks or management units must be viewed as preliminary (Taylor and Dizon 1996).

Mesnick et al. (1999; unpublished data) addressed the question of population structure among sperm whales in the North Pacific using a data set of over 500 samples collected from 84 social groups and a custom-written program to control for the biases of relatedness among individuals sampled within groups (Taylor and Mesnick, manuscript). The authors analyzed variation in mtDNA and nuclear (microsatellite) loci and found significant north-south subdivision between samples collected in the California Current and samples collected to the south (between the Gulf of California and waters off central and northern South America and the Galapagos) and little east-west structure throughout the rest of the North Pacific. Estimates of population structure using all individuals (including relatives), or using only one individual per group, showed positive (more structure) and negative (less structure) biases, respectively, illustrating the need for factoring social structure into population level studies. Rendell et al. (2005, 2006) addressed the question of cultural philopatry by examining mitochondrial DNA variation among vocal clans of sperm whales using samples from 194 individuals from 30 social groups belonging to one of three vocal clans. Both hierarchical AMOVAs and partial Mantel tests showed greater genetic subdivision among vocal clans than putative populations based on geography (Chile/Peru, Galapagos/Ecuador, and SW Pacific).

E.2 Distribution and Habitat Use

The known distribution of sperm whales in the North Pacific Ocean can be attributed to whaling records, shipboard surveys, and recordings on acoustic devices. The northern limit of adult male sperm whales in the North Pacific Ocean is approximately a line from Cape Navarin, Russia, to the Pribilof Islands in the northeastern Bering Sea (Berzin and Rovnin 1966). Females and juveniles generally range no further north than about 50-51°N, in the southern Gulf of Alaska (Berzin and Rovnin 1966).

Whaling records from the 19th century show that the primary whaling grounds for sperm whales were (1)the Panama, Galapagos, and Offshore grounds in the eastern tropical Pacific; (2) the On-the-Line Ground, an almost continuous equatorial belt extending a few degrees north and south of the Equator in the central Pacific; (3) the Hawaiian Ground centered between approximately 20°N and 35°N; (4) areas off Baja California and mainland Mexico; (5) the Japan Ground (28-35°N, 150-179°E); (6) the Coast of Japan Ground (34-40°N, 142-149°E); and (7) the Bonin Islands Ground southeast of southern Japan (Townsend 1935). The more northern grounds were visited mainly in summer and fall, while the equatorial areas afforded opportunities for sperm whaling during other seasons, and in some cases, year-round. Sperm whales, including females and young males, were abundant on the whaling grounds up to 200 miles offshore from Vancouver Island and the Queen Charlotte Islands, British Columbia from spring through fall (Pike and MacAskie 1969). Although Townsend's (1935) charts show little evidence of sperm whales in the Gulf of Alaska and around the Aleutians, modern shore and pelagic whalers took adult males regularly in summer in deep offshore waters of the eastern Aleutians and Kodiak Island (Reeves et al. 1985). Discovery Mark data from the commercial whaling days reveals much east-west movement between Alaskan waters and the coast of Japan Ground and Bonin Islands Ground, with little movement north-south in the eastern Pacific. Large concentrations of breeding schools were reported by modern pelagic whalers along a line from 38°N, 142°W to 45°N, 135°W, thence northwestward to 50°N, 138°W and westward to 52°N, 148°W (Berzin 1972). The largest concentrations were centered around 50°N, 138°W and in a strip from 42°N, 140°W to 50°N, 154°W. Large numbers of females were observed along 41°N latitude (Berzin 1972).

A recent vessel survey south of the eastern Aleutians found sperm whales in waters 4,000-5,000 m deep, either over the Aleutian Abyssal Plain or north of the Aleutian Trench over deep basins (Forney and Brownell 1997). Sperm whales have also been heard year-round on remote acoustic recorders in the Gulf of Alaska, but the number of sperm whale detections was approximately twice as high in summer compared to winter (Mellinger et al. 2004).

Sperm whales are present in all months off California (Dohl et al. 1983; Barlow 1995; Forney et al. 1995), but they reach peak abundance from April through mid-June and again from the end of August through mid-November (Rice 1974). They are also present in all seasons except mid-winter (Dec.-Feb.) off Oregon and Washington (Green et al. 1992). Figure 1 illustrates the location of sperm whales seen on Southwest Fisheries Science Center surveys in the eastern North Pacific from1986 through 2005.

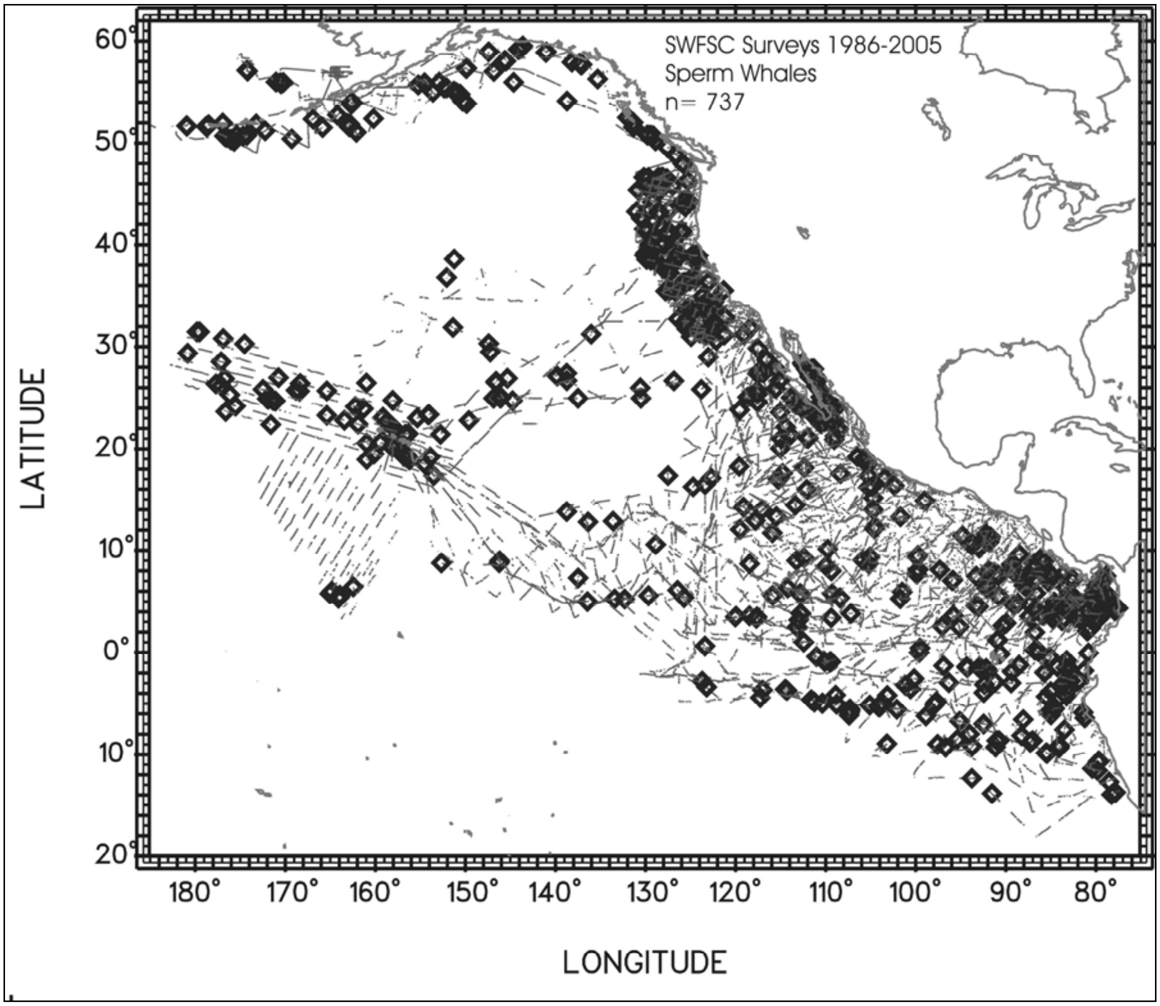

Figure 1. Location of sperm whales (◊) seen on Southwest Fisheries Science Center surveys in the eastern North Pacific (1986-2005). Fine lines represent tracklines surveyed during those years.

E.3 Feeding and Prey Selection

See summary in Section D.3.

E.4 Competition

Sperm whales are known to interact with longline fisheries in many parts of the world (e.g., around South Georgia; Ashford et al. 1996), including the Gulf of Alaska where they reportedly take fish from gear set to catch sablefish (Anoplopoma fimbria) (Rice 1989) and halibut (Hippoglossus stenolepis) (Hill et al. 1997). Direct action taken by fishermen to protect their catch and gear from depredation by sperm whales could result in serious injury or mortality of the whales. In seeking to explain trends in North Pacific sperm whale populations, Kasuya (1991) referred to the possibilities of "competition for food resources among the males" and competition with trawl fisheries. As discussed in

Section D.4, it is exceedingly difficult to evaluate the role of competition as a causative factor in population abundance and trends for large, wide-ranging cetaceans that feed on a variety of types of prey.

E.5 Reproduction

No differences in the basic reproductive biology of sperm whales in the North Pacific and North Atlantic are known or suspected, so, in general, the summary in Section D.5 applies here as well. One important consideration, however, is that the numbers of female sperm whales killed in the North Pacific by modern Japanese and Soviet whalers were greatly under-reported. Therefore, the killing of large breeding males in this ocean basin may not have reduced the pregnancy rate as much as previously believed. In other words, the low number of whales may be due as much to the loss of potential mothers, as to the scarcity of potential fathers.

E.6 Natural Mortality

No differences in the natural mortality of sperm whales in the North Pacific and North Atlantic are known (see summary in Section D.6). However, the relatively greater abundance of killer whales in the eastern North Pacific than the western North Atlantic (if indeed, this supposition is correct) could indicate that sperm whales are at greater risk of predation in the Pacific.

E.7 Abundance and Trends

Rice (1989) provided a crude estimate of 1,260,000 for the total pre-exploitation abundance of sperm whales in the North Pacific, while the current abundance was estimated to be approximately 930,000. Rice's estimates for the North Pacific exceed the current worldwide abundance estimate for sperm whales (300,000-450,000; Whitehead 2002). According to Hill et al. (1997), "recent information indicates that these estimates are positively biased." No further explanation was provided by these authors. Barlow et al. (1997) refer to the same set of estimates (Gosho et al. 1984) and dismiss them as based on a discredited catch-per-unit-effort method. A practical working range for estimates for sperm whale abundance in the entire North Pacific might be 100,000-200,000 (see last paragraph in this section).

Wade and Gerrodette (1993) estimated that there were 22,700 (CV 0.224) sperm whales in the eastern tropical Pacific. These whales are thought to belong to a different population from those off California, Oregon, Washington, and northward. Barlow and Gerrodette (1996) estimated that there were 1,231 (CV=0.39; 1.5 per 1000 km2) in California coastal waters (within 300 nmi of shore) during summer and fall 1991-93, and Barlow (1997) estimated about 1,200 (1,191, CV=0.22) within the same distance off California, Oregon, and Washington in 1996. All of the foregoing estimates were based on line-transect ship surveys. Aerial surveys in California produced an estimate of 892 sperm whales (CV=0.99) during winter and spring (Forney et al. 1995), and this would need to be adjusted upward by 3 to 8 times to account for diving whales and provide a closer approximation to the true abundance (Barlow et al. 1997).

A shipboard line-transect survey for sperm whales, using combined visual and acoustic methods, was conducted in a 7.8 million km2 area between the west coast of the continental United States and Hawaii in March-June 1997 (Barlow and Taylor 2005). The acoustic and sighting data were analyzed separately, yielding estimates of 32,100 (CV=0.36) and 26,300 (CV=0.81), respectively. The two estimates were not significantly different. Barlow (2006) estimated sperm whale abundance in the U.S. EEZ waters surrounding Hawaii as 6,900 (CV=0.81). No recent abundance estimates are available for sperm whales in Alaskan waters.

The density of sperm whales (individuals per 1000 km2) has been estimated for five large study areas in the North Pacific: 1.36 in the eastern tropical Pacific (Wade and Gerrodette 1993, as corrected by Whitehead 2002); 1.16 in the western North Pacific (Kato and Miyashita 1998, as corrected by Whitehead 2002); 1.08 off the U.S. West Coast; 3.4 to 4.2 in the eastern temperate Pacific (Barlow and Taylor 2005); and 2.82 in the Hawaiian EEZ (Barlow 2006). Collectively, these surveys cover the majority of sperm whale habitat in the North Pacific. If the mean density in those areas (2.33 per 1000 km2) were extrapolated to the 80 million square kilometers in the entire North Pacific, the sperm whale population would be about 187,000. Using Whitehead's (2002) global average of sperm whale density (1.40 per 1000 km2), the North Pacific would have approximately 112,000 sperm whales. Given these extrapolations, a practical working range for estimates for sperm whale abundance in the entire North Pacific might be 100,000-200,000.

F. Life History- Southern Hemisphere Population

F.1 Population Structure

For the purposes of worldwide popu¬lation assessment and management, the IWC recognizes the area south of the Equator as one biogeographical region, the Southern Hemisphere. The Com¬mission has divided this circumpolar region into nine sperm whale “Divi¬sions.” Donovan (1991) noted that these divisions are based more on manipulating available data from com¬mercial whaling than on actual biologi¬cal information. The divisions 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).

The Indian Ocean Sanctuary was cre¬ated in 1979, under Article v(1)(c) of the International Whaling Convention for the Regulation of Whaling (ICRW), and all commercial whaling was prohibited within its boundaries. This boundary extends from the Antarc¬tic continent to lat. 55°S and from long. 20°E to 130°E. In the western Indian Ocean (Division 3), there is evi¬dence that concentrations of mixed female/immature whale groups exist south of the Seychelles (James and Soundararajan, 1979; Kasuya and Wada 1991; Kahn et al. 1993; Eyre 1995). In the central Indian Ocean (Di¬vision 4), concentrations of sperm whales have been recorded to the north of St. Paul and Amsterdam Islands in the austral summer (Gosho et al. 1984).

Since the IWC last did a formal assessment of sperm whales, new data indicate that the Southern Hemisphere contains at least some populations that extend into the Northern Hemisphere. Rice (1977), Wade and Gerrodette (1993), and Dufault and Whitehead (1995) suggested that a separate equa¬torial Pacific sperm whale population exists. Photo-identification matches and genetic data indicate movement between the Gulf of California and the Galapagos Islands, which includes movement across the equator (Jaquet et al. 2003). In all likelihood, at least the females and immatures are resident in these tropical and subtropical waters year-round. Genetic data indicate that these animals differ from those found off coastal California (Mesnick et al. 1999a,b). Photo-identification studies off the Galapagos Islands and mainland Ecuador and North Peru indicate that there may also be a geographical separa¬tion between Galapagos and Ecuador/ North Peru whales, although their genetic discreteness has yet to be verified (Dufault and Whitehead 1995). This opens the possibility that the strict north-south boundaries drawn by IWC may inadequately capture sperm whale population structure and that tropical and temperate population structure may also be present.

Genetic studies based on maternally inherited (mtDNA) markers show significant genetic differentiation between the southern hemisphere and the North Pacific and North Atlantic (Lyrholm et al. 1996, 1998), and no significant heterogeneity in bi-parentally inherited (microsatellite) markers was found (Lyrholm et al. 1999). These contrasting patterns suggest that interoceanic movement have been more prevalent among males than females (Lyrholm et al. 1999), consistent with observation of females having smaller geographic ranges (Dufault and Whitehead 1995). The recent finding that vocal clan is a more important factor in genetic structure than geography in the eastern South Pacific draws into question the practice of basing populations solely on geographic strata (Rendell et al. 2005, 2006). A similar well-documented situation occurs among the highly social and vocal killer whales in the Pacific Northwest where vocal clans are sympatric, but genetically distinct (Krahn et al. 2005).

F.2 Distribution and Habitat Use

Male sperm whales are widely dis¬persed 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 At¬lantic of lat. 50–54°S (Gosho et al., 1984; Tynan, 1998). Only male sperm whales are seen off Kaikoura in New Zealand at lat. 42°S (Jaquet et al. 2000).

F.3 Feeding and Prey Selection

See Northern Hemisphere sections.

F.4 Competition

See Northern Hemisphere sections.

F.5 Reproduction

See Northern Hemisphere sections.

F.6 Natural Mortality

Killer whales presumably attack sperm whales, at least occasionally.

F.7 Abundance and Trends

The current estimate of 299,400 (no CV) sperm whales from the Equator to lat. 70S dates from 1977 and is statistically unreliable (IWC 1988). This estimate was calculated on the basis of historical whaling records and Death per Unit Effort (DPUE) data from whaling operations (Odell 1992). Whitehead (2002) estimated current sperm whale abundance to be approximately 300,000-450,000 worldwide, but does not make a separate estimate for the Southern Hemisphere. Given that the seas of the Southern Hemisphere include more surface area than those in the North, Whitehead’s methods would predict greater than 150,000-225,000 sperm whales in the Southern Hemisphere.

Using Japanese Scouting Vessels (JSV) and IWC/ International Decade of Cetacean Research (IDCR) survey data Butterworth et al. estimated sperm whale abundances south of lat. 60oS (3,200-14,000; CV = 0.39-0.19) and south of lat. 30oS (128,000-290,000; CV = 0.44-0.46, respectively). Given the latitudes surveyed, these numbers most likely represent a large proportion of males.

In South Pacific waters, Childerhouse et al. (1995) determined, using photo-identification and an "open" mark-re-capture 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. 1992a,b).

The historical abundance estimates for the nine Southern Hemisphere divisions for the entire Southern Hemisphere for the year 1946 is 547,600 sperm whales (no CV) (Gosho et al. 1984). These estimates are statistically un¬reliable due to their use of historical whaling catch data and CPUE22 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 in¬dicate considerable underreporting of sperm whale catches (Zemsky et al. 1995; Zemsky et al. 1996). According to these "new" catch data, approxi¬mately 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 esti¬mates will need to be revised.

G. Threats

The following table provides a visual synopsis of the text regarding threats to sperm whales and the sources of these threats, which starts directly following the table. Where threats can be identified to the population level, e.g., for fisheries in U.S. waters, this has been done. In all other cases, the source, severity, uncertainty of information, and relative impacts to recovery are estimated for the global species.

Table 1. Sperm whale threats analysis table.

Population	Stress/Threat	Source of Stress	Severity	Uncertainty	Relative Impacts to Recovery
			(Unknown, Low, Med, High, V. High)	(Unknown, Low, Med, High, V. High)	(Unknown, Low, Med, High, V. High)
	Fishery Interactions:				
CA/OR/WA	Injury from drift gillnet entanglement	CA/OR thresher shark/swordfish gillnet ($\geq$14 in. mesh)	Medium	Low	Low
HI	Injury from longline gear entanglement	Hawaii-based longline fishery	Low	Low	Low
HI	Injury from longline gear entanglement	Experimental longline fishery	Low	Low	Low
North Pacific	Injury from longline gear entanglement	AK Gulf of Alaska sablefish longline	Low	Low	Low
Northern Gulf Of Mexico	Injury from longline gear entanglement	Longline fishery	Low	Low	Low
North Atlantic	Injury from pelagic drift gillnet	Pelagic drift gillnet fishery	Low	Low	Low
Global	Injury from gillnet gear entanglement	Gillnet gear	Low	Medium	Low

Global	Injury from longline gear entanglement	Longline gear	Low	Medium	Low
Global	Anthropogenic Noise	Mid-frequency Sources	Unknown	High	Unknown
	Vessel Interactions:				
Global	Ship Strikes	Areas of high vessel traffic and/or high speed vessel traffic	Medium	Medium	Medium
Global	Disturbance from Vessels	Whale watching	Low	Medium	Low
Global	Contaminants and Pollutants	?	Unknown	High	Unknown
Global	Disease	Parasites, other	Low	Medium	Low
Global	Injury from entanglement in marine debris	Plastics blown into sea; abandoned fishing gear; plastics from ships	Low	Medium	Low
Global	Noise, Entanglement, and Oil Spills from Oil and Gas Exploration and Other Activities	Seismic surveys, noise from construction and operations of oil exploration work and LNG facilities, oil spills	Unknown	High	Unknown
Global	Strikes and Noise due to Military Operations	Vessel interactions, ship shock trials, low and mid-frequency sonar	Unknown	High	Unknown

Global	Disturbance due to Research	Oceanographic surveys and acoustic studies, collection of information on whales	Low	Medium	Low
Global	Predation and Natural Mortality	Killer whales; bone necrosis	Low	Medium	Low
Global	Direct Harvest	Human harvest	Medium (potential)	Medium	Medium
Global	Competition for Resources	Other whales, human fisheries	Low	Medium	Low
Global	Loss of Prey Base due to Climate and Ecosystem Change	Climate and Ecosystem Change	Medium	High	Medium

G.1 Fishery Interactions

The vulnerability of sperm whales to incidental capture in fishing gear, especially gillnets set in deep water for pelagic fish (e.g., sharks, billfish, tuna) and bottom-set longline gear, is well documented (Di Natale and Notarbartolo di Sciara 1994; Haase and Félix 1994; Félix et al. 1997; Hill et al. 1999; Straley et al. 2005; Warner et al. 2005). Sperm whales may break through or carry away fishing gear. Whales carrying gear may die at a later time due to trailing fishing gear, become debilitated or seriously injured, or have normal functions impaired, but with no evidence of the incident recorded. Sperm whales may also become entangled while attempting to depredate fish off fishing gear.

G.1.1 North Atlantic

In U.S. east-coast waters, by-catch of sperm whales has been documented in the pelagic drift-net fishery which targeted primarily swordfish and tuna (Waring et al. 1997). Two incidents were reported between 1990 and 1995, both on Georges Bank. In 1990, one whale was found entangled and was released in “injured” condition. In 1995, another was found, also injured, and released while still carrying gear (Waring et al. 1997). There have been no recent interactions between sperm whales and commercial fishing gear in the U.S. Atlantic of Gulf of Mexico (Waring et al. 2005). It is likely that some mortality and injury occurs in offshore fisheries without being documented, such as resulting from “ghost fishing” by lost or discarded gear, but the level is unknown.

Sperm whales may become entangled in fishing gear (most often demersal long-line gear) while attempting to take fish off of the gear, also known as “depredation” (Warner et al. 2005). There are few known cases in the North Atlantic. However, In the Flemish Cap region, Karpouzli and Leaper (2004) recorded interactions with deep-water trawlers, where sperm whales appeared during hauling operations and were thought to be possibly feeding on fish escaping from the net. There is one recorded death by entanglement in longline gear in the Caribbean (Northridge 1996). In 1990, a sperm whale was entangled and released injured; in 1995, one sperm whale released alive, but entangled in gear. Pelagic drift gillnet fishery closed in 1997 and use of drift gillnets prohibited in 1999.

G.1.2 North Pacific

The offshore drift gillnet fishery targeting swordfish and sharks off Oregon, California, and Baja California (Mexico) are a recognized threat to sperm whales. An estimated 1.0 sperm whales are killed annually in the driftnet fishery for thresher sharks and swordfish off Oregon and California (Carretta et al. 2006). No estimates of mortality are available for the Mexican drift gillnet fisheries. Palacios and Gerrodette (1996) noted that sperm whales are at least occasionally killed in artisanal gillnet fisheries for sharks and large pelagic fishes off the Pacific coasts of northwestern South America, Central America, and Mexico. One sperm whale has been reported entangled in a longline fishery near Hawaii (Carretta et al. 2006), but that animal freed itself and was not considered to be seriously injured (Forney 2004).

Sperm whales have learned to depredate deep-water sablefish longlines in the waters of the eastern North Pacific (Hill et al. 1999; Straley et al. 2005). Reports of depredation were first noted in 1978 and have steadily increased in frequency and severity, with a notable increase since the late 1990s. Based on information documented from 1999-2003 (observer data), one sperm whale was observed with trailing gear from the Gulf of Alaska sablefish longline fishery. Estimated mean annual mortality for the North Pacific Stock (Alaska) is 0.45 (CV=0.75) (Angliss and Outlaw 2005). From annual longline surveys conducted since 1998, between 1989-2003, 38 of the surveyed stations recorded sperm whale predation on catch; all predation events occurred in the Gulf of Alaska, none in the Bering Sea (Angliss and Outlaw 2005). In collaboration with fishermen, genetic, acoustic and fishing behavior studies have been conducted in the Sitka area to gain insight into what may attract sperm whales to longlining activity (Sigler et al. 2003; Straley et al. 2005). Preliminary analyses found that during a typical encounter when sperm whales are present during the haul, about 3%-6% of the catch was estimated to be removed, but sometimes over 50% of the catch has been lost by individual fishermen. As the frequency of depredation events increases, there are growing concerns about the potential for sperm whale entanglements and the prospect of growing economic losses.

Haase and Félix (1994) record two instances in which sperm whales were killed after becoming trapped in tuna purse-seine nets off Ecuador.

G.1.3 Southern Hemisphere

Sperm whales may become entangled in fishing gear (most often demersal long-line gear) while attempting to take fish off of the gear, also known as “depredation” (Warner et al. 2005). Southern Ocean interactions involve demersal longline fisheries for Patagonian toothfish (Dissostichus eleginoides). There are records of depredation or possible depredation occurring at several locations in the southern hemisphere (Chile, Falkland, South Georgia, Crozet, and Kerguelen Islands; Ashford et al. 1996; Capdeville 1997; CCAMLR 1994; Crespo et al. 1997; Gonzalez 2001; Gonzalez et al. 2001; Hucke-Gauete et al. 2004; Nolan and Liddle 2000; Northridge 1996; Olivarria 2002; Oporto and Brieva 1994; Purves et al. 2004). In the Falkland Islands (Nolan and Liddle 2002), in Crozet Island (Jerome Maison, pers. comm.) and in Chile (Hucke-Gaete et al., 2004), aggressive competition between sperm and killer whales for a spot at the hauling station of longliners were reported. Entanglements in longline fishing gear have been observed in South Georgia (Purves et al 2004), Chile (Ashford et al 1996) and the Falklands Islands (Helen Otley, pers. comm.). Although the magnitude of these interactions is infrequently documented there are reports of sperm whales that have been shot by guns or harpoons and the use of explosives to keep animals away from fishing gear (e.g., Gonzalez 2001).

G.2 Anthropogenic Noise

Response to noise varies by the type and characteristics of the noise source, distance between the source and the receptor, receptor sensitivity, and time of the day. Noise may be intermittent or continuous, steady or impulsive, and may be generated by stationary or transient sources. Specific concerns are the potential continuous or impulse noise effects on sperm whales. Sound transmissions in the marine environment may impact sperm whales by causing damage to body tissue or gross damage to ears, causing a permanent threshold shift or a temporary threshold shift. An animal's detection threshold may be masked by noise that is at frequencies similar to those of biologically important signals, such as mating calls. Masking occurs when noise interferes with a marine animal's ability to hear a sound of interest. Animals may adapt to shift vocalizations and interruption of normal behavior could be acutely changed for a period of time or slightly modified which could have efficiency and energetic consequences. If the noise is chronic, individuals may have an increased vulnerability to disease or increased potential for negative cumulative effects, such as chemical pollution combined with noise-induced stress. Sensitization to noise could also exacerbate other effects and habituation to chronic noise could cause animals to remain close to damaging noise. Sound transmissions could also displace animals from areas for a short or long time period. Noise may also reduce the availability of prey, or increase vulnerability to other hazards, such as collisions with ships, fishing gear, predation, etc.

It is important to recognize the difficulty of measuring behavioral or stress responses in free-ranging whales. The cumulative effects of habitat degradation are difficult to define and almost impossible to evaluate. For more specific information on potential noise impacts associated with military activities, coastal development, oil and gas exploration, and research, see sections below.

Ambient noise is background noise and, in the ocean, such noise arises from wind, waves, organisms, fishing boats, etc. Human-made noise can interfere with detection of acoustic signals, such as communication calls, echolocation sounds, and environmental sounds important to sperm whales. If the noise is strong enough relative to the received signal, the signal will be "masked" and undetectable. The size of this "zone of masking" of a marine mammal is highly variable, and depends on many factors that affect the received levels of the background noise and the sound signal. Sounds may be transient (pulsed), of relatively short duration having an obvious start and end (explosions, sonars, etc.), or they may be continuous, seeming to go on and on (e.g., an operating drillship). An animal's response to a pulsed sound with a particular peak level can be quite different than its response to a continuous sound at the same level.

The odontocete inner ear is primarily adapted for echolocation, and the ears have exceptional frequency discrimination abilities. The middle and inner ears are most heavily modified structurally from those of terrestrial mammals in ways that accommodate rapid pressure changes. The result is an acoustically sensitive ear that is simultaneously adapted to sustain moderately rapid and extreme pressure changes and appears capable of accommodating acoustic power relationships several magnitudes greater than air (Ketten 1995).

Based upon the best scientific evidence available, the hearing of dolphins, porpoises and other small whales is generally poor at frequencies less than 1,000 Hz. While odontocetes can hear sounds over a very wide range of frequencies, from as low as 40-75

Hz in bottlenose dolphins and belugas (Delphinapterus leucas) (Johnson, 1967; Awbrey et al., 1988) to 105-150 kHz in several other species (Richardson et al., 1995), underwater audiograms indicate that odontocetes hear best at frequencies above 10 kHz. There are no specific data on the absolute hearing thresholds of the large, deep-diving toothed whales, such as the sperm whale.

Very little systematic information is available regarding the reactions of toothed whales to impulsive noises. Most of the energy in seismic pulses is at low frequencies (<125 Hz), where the auditory systems of small and medium-sized toothed whales are not very sensitive. Even so, seismic pulses are strong enough to be detectable to small-to-moderate sized odontocetes many miles away, although avoidance reactions by these animals may be limited to considerably small distances (Richardson and Wursig 1997; Goold and Fish 1998). Thus, more information is needed regarding the effect of impulsive sound on toothed whales, and particularly on the specific pulse levels that may cause behavioral or other reactions. Some species may become silent (i.e., sperm whale) and/or move away from some sources of strong impulsive sounds, but the reactions vary depending on the species and their activities. In the presence of abundant food or during sexual encounters, toothed whales sometimes are extremely tolerant of noise pulses. There is currently no evidence of long-term changes in behavior or distribution as a result of occasional exposure to pulsed acoustic stimuli.

Sperm whales are known to respond, often dramatically, to unfamiliar noise. Whales exposed to the sounds of pingers used in calibration systems to locate hydrophone arrays temporarily fell silent (Watkins and Schevill 1975). This response to sounds in the frequency range of 6-13 kHz was interpreted as one of listening, rather than of fear. A stronger response was observed in sperm whales exposed to the intense sonar signaling and ship propeller noise from military operations in the Caribbean Sea during the U.S. invasion of Grenada in 1983. The whales fell silent, changed their activities, scattered, and moved away from the sound sources (Watkins et al. 1985). They also showed longer-term responses by becoming quieter and seemingly more wary of a research vessel that had visited the same area in previous years (Watkins et al. 1985). Sperm whales in the Indian Ocean appeared to react similarly (i.e., by ceasing to vocalize) to the airgun pulses from a seismic vessel more than 300 km away and to the low-frequency sounds transmitted during the pre- Acoustic Thermometry of Ocean Climate (ATOC) “Heard Island Feasibility Test” (Bowles et al. 1994). Stone (2003) summarized the responses of marine mammals to seismic surveys off the U.K. and found that sperm whales showed no noticeable avoidance response. Playback experiments were conducted in the Canary Islands using sounds expected to be aversive and to drive sperm whales away from a ferry route. One interpretation of the results was that sperm whales have a high tolerance for certain kinds of noise (André et al. 1997). Madsen and Møhl (2000) found that sperm whales did not react to sounds from detonators. A recent preliminary analysis of acoustical data from the northern Gulf of Mexico also indicates that sperm whales are, in some cases, affected by the passing of vessels, with fewer clicks and fewer whales detected afterwards (Ioup et al. 2005). It is not know if this reflects a change in sound-producing behavior, or the physical movement of whales away from the source. Interestingly, similar changes were observed, when the data were analyzed for the effects of a passing tropical storm (Newcomb et al. 2004). In summary, it appears that sperm whales may react strongly to a novel acoustic stimulus but that they may habituate to the presence of some anthropogenic sounds.

G.3 Vessel Interactions

G.3.1 Ship Strikes

Sperm whales spend long periods (typically up to 10 minutes; Jacquet et al. 1998) "rafting" at the surface between deep dives. This could make them exceptionally vulnerable to ship strikes. Berzin (1972) noted that there were "many" reports of sperm whales of different age classes being struck by vessels, including passenger ships and tug boats. There were also instances in which sperm whales approached vessels too closely and were cut by the propellers.

G.3.1.1 North Atlantic

Reports of ships colliding with sperm whales are said to be "frequent" in the Canary Islands, where ship traffic is heavy and the local density of sperm whales relatively high (André et al. 1997). For example, in 1992, a high-speed ferry collided with a sperm whale, and one of the ferry passengers died as a result (André et al. 1997).

One of nine sperm whales found stranded on the north coast of the Gulf of Mexico between 1987 and 1994 had "deep, parallel cuts posterior to the dorsal ridge that were believed to be caused by the propeller of a large vessel" (Waring et al. 1997). During 2001-2003 one of ten stranded sperm whales was reported struck by a naval vessel, and an additional whale was reported struck by a merchant vessel near Rhode Island (Waring et al. 2005). Due to the sperm whale's offshore distribution, it is likely that mortality and injury from ship strikes off the east coast of North America are documented less often than they occur (i.e. they are less likely to drift to shore and strand).

G.3.1.2 North Pacific

Although no recent documentation is available from the eastern North Pacific, this lack of evidence should not lead to the assumption that no mortality or injury from collisions with vessels occurs. Two whales described as "possibly sperm whales" are known to have died in U.S. waters in 1990 after being struck by vessels (Barlow et al. 1997). Carcasses that do not drift ashore may go unreported, and those that do strand may show no obvious signs of having been struck by a ship.

G.3.2 Disturbance from Vessels and Tourism

Concern about the effects of whale-watching vessels prompted field studies of sperm whale responses to boat approaches in New Zealand (Gordon et al. 1992). The results suggest that sperm whales adjusted their diving and acoustic behavior to the whale-watching boats, but also that with frequent exposure, whales become increasingly tolerant of the vessels' presence. Sperm whales are not often seen from whale-watching vessels (either because the vessels are not located in areas where sperm whales are typically found or the vessels are disruptive and the sperm whales avoid them) on the east coast of the United States and Canada, and the potential for disturbance to sperm whales by such vessels is probably low.

G.4 Contaminants and Pollutants

A dramatic increase in the rate of sperm whale strandings in western Europe since the early 1980s has raised concern that pollution may be implicated (Goold et al. 2002). Although the tissues of some of the stranded whales have been analyzed thoroughly for a wide range of contaminants, and detailed pathological examinations have been carried out on some of the whales, no clear link between contamination and stranding has been found (Jacques and Lambertsen 1997). Levels of mercury, cadmium, and certain organochlorines in these whales' tissues, however, were high enough to cause concern about toxicity and other possibly indirect and less obvious effects (Bouquegneau et al. 1997; Law et al. 1997).

Levels of organochlorine contaminants in sperm whales killed off northwestern Spain were intermediate between the levels found in fin whales (Balaenoptera physalus) and small odontocetes, in the same region (Aguilar 1983). Also, the levels in females were consistently higher than those in males, a finding contrary to the typical findings in cetaceans. Placental and milk transfer from mothers to their young normally results in a net lowering of contaminant burdens in adult females. Given that male and female sperm whales are geographically separated during much of the year, it is possible that males feed in less polluted waters or perhaps on less contaminated prey than females.

Japanese scientists have investigated the hypothesis that sperm whales provide a medium for transporting radioactive cobalt (and other artificial radionuclides) from the deep seabed to surface waters. Umezu et al. (1984) showed that 60Co bio-accumulates in sperm whales (from their diet that includes mesopelagic cephalopods). The authors proposed that 60Co is dispersed in surface waters when the whales defecate there. The implications for the overall health of sperm whales were not considered.

G.5 Disease

Disease presumably plays a role in natural mortality of sperm whales, but little is known. Only two naturally occurring diseases that are likely to be lethal have been identified in sperm whales: myocardial infarction associated with coronary atherosclerosis, and gastric ulceration associated with nematode infection (Lambertsen 1997). The potential for parasitism to have a population level affect on sperm whales is largely unknown. Although parasites may have little effect on otherwise healthy animals, effects could become significant if combined with other stresses.

G.6 Marine Debris

Harmful marine debris consists of plastic garbage washed or blown from land into the sea, fishing gear abandoned by recreational and commercial fishers (see section G.1), and solid non-biodegradable floating materials (such as plastics) disposed of by ships at sea. Examples of plastic materials are bags, bottles, strapping bands, sheeting, synthetic ropes, synthetic fishing nets, floats, fiberglass, piping, insulation, paints and adhesives. Marine species confuse plastic bags, rubber, balloons and confectionery wrappers with prey and ingest them. The debris usually causes a physical blockage in the digestive system, leading to painful internal injuries. Given the limited knowledge about the impacts of marine debris on sperm whales, it is difficult to determine the extent of the threat to this species.

The bottom-feeding habit of sperm whales, which might involve a suction mechanism (as suggested by observations of apparently healthy sperm whales with deformed or broken jaws), indicates that they often ingest marine debris (Lambertsen 1997). The consequences can be debilitating and even fatal. One of 32 sperm whales examined for pathology in Iceland had a lethal disease thought to have been caused by the complete obstruction of the gut with plastic marine debris (Lambertsen 1990).

G.7. Oil and Gas Exploration and Other Industrial Activities

Drilling for oil and gas generally produces low-frequency sounds with strong tonal components. There are few data on the noise from conventional drilling platforms. Recorded noise from an early study of one drilling platform and three combined drilling production platforms found that noise was so weak it was almost not detectable alongside the platform at sea states of three or above. The strongest tones were at very low frequencies near 5 hertz, and received levels of these tones at nearfield locations were 119-127 decibels re 1μPa (Richardson et al. 1995).

A variety of devices and technologies exist which introduce energy into the water for purposes of geophysical research, bottom profiling, and depth determination. They are often characterized as high-resolution or low-resolution systems. Low-resolution systems such as 2-D and 3-D seismic surveys, put much more sound energy into the water and operate at low frequencies, which overlap those used by baleen whales. Odontocete reactions to seismic exploration have received little study. Sperm whales behavioral reactions to seismic pulses may occur at longer ranges, than baleen whales. Sperm whales in the Gulf of Mexico apparently moved away, possibly by 50+ km, when seismic surveys began (Mate et al. 1994). Also, sperm whales in the southern Indian Ocean ceased calling during some, but not all, seismic pulses that were received from an airgun array >300 km away (Bowles et al. 1994). These data are limited, but show that reactions of sperm whales and other odontocetes to seismic studies do occur (Richardson et al. 1995).

During exploration, noise is also produced by supply vessels and low-flying aircraft, construction work, and dredging. The transmission of aircraft sound to cetaceans or other marine mammals while they are in the water is influenced by the animal’s depth, the altitude, aspect, and strength of the noise coming from the aircraft, as well as by bottom characteristics and other factors. Generally, the greater the altitude of the aircraft, the lower the sound level received underwater.

Heezen (1957) documented marine mammal entanglement in submarine cables based on data from the late 1800s to 1955. All identified specimens were sperm whales. The author concluded that the sperm whales became entangled in extremely slack or looped cables while foraging along the seafloor. No instance of marine mammal entanglement in submarine cables has been documented since the 1950s (STARS 2002). Plow marks, possibly made by sperm whales bottom feeding, also suggest sperm whales are foraging in areas where cables are placed, and could potentially become entangled in underwater cables; however, improved route selection and burial technologies have reduced the threat of entanglement by minimizing looping in cables

Oil spills that occurred while sperm whales are present could result in skin contact with the oil, ingestion of oil, respiratory distress from hydrocarbon vapors, contaminated food sources, and displacement from feeding areas (Geraci, 1990). Actual impacts would depend on the extent and duration of contact, and the characteristics (age) of the oil. Most likely, the effects of oil would be irritation to the respiratory membranes and absorption of hydrocarbons into the bloodstream (Geraci, 1990). If a marine mammal was present in the immediate area of fresh oil, it is possible that it could inhale enough vapors to affect its health. Inhalation of petroleum vapors can cause pneumonia in humans and animals, due to large amounts of foreign material (vapors) entering the lungs (Lipscomb et al., 1994). Contaminated food sources and displacement from feeding areas also may occur as a result of an oil spill.

In recent years, many Liquefied Natural Gas (LNG) facilities have been proposed worldwide. The noise generated from construction and operation activities could affect marine mammals located within the vicinity of the project site. In addition, any increase in vessel traffic resulting from construction or operation of an LNG facility could negatively impact marine mammals migrating through the area.

G.8 Military Operations

Sperm whales are potentially affected by military operations in a number of ways. They can be struck by vessels and disturbed by sonar and other anthropogenic noise. In addition, their deep diving and large size make sperm whales potential false targets in submarine warfare (or target practice). Evidence suggests that strandings of another deep-diving, pelagic toothed whale, Cuvier's beaked whale (Ziphius cavirostris) is related to tests of Navy mid-range sonar and possibly Low Frequency Active (LFA) sonar in Greece, the Bahamas, and the Canary Islands (Frantizis 1998; Anon. 2001; Jepson et al. 2003; NOAA and U.S. Navy 2001; Freitas 2004; Fernandez 2004; Fernandez et al. 2005). The extremely loud signals (maximum output 230 decibels re 1 µPa) are in the frequency range of 250-3,000 hertz (Frantzis 1998), which is well within the likely range of sperm whale hearing. Similarly, mid-frequency sonar (e.g., U.S. Navy 53C) can produce equally loud sounds at frequencies of 2,000-8,000 hertz (Evans and England 2001), which are also likely to be heard by sperm whales. Clicks produced by sperm whales (and presumably heard by them) are in the range of < 100 hertz to as high as 30 kHz, often with most of the energy in the 2 to 4 kHz range (Watkins 1980). There have been no sperm whale strandings attributed to Navy sonar. However, the large scale and diverse nature of military activities in large ocean basins indicates that there is always potential for disturbing, injuring, or killing these and other whales.

Studies to assess the impact of loud low-frequency active sonar signals by the U.S. Navy continues under its Surveillance Towed Array Sensor System (SURTASS) Low Frequency Active (LFA) sonar program. The U.S. Navy completed a three-phase research program as the basis for an Environmental Impact Statement (EIS) on their SURTASS LFA sonar system. Phase I focused on the effects of the LFA signal on foraging blue whales in California; Phase II focused on the effects on migrating gray whales (Eschrichtius robustus) off California; and Phase III focused on its effects on humpback whales off Hawaii. These studies found that marine mammals exposed to the sound demonstrated no biologically significant response to the LFA sonar. A draft EIS was released for public comment in March 1999, and a final EIS was released in January 2001. A draft Supplemental EIS was released for public comment in November 2005, and a final Supplemental EIS is expected to be released in the last quarter of 2006. NMFS expects to reassess marine mammal impacts based on information contained in the Supplemental EIS in the next several months (Kenneth Hollingshead, pers. comm. 2006).

G.9 Research

Research activities may sometimes result in disturbance, but activities are closely monitored and evaluated in an attempt to minimize any impact of research necessary to the recovery of sperm whales. Research is likely to continue and increase in the future on sperm whales, especially for oceanographic surveys, the collection of genetic information, photographic studies, and acoustic studies. For example, studies of the responses of several whale species to the Acoustic Thermometry of Ocean Climate (ATOC) signal at Pioneer Seamount off Half Moon Bay, California, have been concluded. The ATOC project has been renamed the North Pacific Acoustics Lab (NPAL) and was authorized (in 2002) to operate an underwater sound source from Kaua'i, Hawaii for a period of five years (67 FR 6237; February 11, 2002). Preliminary analysis of data from Pioneer Seamount shows that whales observed during trials were distributed slightly farther from the source when it was activated, compared with when it was not. No other significant changes in behavior or distribution were observed.

G.10 Predation and Natural Mortality

Sperm whale calves are subject to predation by killer whales (Arnbom et al. 1987) and possibly large sharks (Best et al. 1984). However, an observation off California showed a prolonged and sustained attack by killer whales on a pod of sperm whales (mainly juveniles and females), resulting in the severe wounding and death of some of the individuals (Pitman and Chivers 1998). Recently, Moore and Early (2005) identified a type of cumulative bone necrosis in sperm whales that might be caused by the formation of nitrogen bubbles following deep dives and subsequent ascents.

G.11 Direct Harvest

Previously, the principal products driving the commercial hunt for sperm whales were sperm oil and spermaceti. The latter is a semi-liquid waxy oil found only in the head of the sperm and some other toothed whales (Norris and Harvey 1972; Rice 1989). Sperm oil, taken from the bodies of sperm whales, has special lubricant properties, and the spermaceti was originally prized for use in candle-making and illumination. Ambergris (a perfume fixative found occasionally in the lower intestines of male sperm whales; Gilmore 1969; Berzin 1972) and tooth ivory were valuable byproducts of sperm whale hunting. Sperm whale skin was used as low-grade leather in the Soviet Union (Berzin 1972). Having declined in the late 19th and early 20th centuries due to the increasing availability of petroleum for lubrication and lamp fuel, the demand for sperm oil and spermaceti in the manufacture of cosmetics and soaps and as machine oil greatly expanded after World War II (Berzin 1972; Rice 1989). Only in a few areas where coastal whaling has been conducted, notably in certain parts of Japan (Beary 1979; Brownell and Omura 1980), the West Indies (Price 1985), and Indonesia (Barnes 1991), has the meat of sperm whales been used regularly for human consumption.

On a global scale, the exploitation of sperm whales can be regarded in terms of two main eras - one the open-boat, sailing-vessel, hand-harpooning period from about 1715 to 1925; the other the modern period from about 1910 to the early 1980s (Best et al. 1984). The total take, worldwide, between 1800 and 1909 has been estimated as close to 700,000; that between 1910 and 1973 as close to 605,000 (Best et al. 1984).

The International Whaling Commission's (IWC's) current moratorium on commercial whaling for sperm whales throughout the North Atlantic and North Pacific has been in place for more than a decade, and it has almost certainly had a positive effect on the species' recovery. There is currently no legal commercial whaling for sperm whales in the Northern Hemisphere. The ongoing threat of commercial whaling was one of the primary factors in the decision to add the sperm whale to the list of Endangered and Threatened Wildlife. This threat is not likely to recur on a more than local scale in the foreseeable future. However, it is important to recognize that sperm whaling in the North Pacific was widespread and intensive as recently as the 1970s, and that the scale of removals was much larger than indicated in official whaling statistics. The ramifications of this recent whaling are uncertain, but give cause for concern.

Two nations whose activities are relevant to sperm whale conservation in the North Atlantic have withdrawn their membership in the IWC -- Canada in 1982 and Iceland in 1992. Iceland has subsequently rejoined the IWC and has announced plans to resume commercial whaling under a formal objection to the IWC moratorium. Norway has also filed an objection and is not bound by the IWC moratorium. Neither Norway nor Iceland have indicated a desire to take sperm whales. Whalers from the Azores and Madeira (both part of Portugal, not an IWC member), would not be legally bound by the IWC's current moratorium on commercial whaling. Future terms in the IWC Schedule under which commercial whaling could be resumed, would also not apply to whalers from these states. There is no evidence that whaling will resume in the Portuguese islands of the Azores and Madeira, even though Portugal remains outside any regulatory body. Canada has continued to ban whaling for the large baleen whales (except the bowhead, Balaena mysticetus) in its territorial waters under domestic regulations, and a resumption of sperm whaling in Canada is unlikely in the near future. Iceland has not resumed its hunting of fin, minke, sei (Balaenoptera borealis), or sperm whales at the time of this writing. Shore-based artisanal whaling in the West Indies may result in the killing of a few sperm whales in some years (Price 1985; Reeves 1988), but there is no reason to expect an immediate expansion in effort or increase in take there.

G.11.1 North Atlantic

The hunting of sperm whales began in New England in the early 1700s and spread by mid-century throughout the North Atlantic Ocean (Starbuck 1878). No detailed, comprehensive record has been compiled of the number of sperm whales taken, but the total kill by the multi-national sailing-vessel, open-boat hunt, including whales lost at sea after being killed or mortally wounded, would likely have been in the hundreds of thousands. Roughly 3,600 were taken (secured) by American pelagic whalers from 1900-1925 in the North Atlantic (including the Gulf of Mexico and Caribbean Sea) (Anon. 1981b).

In contrast, the record of kills by modern whalers (including the whalers at shore stations in the Azores and Madeira who continued using open-boat, hand-harpoon whaling techniques until the stations closed in the 1980s) is nearly complete. An attempted compilation of all catches in the North Atlantic north of 20°N from 1905 onward, gave totals of 28,728 males and 9,507 females taken (Anon. 1981a).

In the eastern and central North Atlantic (as far west as Iceland), nearly 30,000 sperm whales were killed between 1893 and 1975 (Jonsgård 1977). More than 16,500 of these were taken at the Azores between 1933 and 1975. The open-boat hunt for sperm whales at the Azores operated continuously from the 1830s to the 1980s, with a highest single-year catch of more than 700 animals (Clarke 1954; Martin and Ávila de Melo 1983; Avila de Melo and Martin 1985). Sperm whale hunting took place at Madeira from 1941 (Avila de Melo and Martin 1985) to 1981 (Klinowska 1991). Shore-based whalers from Portugal, Spain, and northwest Africa took close to 7,500 sperm whales between 1921 and 1980 (Sanpera and Aguilar 1992).

The exploitation of sperm whales in the western North Atlantic during the 20th century was comparatively low. It must be borne in mind, however, that pelagic whaling by sailing-ship whalers continued until the 1920s (Townsend 1935; Clarke 1954; Hegarty 1959), and their catches, many of which were made in the whaling grounds off the American coast (Reeves, unpublished data), have not been included in most statistical compilations. Canadian whalers based in Labrador and Newfoundland took about 424 sperm whales between 1904 and 1972, all of them males (Mitchell and Kozicki 1984). A total of 109 sperm whales, all males, were taken off Blandford, Nova Scotia, between 1964 and 1972 (Mitchell 1975; Mitchell and Kozicki 1984). Reported kills in Davis

Strait (off West Greenland), including both land-based and pelagic whaling, totaled 147 from 1924 to 1972 (Kapel 1979). Greenlanders consider sperm whale flesh unfit for human consumption and only poor-quality dog food. Sperm whales have been taken in small numbers in the West Indies by whalers using hand-harpoon, open-boat techniques (Price 1985; Reeves 1988).

G.11.2 North Pacific

The American pelagic sperm whale hunt reached North Pacific waters in the first quarter of the 19th century and remained active there for approximately a century (Starbuck 1878; Best 1983; Hegarty 1959). European whalers also whaled for sperm whales in the North Pacific through at least the first third of the 19th century, but then gave way to the American whalers (Stackpole 1972; Best 1983).

Shore whaling stations that became established following the advent of steam power and the invention of the exploding grenade harpoon, took sperm whales in Alaska (Reeves et al. 1985), British Columbia (Pike and MacAskie 1969), Washington (Scheffer and Slipp 1948), and California (Rice 1974; Clapham et al. 1997), as well as Japan, the Kurile Islands, and Kamchatka in the western North Pacific (Berzin 1972; Ohsumi 1980). Pelagic whaling for North Pacific sperm whales by factory ship operations began in the Soviet Union in 1932 and in Japan, soon after World War II. Peak annual catches by modern whaling before the war were less than 2,000, but after the war they reached more than 16,000 in 1968 (Ohsumi 1980). According to Ohsumi (1980), approximately 269,000 sperm whales were taken by modern whalers in the North Pacific between 1910 and 1976 (but see below regarding under-reporting and mis-reporting of catch data). Based on official statistics after 1947, the overall male:female ratio in the catches was about 3:1 (however, see below).

Data presented by Kasuya (1998) indicate large-scale manipulation of the post-war catch statistics in Japanese shore-based whaling, including not only the falsification of body lengths of under-sized whales and the under-reporting of catches, but also the deliberate listing of females as males. Soviet mis-reporting is also known to have occurred on a massive scale (Yablokov 1994; Zemsky et al. 1995). Brownell et al. (1998) estimated that the true catch of sperm whales by the USSR between 1949 and 1971 (the year before the IWC's international observer scheme came into effect) was about 180,000, or some 60% higher than was officially reported. Moreover, these authors surmised that the scale of under-reporting was much greater for females than for males - about 1.3 vs. 9.6 times, respectively. It is clear that previously reported totals and sex ratios for North Pacific sperm whale catches are wrong.

It has been suggested that the large 20th century catches of sperm whales in the North Pacific not only further reduced the population below its pre-exploitation level and (possibly) reduced pregnancy rates by reducing the number of breeding males (Whitehead 1987), but also may have (1) increased mortality within family units because key individuals were lost, making groups less able to defend themselves against killer whales and less adept at tracking resources; and (2) affected social structure, forcing depleted or fragmented pods to coalesce and form groups of mixed maternal lineages (Richard et al. 1996).

G.12 Competition for Resources

The prey species taken by sperm whales are also taken by other cetaceans. Thus, competitive interactions are possible; however, there is no basis for assuming that competition for food among these cetacean species is a factor in determining their population trend and abundance. Fishery-caused reductions in prey resources could also have an influence on sperm whale abundance.

G.13 Climate and Ecosystem Change

Climate change has received considerable attention in recent years, with growing concerns about global warming and the recognition of natural climatic oscillations on varying time scales, such as long term shifts like the Pacific Decadel oscillation or short term shifts, like El Niño or La Niña. Evidence suggests that the productivity in the North Pacific (Quinn and Neibauer 1995; Mackas et al. 1998) and other oceans, is affected by changes in the environment. Increases in global temperatures are expected to have profound impacts on arctic and sub-arctic ecosystems and these impacts are projected to accelerate during this century. The potential impacts of climate and oceanographic change on sperm whales will likely impact habitat availability and food availability. Site selection for whale migration, feeding, and breeding for sperm whales may be influenced by factors such as ocean currents and water temperature. There is some evidence from Pacific equatorial waters that sperm whale feeding success and, in turn, calf production rates are negatively affected by increases in sea surface temperature (Smith and Whitehead 1993; Whitehead 1997). This could mean that global warming (regardless of whether it is driven primarily by natural or anthropogenic processes) will reduce the productivity of at least some sperm whale populations (Whitehead 1997). Any changes in these factors could render currently used habitats areas unsuitable. Changes to climate and oceanographic processes may also lead to decreased productivity in different patters of prey distribution and availability. Such changes could affect sperm whales that are dependent on those prey.

H. Protective Legislation

Although minimum size limits of 38 feet for male and 35 feet for female sperm whales were included in the first regulations of the IWC, commercial whaling for this species was essentially unregulated until 1970, when quotas were introduced in the North Pacific Ocean (IWC 1971). Quotas were introduced in the Southern Ocean in 1971. Soon thereafter, catch limits were set separately for males and females. No catch limits were placed on sperm whales in the North Atlantic until 1977.

The IWC accorded sperm whales complete protection from commercial whaling by member states beginning with the 1981/82 pelagic fishing season and the 1986 coastal fishing season (IWC 1982). Japan formally objected to this whaling ban and continued its shore-based hunt through the 1987 season, after which its objection was withdrawn and this hunt ceased (IWC 1989). Currently, Japan takes a small number of sperm whales each year under an IWC exemption for scientific research. Norway and Iceland have formally objected to the IWC ban on commercial whaling and are therefore free to resume hunting sperm whales under IWC rules, but neither country has expressed an interest in taking sperm whales. Although commercial in nature, sperm whale hunting at the Azores and Madeira in the North Atlantic was exempt from IWC regulation because Portugal, which owned these islands, was not a member of the IWC. Shore-based whaling continued at the Azores until the 1980s.

In U.S. waters, sperm whales are currently protected under both the ESA and the MMPA. The species is classified as Vulnerable in the World Conservation Union (known as the IUCN) Red List of Threatened Animals, meaning that it is “facing a high risk of extinction in the wild in the medium-term future” (Baillie and Groombridge 1996). The criterion used for this classification was that the aggregate world population of the species had been reduced by at least 20% over the last three generations (i.e., since the first half of the 20th century, a sperm whale generation being at least 20 years). The sperm whale is also listed in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (known as CITES). The CITES clarification is intended to ensure that no commercial trade products of sperm whales occurs across international borders.

The total take of sperm whales worldwide between 1800 and 1909, has been estimated as close to 700,000 and between 1910 and 1973, as close to 605,000 (Best et al. 1984). There is large evidence of large-scale mis-reporting of whaling data from Soviet factory ships (Yablokov 1994; Zemsky et al. 1995). Kasuya (1998) also reported that post-war catch statistics from Japanese shore-based whaling also provided inaccurate data. It is clear that previously reported totals and sex ratios for North Pacific sperm whale catches are wrong, and it seems likely that the officially reported data from other areas, will prove to be equally unreliable.

II. RECOVERY STRATEGY

The main direct threat to sperm whales was addressed by the International Whaling Commission whaling moratorium, and an important element in the strategy to protect sperm whale populations is to continue the effective international regulation of whaling.

Another important component of this recovery program is to determine population structure of the species and population discreteness. This would be a first step in estimating population size, monitoring trends in abundance, and enabling an assessment of the species throughout its range.

Another element of the strategy is to identify factors that may limit population growth and determine actions necessary to allow the populations to increase. Potential threats to sperm whale populations include collisions with vessels, entanglement in fishing gear, reduced prey abundance due to overfishing, habitat degradation, and disturbance from low-frequency noise. In addition, the possible effects of pollution on sperm whales should be identified, as they remain poorly understood.

Because sperm whales move freely across international borders, it would be unreasonable to confine recovery efforts to U.S. waters, and this plan stresses the importance of a multinational approach to management. The plan recognizes the limits imposed by the national nature of protective legislation. As demonstrated by recent work on humpback whales, Structure of Populations, Levels of Abundance and Status of Humpbacks (SPLASH) and the Year of the North Atlantic Humpback (YONAH), involving a number of researchers from different countries (Palsbøll et al. 1997; Smith et al. 1999), considerably more information is gathered for management of whale populations when research is conducted on the basis of biological, rather than political, divisions and through multilateral cooperation. Ideally, both research and conservation should be undertaken at oceanic rather than national levels.

Although not an explicit goal, the Plan is also expected to help achieve the MMPA's purpose of maintaining marine mammal populations at optimum sustainable levels.

III. RECOVERY GOALS AND CRITERIA

A. Goals

The goal of this Plan is to promote recovery of sperm whale populations to levels at which it becomes appropriate to downlist them from endangered to threatened status, and ultimately to remove them from the list of Endangered and Threatened Wildlife and Plants, under the provisions of the ESA. The ESA defines an "endangered species" as "any species which is in danger of extinction throughout all or a significant portion of its range." A "threatened species" is defined as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range."

B. Criteria

Recovery criteria take two forms: (1) Criteria that indicate effective management and elimination of threats, and (2) criteria that reflect the status of the species itself. The latter criteria may include population numbers, sizes, trends, distribution, recruitment rates, and other population information, or they may explicitly state a certain risk of extinction as a threshold for downlisting or delisting and use models to assess whether this threshold has been reached. In this recovery plan, we have provided options for using available population levels and trend information (1.a.) or a model such as a PVA to assess extinction risk (1.b.). Because sperm whales currently occur in large numbers (at least a hundred thousand in each ocean basin) but it is unlikely that they're near pre-exploitation estimates, the trend required for the first recovery criterion (1.a.) is that the whales are stable or increasing. This is believed to be reasonable because a stable population would reflect populations of a reasonable size, yet increases in numbers are possible as it's unlikely they're near carrying capacity based on pre-exploitation estimates (although their prey base may limit such growth). For either the PVA-based criteria or the population trend criteria, we require that the analysis be done and the criteria met for each ocean basin within which sperm whales occur, i.e., Atlantic, Pacific and Southern Oceans. This should ensure that the species will persist within a significant portion of its range, thus meeting the intent of the ESA.

With regard to the PVA-based criterion, guidance on appropriate levels of risk for listing and down-listing decisions was developed in a workshop for large cetaceans. This guidance was employed in the North Atlantic Right Whale Recovery Plan criteria and is also appropriate here. A probabilistic framework was suggested as follows: A large cetacean species shall no longer be considered endangered when, given current and projected conditions, the probability of extinction is less than 1% in 100 years; and a large cetacean species shall no longer be considered threatened when, given current and projected conditions, the probability of becoming endangered is less than 10% in a period of time no shorter than 10 years and no longer than 25 years, with the period depending on the volatility of the dynamics of the population, the power of monitoring to detect changes and the expected response time of the management agency (Angliss et al. 2002). In the case of the sperm whale the period of 25 years is considered necessary to estimate trends in abundance. Both of these would also address threats to the species and recurrence of threats that brought the species to the point that warranted listing.

The primary purpose of the Plan is to identify actions that will minimize or eliminate effects from human activities that are detrimental to the recovery of sperm whale populations. Immediate objectives are to identify factors that may be limiting abundance, and actions necessary to allow the populations to increase. Although not an explicit goal, the Plan is also expected to help achieve the MMPA's purpose of maintaining marine mammal populations at optimum sustainable levels.

B.1 Downlisting Criteria

Sperm whales may be considered for delisting when the following criteria are met:

1.a. The overall population in each ocean basin (North Atlantic, North Pacific, and Southern Hemisphere Oceans) has remained stable or increased for at least 40 years (1.5 generations assuming 26.5 years/generation); or

1.b. Given current and projected threats and environmental conditions, the overall sperm whale population in each ocean basin in which it occurs (Atlantic, Pacific, and Indian Ocean) satisfies the risk analysis standard for threatened status (has no more than a 1% chance of quasi-extinction in 100 years). (These analyses should expressly indicate the assumptions, goals, uncertainties and approximations of the models used, include sensitivity analyses of parameters and assumptions, and be peer reviewed before being accepted as criteria); and

2. Factors that may limit population growth have been identified and are being or have been addressed to the extent that they allow for continued growth of populations. Specifically, the factors in 4(a)(1) of the ESA are being or have been addressed:

Factor A: The present or threatened destruction, modification or curtailment of a species' habitat or range.
- Fishing gear interactions have been identified and action is being taken to address problems, where necessary. Fishing gear interactions to be investigated include interactions with drift gillnet, longline, and any other gear determined to have an effect on sperm whale populations.
- Effects of reduced prey abundance are identified and action is being taken to address the issue, if necessary.
- Effects of vessel interactions (ship collisions, noise, pollution, disturbance) have been identified and actions are being or have been taken to address the issues, where necessary.
- Effects of anthropogenic noise are being or have been have been investigated and actions taken to minimize potential effects.

Factor B: Overutilization for commercial, recreational or educational purposes.
- Directed human kills (commercial, subsistence and scientific) are being managed on a sustainable basis by the IWC.

Factor C: Disease or Predation.
- Disease and predation have been investigated and determined not to be appreciably affecting the recovery of the species.

Factor D: The inadequacy of existing regulatory mechanisms.
- The IWC is continuing to regulate directed take of whales on a sustainable basis.
- The ESA, MMPA and other applicable laws (e.g., other U.S. laws and laws of other nations that regulate take within their EEZ) are adequately regulating takes of whales

through vessel collisions and fishing interactions.

Factor E: Other natural or manmade [sic] factors affecting its continued existence.

- Other natural or anthropogenic factors have been investigated and determined not to be limiting the recovery of the species.

B.2 Delisting Criteria

Sperm whales shall be considered for delisting when the following criteria are met:

1.a. The overall population in each ocean basin (North Atlantic, North Pacific, and Southern Hemisphere Oceans) is determined to have been stable or increased for at least 80 years (3 generations); or

1.b. Given current and projected threats and environmental conditions, the overall sperm whale population in each ocean basin in which it occurs (Atlantic, Pacific, and Indian Ocean) satisfies the risk analysis standard for threatened status (has no more than a 1% chance of quasi-extinction in 100 years). (These analyses should expressly indicate the assumptions, goals, uncertainties and approximations of the models used, include sensitivity analyses of parameters and assumptions, and be peer reviewed before being accepted as criteria); and

2. Factors that may limit population growth have been identified and are being or have been addressed to the extent that they allow for continued growth of populations. Specifically, the factors in 4(a)(1) of the ESA are being or have been addressed:

Factor A: The present or threatened destruction, modification or curtailment of a species' habitat or range.

- Fishing gear interactions have been identified and actions taken to address the problems have been proven effective, in that they allow for continued growth of the population. Fishing gear interactions to be investigated include interactions with drift gillnet, longline, and any other gear determined to have an effect on sperm whale populations.
- Effects of reduced prey abundance have been identified, and actions taken to address prey abundance are shown to be effective, i.e., reduced prey abundance is determined not to affect sperm whale populations.
- Effects of vessel interactions (ship collisions, noise, pollution, and disturbance) have been identified and actions being or having been taken to address the issues shown to be effective, i.e., have been determined not to have an effect on sperm whale populations.
- Effects of anthropogenic noise have been investigated and actions being or having been taken to minimize potential effects have proven effective, allowing for the continued growth of the population.

Factor B: Overutilization for commercial, recreational or educational purposes

- Whaling and subsistence take is managed on a sustainable basis by the IWC and directed take in U.S. waters is in accordance with the MMPA, i.e., managed for Optimum Sustainable Populations.

Factor C: Disease or Predation

- Disease and predation have been investigated and determined not to be appreciably affecting the recovery of the species

Factor D: The inadequacy of existing regulatory mechanisms

- The IWC is continuing to regulate directed take of whales on a sustainable basis.
- The MMPA and other applicable laws (e.g., other U.S. laws and laws of other nations that regulate take within their EEZ) are adequately regulating takes of whales through vessel collisions and fishing interactions.

Factor E: Other natural or manmade [sic] factors affecting its continued existence.

- Other natural or anthropogenic factors have been investigated and determined not to be limiting the recovery of the species.

IV. RECOVERY PROGRAM

A. Recovery Action Outline

Items in this outline are not in order of priority. Priorities are identified in the Implementation Schedule below.

1.0 Coordinate State, Federal, and International Actions to Implement Recovery Actions and Maintain International Regulation of Whaling for Sperm Whales.

1.1 *Cooperate with the IWC (and other relevant international bodies or agreements) to ensure that any resumption of commercial whaling on sperm whales is prosecuted on a sustainable basis and that all whaling activity is conducted within the purview of the IWC (i.e., there is no "pirate" whaling).*

1.2 *Identify representatives of the scientific community and of private, state, and federal agencies (and international agencies where applicable) to periodically review and update this Recovery Plan.*

2.0 Determine Population Discreteness and Population Structure of Sperm Whales.

2.1 *Support existing studies and initiate new studies to investigate population discreteness and population structure of sperm whales using genetic analyses.*

2.2 *Assess daily and seasonal movements and inter-area exchange, using telemetry and photo-identification.*

2.3 *Support ongoing studies and initiate new studies to investigate social structure and how it influences population structure.*

3.0 Develop and Apply Methods to Estimate Population Size and Monitor Trends in Abundance.

3.1 *Conduct surveys to estimate abundance and monitor trends in sperm whale populations worldwide.*

4.0 Conduct Risk Analyses.

4.1 *Conduct risk analyses for Atlantic and Pacific.*

4.2 *Conduct risk analyses for the Indian Ocean.*

5.0 Identify and Protect Habitat Essential to the Survival and Recovery of Sperm Whale Populations in U.S. Waters and Elsewhere.

5.1 *Promote actions to define, identify, and protect important habitat in U.S. waters.*

5.2 *Promote actions to define, identify, and protect important habitat in foreign or international waters.*

5.3 *Improve knowledge of sperm whale feeding ecology.*

5.4 *Improve Knowledge about the characteristics of important sperm whale habitat, and how these whales use such areas.*

6.0 Investigate Causes and Reduce the Frequency and Severity of Human-caused Injury and Mortality.

6.1 *Identify areas where concentrations of sperm whales coincide with significant levels of maritime traffic, fishing, or pollution.*

6.2 *Investigate the significance of mortality and serious injury from ship collisions, interactions with fishing gear including the extent of depredation, and retaliatory actions by fishermen.*

6.3 *As appropriate following 6.2, implement measures to reduce the frequency and severity of these kinds of human-whale interactions.*

6.4 *Conduct studies of environmental pollution that may affect sperm whale populations and their prey.*

7.0 Determine and Minimize Any Detrimental Effects of Anthropogenic Noise in the Oceans.

7.1 *Support ongoing and additional studies to evaluate the effects of sound on sperm whales.*

7.2 *Implement appropriate regulations on sound-production activities which are found to be potentially detrimental to sperm whales, until otherwise demonstrated.*

8.0 Maximize Efforts to Acquire Scientific Information from Dead, Stranded, and Entangled or Entrapped Sperm Whales.

8.1 *Maintain the system for reporting dead, entangled, or entrapped sperm whales.*

8.2 *Improve the existing programs to maximize data collected from dead sperm whales.*

9.0 Develop Post-Delisting Monitoring Plan.

B. Recovery Action Narrative

1.0 Coordinate State, Federal, and International Actions to Implement Recovery Actions and Maintain International Regulation of Whaling for Sperm Whales.

A coordinated approach to the tasks described in this Plan would greatly facilitate their completion. The establishment of a team charged with coordinating state and federal implementation efforts, and with pursuing international cooperative efforts, is highly desirable. Liaison efforts between the team and the lead agency would be the responsibility of the designated individual from the latter body.

> 1.1 *Cooperate with the IWC (and other relevant international bodies or agreements) to ensure that any resumption of commercial whaling on sperm whales is prosecuted on a sustainable basis and that all whaling activity is conducted within the purview of the IWC (i.e., there is no "pirate" whaling).*
>
> The international regulation of commercial whaling is vital to recovery efforts. This is particularly true for sperm whales because of their wide distribution, far-ranging movements, and high commercial value. The IWC's Revised Management Procedure was developed for use with baleen whale populations and has yet to be adapted for toothed whales. Therefore, even if the resumption of carefully managed exploitation of sperm whales were to be justified on the basis of relatively large and productive populations in particular areas, the lack of an agreed international scheme for monitoring and regulating the take would preclude the U.S. government from supporting such a presumption. Pending results of studies outlined under 3.0, below, it is precautionary to assume that sperm whale populations in U.S. North Atlantic and North Pacific waters range into international waters and into waters under the jurisdictions of other countries. Therefore, an international regime for managing any directed exploitation is essential. This imperative applies equally to the issue of international trade in sperm whale products (e.g., under CITES).
>
> 1.2 *Identify representatives of the scientific community and of private, state, and federal agencies (and international agencies where applicable) to periodically review and update this Recovery Plan.*
>
> As this plan is implemented, new information will be obtained and the priorities of implementing agencies will accordingly require periodic review and revision. Representatives of the relevant agencies and scientific community should be appointed to revise the Plan every five years for the first 15 years of implementation, and every ten years thereafter. This schedule would, of course, be subject to change in the event of resumed or expanded whaling for sperm whales, or if the scale of some other threat (e.g., pollution, fishery interactions) were found to have increased rapidly.

2.0 Determine Population Discreteness and Population Structure of Sperm Whales.

Existing knowledge of the population structure of sperm whales is insufficient, and a more nearly comprehensive understanding is essential for developing strategies to promote recovery and for classifying the populations according to their recovery status. Sperm whales were listed under the since 1970 under the precursor to the ESA) and the remained on the list of threatened and endangered species after the passage of the ESA in 1973. In 1996, the Policy Regarding the Recognition of Distinct Vertebrate Population Segments (DPS) (61 FR 4722), stated that ``Any Distinct Population Segment of a vertebrate taxon that was listed prior to implementation of the DPS policy will be reevaluated on a case-by-case basis as recommendations are made to change the listing status for that distinct population segment." It is certain that the global listing of sperm whales inadequately captures the current levels of population structure protected under the ESA, which list species, sub-species, and DPSs. Because threats and levels of past exploitation differ at least at the Ocean Basin level, defining DPSs should promote more appropriate recovery actions and allow more efficient future considerations of whether sperm whales should be down- or de-listed. Existing knowledge of the population discreteness is insufficient, and a more nearly comprehensive understanding is essential for classifying sperm whale DPSs, according to their recovery status, and developing strategies to promote recovery, where necessary.

To the maximum extent possible, data should be collected in such a way that comparisons with historical data are practicable. It may be necessary to develop calibration methods so that results of studies using new or recent techniques, can be compared with those obtained using more traditional ones. Analyses should be directed at examining trends over time, and attempts should be made to correlate observed changes in sperm whale populations with physical, biological, or human-induced changes in the environment. Data collected through any research outlined in this Plan should be analyzed and reported in a timely manner. Reports should be thoroughly referenced and follow standards of organization to facilitate comparison with other reports. As much as possible, data should be presented in peer-reviewed journals and other open publications to ensure that research programs benefit from regular peer scrutiny.

2.1 *Support existing studies and initiate new studies to investigate population discreteness and population structure of sperm whales using genetic analyses.*

Initial investigations of genetic population structure of sperm whales, based on mitochondrial DNA, indicated genetic relatedness within groups but relatively little geographic structure (Dillon 1996, Lyrholm and Gyllensten 1998). The suggestion of low genetic differentiation should not be accepted without first exploring other types of analyses and interpreting the results within a demographic, behavioral, morphological, or comparative context (Baker and Palumbi 1997; Whitehead and Mesnick 2003a,b). As discussed by Taylor and Dizon (1996), until analyses with sufficient power are applied, the precautionary assumption should be that structuring exists, and reasonable provisional management units should be recognized on the basis of catch history, sighting distribution, and other data. Preliminary investigations of calving seasonality suggest, for example, that the sperm whales in the Gulf of California, Mexico, are on a different schedule from those in the California Current system (B.L. Taylor, pers. comm. 2006). Moreover, the year-round presence of sperm whales in some areas (e.g., northern Gulf of Mexico) suggests that there may be "resident' populations in certain productive coastal areas.

Over the past decade, several additional authors have investigated population structure in sperm whales using sequence variation within the mitochondrial control region DNA (mtDNA) and/or polymorphic nuclear loci (microsatellites). In general, results tend to find low genetic differentiation among ocean basins and little evidence of subdivision within ocean basins, with the exception of some isolated basins such as the Mediterranean and Gulf of Mexico (Dillon 1996; Lyrholm and Gyllensten 1998; Mesnick et al. 1999a,b; Bond 1999; Lyrholm et al. 1999; Engelhaupt 2004). However, several problems hinder these studies, such as low sample sizes, low mtDNA haplotypic diversity, and social structure, which alone and together reduce the power to detect population structure. A priori definition of strata is problematic and hypotheses of structure may be based on geographic, oceanographic, ecologic and cultural designations (Whitehead and Mesnick 2003a,b). Informative models may also be based on historical calving grounds, contaminant measures, scarring patterns. To address the potential bias due to relatedness within groups, novel analytical approaches are needed (Taylor and Mesnick, manuscript). Although it will be more difficult to obtain samples of sufficient size, population structure in males will be particularly interesting to address in comparison to the pattern of structure in females (Bond 1999).

The low mtDNA diversity in sperm whales requires that studies using this marker have large sample sizes. Mesnick et al. (2005) compiled over 2,473 tissue samples and 1,038 mtDNA sequences. While sufficient sampling exists to get a rough idea of scale, sample gaps remain large, particularly in the North Atlantic, Western Pacific and southern hemisphere. This compilation is remarkable for its low diversity: 24 variable sites defined 28 haplotypes worldwide. The three most common haploytpes ("a", "b" and "c") comprise 82% of the total; 39% are "a". Several hypotheses for the lack of diversity have been proposed (Lyrholm et al. 1996; Whitehead 1999; Hyde et al. 2001; Amos 1999; Tiedemann and Milinkovitch 1999).

Sperm whales are found in sufficient densities off the Atlantic, Gulf of Mexico, and Pacific coasts of North America, thereby making biopsy sampling at sea an efficient way of supplementing tissue samples obtained from stranded whales. Such sampling should be routinely integrated into sighting surveys, regardless of whether these are dedicated sperm whale surveys or surveys for other species. Collaborative efforts with foreign agencies and researchers will probably be necessary to obtain sufficient samples at the appropriate geographic scale (ocean basin). Standard sampling protocols and analytical procedures should be used to ensure that results are conclusive. All biopsy samples should be preserved in such a way that the accompanying blubber can be used for diet and contaminant analyses (items 4.3 and 5.4). A central repository for sperm whale tissue samples would facilitate research.

A parallel initiative should be undertaken to ensure that preserved samples from whales killed by the whaling industry in the past are made available for genetic analyses, and that maximum use be made of these samples to elucidate population-identity issues. A very large sample of sperm whale tissues, including specimens from the eastern, central, and North Pacific, exists in Japan. These tissues were collected routinely as Japanese vessels hunted sperm whales in the 1960s to early 1980s throughout the North Pacific.

2.2 *Assess daily and seasonal movements and inter-area exchange, using telemetry and photo-identification.*

Telemetry studies using satellite-linked and VHF radio tags are needed to investigate patterns and ranges of daily, seasonal, and longer-term movements of individual sperm whales. Exchange rates between populations might also be addressed to some degree by telemetry studies such as those currently being conducted under the SWSS program in the Gulf of Mexico (Jochens and Biggs 2004).

Photo-identification of sperm whales, primarily by reference to features of the trailing edges of their flukes, has been used for population studies in several parts of the world (e.g., Whitehead and Gordon 1986; Arnbom 1987; Dufault and Whitehead 1995; Jaquet et al. 2003). It may not be realistic to use photo-identification of sperm whales in U.S. waters for mark-recapture population estimation, or even for detailed investigations of social organization and behavior. However, opportunistic efforts to photo-document sightings could contribute to knowledge of individual animal movements and residency times. For example, Jaquet et al. (2003) documented the movement of 7 sperm whales from the Galapagos Islands to the Gulf of California. A central repository for sperm whale fluke (and other) photographs, and a system for curating and analyzing them, should be established. Photographs should be supplemented whenever possible by tissue samples (whether sloughed skin or biopsies), for DNA fingerprinting (Amos and Hoelzel 1990).

2.3 *Support ongoing studies and initiate new studies to investigate social structure and how it influences population structure.*

Whitehead et al. (1998) used acoustic dialects, fluke markings and genetics (mtDNA haplotypes) to test for geography-based population structure of sperm whales in the South Pacific. Although no such structure was found, the approach used by those authors, if applied more intensively and on a larger geographic scale, could help elucidate the process of population differentiation (or lack of differentiation) in sperm whales.

Rendell et al. (2005, 2006) examined mitochondrial DNA variation among vocal clans of sperm whales from social groups sampled from three broad areas of the Pacific (Chile/Peru, Galapagos/Ecuador, and the SW Pacific). The authors found that acoustic dialect showed greater genetic structure than geography, Coda dialects could be especially significant as they directly describe an apparently important type of non-geographical population structure.

As noted above, to address the potential bias due to relatedness within groups, novel analytical approaches are needed (Taylor and Mesnick, manuscript). Sperm whales have a complex social structure with the observed “group” of females and immatures being temporary associations between more stable social “units” and with breeding males roving between female groups, although important elements of the mating system are also unknown (Christal and Whitehead 2001; Whitehead 2003). At present, there is no known genetic evidence of a strictly or largely matrilineal unit or group of sperm whales. Rather, genetic results suggest that groups of female and immature sperm whales generally contain more than one matriline, as indicated by the presence of multiple mtDNA haploytpes. Both "groups" and "units" contain clusters of closely related animals, but some individuals have no close relations. These results are consistent across 50+ groups sampled at sea and in strandings in four different ocean basins (Richard et al. 1996; Christal 1998; Bond 1999; Lyrholm et al. 1999; Mesnick 2001; Mesnick et al. 2003; Engelhaupt 2004). Groups from areas without a significant whaling history (e.g., the western North Atlantic) will be particularly valuable in addressing whether the non-matrilineal structure is an artifact of removal by commercial whaling. Less is known about relatedness among males. Analyses of stranded groups of subadult males find predominantly unrelated individuals. However, there were cases for half-siblings within each of the two groups (Bond 1999; Engelhaupt 2004).

3.0 Develop and Apply Methods to Estimate Population Size and Monitor Trends in Abundance.

Assessment of the recovery status of sperm whales requires reliable estimates of abundance and information on trends. The complexity of the sperm whale’s migratory behavior, involving major differences between sex and age classes; its proclivity for deep, prolonged dives; and its extremely wide geographic distribution, make population size estimation particularly challenging. Various methods have been used for sperm whales, including population modeling based on whaling data, acoustic and visual shipboard surveys, and visual aerial surveys. Mark-recapture estimation from photographic or genetic (biopsy) data is another approach that deserves consideration. More developmental work is needed to evaluate and compare methodologies.

3.1 *Conduct surveys to estimate abundance and monitor trends in sperm whale populations worldwide.*

Initial survey efforts in the western North Atlantic and Gulf of Mexico (Waring et al. 1997) and the eastern North Pacific (Barlow et al. 1997; Barlow and Taylor 2005) provide a baseline for population assessment. These programs should be continued and expanded geographically and perhaps temporally, with surveys designed explicitly to provide indices of sperm whale population abundance and trends. For meaningful estimates of entire populations, it will be necessary to conduct cooperative surveys with foreign scientists in non-U.S. waters. Findings from the population structure studies outlined under item 2.0 will be needed for meaningful interpretation of survey results. Because of the relatively long generation time of sperm whales, and the time scales on which environmental factors affecting their distribution and abundance may operate, programs to monitor trends in their populations must involve long-term commitments.

4.0 Conduct Risk Analyses

Risk analyses incorporate known and projected risks into a population projection. Given the large uncertainties in abundance and population growth rate, such uncertainties should also be directly incorporated into population projections. The output will be the probability of extinction over time for use in the down and delisting criteria.

Generally accepted classification criteria do not exist. Sperm whales present a special difficult case in assessing risk to the species because of their worldwide and nearly continuous distribution. A workshop may be needed to address how to treat uncertainty in population structure in risk assessment.

4.1 *Conduct risk analyses for Atlantic and Pacific.*

Conduct simulations for Criterion 1b) to estimate risk of extinction. Two essential pieces of required data are minimum abundance estimates will be needed for a significant portion of the range together with some estimates on trends in abundance.

4.2 *Conduct risk analyses for the Indian Ocean.*

Conduct simulations for Criterion 1b) to estimate risk of extinction. Two essential pieces of required data are minimum abundance estimates will be needed for a significant portion of the range together with some estimates on trends in abundance. This action is separated because no data currently exist for a risk analysis so the analysis is anticipated to occur at a much later date.

5.0 Identify and Protect Habitat Essential to the Survival and Recovery of Sperm Whale Populations in U.S. Waters and Elsewhere.

Areas where sperm whales are consistently seen and heard are assumed to be important to their survival. Areas used infrequently or for short periods may also be linked to population fitness. Habitat characterization involves, among other things, descriptions of prey types, densities, and abundances, and of associated oceanographic and hydrographic features. Inter-annual variability in habitat characteristics, and in sperm whale habitat use, are important components of habitat characterization. Researchers in many different areas have begun to explore the correlations between sperm whale occurrence and habitat features (Jaquet and Whitehead 1996; Jaquet et al. 1996, 1998; Waring et al. 1993; Davis et al. 1998; Hooker et al. 1998). More research is needed to define rigorously and specifically the environmental features that make an area important to sperm whales. A predictive framework for identifying potentially important sperm whale habitat would be a useful management tool. Some areas are known to be important habitat while others may be discovered during survey work discussed in sections 2.0 and 3.0, above. Protection of such areas is essential to the full recovery of sperm whale populations.

5.1 *Promote actions to define, identify, and protect important habitat in U.S. waters.*

Sperm whales occupy vast portions of the outer continental shelf and slope regions off the U.S. Atlantic, Gulf of Mexico, and Pacific coasts (Waring et al. 1997; Barlow et al. 1997). They also occur regularly in discrete areas, such as the vicinity of the Mississippi Canyon in the north-central Gulf of Mexico (Davis et al. 1998) and a small area of the continental shelf southeast of Montauk, New York (Scott and Sadove 1997). Any action that protects marine offshore habitat from noise and chemical contamination, or that reduces the intensity of ship traffic, fishing, military activities, and resource exploration and exploitation in the deep waters used by sperm whales, should benefit these animals. Efforts to protect the habitat of other endangered species, particularly blue and sei whales, which share much of the sperm whale's offshore habitat, should also benefit sperm whales.

5.2 *Promote actions to define, identify, and protect important habitat in foreign or international waters.*

Cooperative efforts should be made with foreign governments, such as those of Mexico, Canada, and the Caribbean states, to protect sperm whale habitat within their EEZ's, and to join multi-national efforts on behalf of marine habitat protection. Because of the very wide-ranging movements of individual sperm whales (demonstrated by tag returns) and the species' extensive distribution in both the North Pacific and North Atlantic, international initiatives to reduce pollution and protect resources on the high seas may be key to the long-term conservation of sperm whale populations.

5.3 *Improve knowledge of sperm whale feeding ecology.*

Improved knowledge of sperm whale feeding ecology would be useful for evaluating or predicting interactions with fisheries and the effects of shifts in prey abundance or distribution caused by climatic fluctuations. Directed studies of sperm whale feeding ecology are especially challenging. The whales are usually distributed far offshore (at least in areas where the shelf is wide) and feed at considerable depth on cephalopod species which are themselves difficult to sample and study. Most of what is known about sperm whale feeding has come from examinations of stomach contents of killed whales. Innovative approaches to studying sperm whale feeding ecology should be encouraged. For example, Whitehead et al. (1989) and Smith and Whitehead (1993) used observed defecation rate as an index of "feeding success" in sperm whales near the Galápagos and related this index to oceanographic conditions. In a separate study, Jaquet et al. (1996) compared 19th century sperm whale distribution in the tropical Pacific (based on whaling catch positions) to satellite-derived pigments. They found that chlorophyll concentration was a good indicator of sperm whale distribution, regardless of spatial scale. Similar analyses have not been published for areas of the North Atlantic and North Pacific. Stable isotope tracers in blubber fatty acids have been used to study the diets of other cetacean species (e.g., Ostrom et al. 1993; Abend and Smith 1995, 1997). Similar work should be conducted with sperm whales using biopsy samples (see 2.1).

5.4 *Improve knowledge about the characteristics of important sperm whale habitat, and how these whales use such areas.*

Characterization of habitat that is used intensively by sperm whales, or alternatively is used infrequently or for short periods but for purposes linked to population fitness, is essential. Only with information on the ecological needs of the species will managers be able to provide necessary protection. Such characterization would include prey types, densities, and abundances along with the associated oceanographic and hydrographic features. Studies to determine inter-annual variability in sperm whale habitat use and habitat characteristics are an important component of such research. Ultimately, the goal should be to develop a predictive framework for identifying potentially important sperm whale habitat.

6.0 Investigate Causes and Reduce the Frequency and Severity of Human-caused Injury and Mortality.

Known or suspected types of anthropogenic mortality and injury in sperm whales include, ship strikes, entanglement or entrapment in fishing gear, and retaliatory measures taken by fishermen who regard the whales as threats to their livelihood. Studies of the circumstances leading to collisions with ships and fishing gear and to harmful actions by fishermen are required before appropriate measures can be developed to reduce the impacts on sperm whales.

6.1 *Identify areas where concentrations of sperm whales coincide with significant levels of maritime traffic, fishing, or pollution.*

Available evidence does not indicate that shipping-related and fishery-related mortality is affecting recovery in U.S. waters, although it is not known what negative effects, if any, observed sub-lethal impacts may have on sperm whales (Ioup et al. 2005). Nevertheless, given the usually offshore distribution of sperm whales, geographical expansion of existing observational effort would be necessary to achieve a comprehensive understanding of the frequency of ship strikes and entanglements. Studies to quantify the volume and type of ship traffic, fisheries, and pollution in areas known to be important to sperm whales would provide a useful perspective on the potential seriousness of these threats.

6.2 *Investigate the significance of mortality and serious injury from ship collisions, interactions with fishing gear including the extent of depredation, and retaliatory actions by fishermen.*

A broad-scale, systematic review of data on sperm whale interactions with ships and fishing operations would be useful. From such a review, it should be possible to make a preliminary evaluation of what types of ship traffic, fisheries, and fishing gear pose the greatest risk to sperm whales. Data from areas outside U.S. waters could be useful for strengthening inferences and extrapolations.

On going collaborative projects in Alaska are investigating the extent and etiology of depredation (Sigler et al. 2003; Straley et al. 2005). Data from fisheries surveys as well as in-depth investigations with acoustic monitoring will document the scope and dynamics of the interactions and be valuable for developing a deterrence system before serious injuries and mortalities occur.

6.3 *As appropriate following 6.2, implement measures to reduce the frequency and severity of these kinds of human-whale interactions.*

The practicality and effectiveness of options to reduce ship strikes, entanglements, and other harmful interactions between sperm whales and human activities should be assessed. Methods and measures developed for other endangered whales (e.g., right whales) should be considered for their possible application to sperm whales.

6.4 *Conduct studies of environmental pollution that may affect sperm whale populations and their prey.*

The inconclusive, but worrisome, nature of studies related to contaminants in sperm (and other toothed) whales makes it difficult to develop (and justify) measures to reduce their risks of exposure. Research is needed on the long-term and trans-generational effects of various contaminants on the whales themselves and on their prey. It should be extended to include studies of metabolic pathways and the influence on contaminant burdens of sex, reproductive condition, and geographic origin. Biopsy samples collected under item 2.1 (above) will be usable for some of this work. The Ocean Alliance collected over 1,200 sperm whale biopsy samples during the five-year, round-the-world voyage of the RV Odyssey, and plans exist to analyze many of these samples for organochlorines and heavy metals. Related studies of pollution sources and transport processes are necessary to provide the basis for management measures.

7.0 Determine and Minimize Any Detrimental Effects of Anthropogenic Noise in the Oceans.

Sperm whales are among the cetaceans most likely to be sensitive to disturbance by loud or unfamiliar noise. Their deep-ocean distribution and far-ranging movements put them in potential conflict with a wide array of human activities, including mineral exploration and exploitation (e.g., seismic testing), military maneuvers, and research using acoustic methods. It is therefore important to understand and mitigate the effects of anthropogenic noise on these animals.

7.1 *Support ongoing and additional studies to evaluate the effects of sound on sperm whales.*

As discussed above under G.2, some research has addressed questions about the effects of noise on sperm whales, but little of this work has been conclusive in regard to the biological significance of observed effects. More studies addressing these and similar questions are needed. In particular, studies in which researchers have experimental control are necessary to provide definitive guidance for managers.

Sperm whales are not often subjected to close approaches by whale-watching vessels in North American waters. The potential impacts of whale-watching on Northern Hemisphere sperm whale populations are probably trivial in comparison to the potential impacts of loud noises produced by industrial, military, and research activities.

7.2 *Implement appropriate regulations on sound-production activities which are found to be potentially detrimental to sperm whales, until otherwise demonstrated.*

If the research mentioned in item 7.1 indicates that certain types of sound have adverse effects on sperm whales, appropriate regulations should be developed and implemented, to minimize or eliminate such effects.

8.0 Maximize Efforts to Acquire Scientific Information from Dead, Stranded, and Entangled or Entrapped Sperm Whales.

Assessment of the causes and frequency of mortality (either natural or human-caused) is important to understanding population dynamics and the threats that may impede the recovery of sperm whale populations. However, discovery of a carcass under circumstances allowing it to be examined in a timely and rigorous manner is a relatively rare event. Accordingly, efforts to detect and investigate sperm whale deaths should be as efficient as possible.

8.1 *Maintain the system for reporting dead, entangled, or entrapped sperm whales.*

The detection and reporting of dead sperm whales, whether stranded or floating at sea, need to be encouraged. The Large Whale Recovery Program coordinator and the National Marine Mammal Stranding Network coordinator, should continue working with representatives of local, state, and federal agencies, private organizations, academic institutions, and regional and national stranding networks, to facilitate efficient observer coverage and information exchange.

8.2 *Improve the existing programs to maximize data collected from dead sperm whales.*

Each sperm whale carcass represents an opportunity for scientific investigation of the cause of death, as well as addressing other questions related to the biology of the species. Delays in attempts to secure or examine a carcass can result in the loss of valuable data, or even of the carcass itself. The Stranding Network coordinator should work with appropriate agencies, organizations, and individuals to ensure that, when a sperm whale carcass is reported and secured: (i) a necropsy is performed as rapidly and as thoroughly as possible by qualified individuals to gather information regarding the cause of death; (ii) samples are taken and properly preserved for studies of genetics, toxicology, and pathology; and (iii) funding is available to notify and transport appropriate experts to the site rapidly and to distribute tissue samples to appropriate locations for analysis or storage. In addition, the coordinator should work with stranding networks and the scientific community, to develop and maintain lists of tissue samples requested by qualified individuals and agencies, and ensure that these samples are collected routinely from each carcass and stored in appropriate locations or distributed to appropriate researchers.

9.0 Develop Post-Delisting Monitoring Plan.

After populations have been identified, determined to be stable or increasing, and threats controlled, a monitoring plan should be developed to ensure that sperm whales do not revert in abundance, or become subject to new threats that cause adverse effects. Normally, this monitoring plan will be a scaled-down version of the monitoring prior to delisting, and will continue for a minimum of 1.5 generations, although it may be continued for longer.

V. IMPLEMENTATION SCHEDULE

An implementation schedule is used to direct and monitor implementation and completion of recovery tasks. Priorities in column 3 of the implementation schedule are assigned as follows:

Priority 1 - An action that must be taken to prevent extinction or to identify those actions necessary to prevent extinction.

Priority 2 - An action that must be taken to prevent a significant decline in population numbers or habitat quality, or to prevent other significant negative trends short of extinction.

Priority 3 - All other actions necessary to provide for full recovery of the species.

This implementation schedule accords priorities to individual tasks to specify their importance in the recovery effort. It should be noted that even the highest-priority tasks within a plan are not given a Priority 1 ranking unless they are actions necessary to prevent extinction. In general, Priority 1 tasks only apply to a species facing a high magnitude of threat. This allows NMFS to set priorities for allocation of available resources among different recovery plans.

Funding is estimated in accordance with the number of years necessary to complete the task once implementation has begun. The provision of cost estimates does not mean to imply that appropriate levels of funding will necessarily be available for all sperm whale recovery tasks.

DISCLAIMER

The Implementation Schedule that follows outlines actions and estimated costs for the recovery program for the sperm whale, as set forth in this recovery plan. It is a guide for meeting the recovery goals outlined in this plan. This schedule indicates action numbers, action descriptions, action priorities, duration of actions, the parties responsible for actions (either funding or carrying out), and estimated costs. Parties with authority, responsibility, or expressed interest to implement a specific recovery action are identified in the Implementation Schedule. When more than one party has been identified, the proposed lead party is indicated by an asterisk (*). The listing of a party in the Implementation Schedule does not require the identified party to implement the action(s) or to secure funding for implementing the action(s).

Action Number	Action Description	Priority	Task Duration (years)	Agencies/ Organizations Involved/ Potentially Involved	Atlantic Ocean (2021)	Pacific Ocean (2021)	Indian Ocean (2021)	Total
Objective 1	***Coordinate State, Federal, and International Actions to Implement Recovery Actions***							
1.1	Cooperate with the IWC to ensure that any resumption of commercial whaling on sperm whales is prosecuted on a sustainable basis and that all whaling activity is conducted within the purview of the IWC.	1	Ongoing	NMFS, IWC, DOS	100	100	100	300
1.2	Identify representatives of the scientific community and of private, state, and federal agencies (and international agencies where applicable) to periodically review and update this Recovery Plan.	2	TBD		120	120	120	360
Objective 2	***Determine Population Discreteness and Population Structure of Sperm Whales that Occur in U.S. Waters and Assess their Relationship to Others in the North Atlantic and North Pacific Ocean Basins***							

Action Number	Action Description	Priority	Task Duration (years)	Agencies/ Organizations Involved/ Potentially Involved				
					Atlantic Ocean (2021)	Pacific Ocean (2021)	Indian Ocean (2021)	Total
2.1	Support existing studies and initiate new studies to investigate population discreteness and population structure of sperm whales using genetic analyses.	2	3	NMFS	200	200	100	500
2.2	Assess daily and seasonal movements and inter-area exchange, using telemetry and photo-identification.	2	5	NMFS	200	200	100	500
2.3	Support ongoing studies and initiate new studies to investigate social structure and how it influences population structure.	2	Ongoing	NMFS	100	100	50	250
Objective 3	***Estimate Population Size and Monitor Trends in Abundance***							
3.1	Conduct surveys to estimate abundance and monitor trends in sperm whale populations worldwide	2	2	NMFS	9000	13500	3000	25500
Objective 4	***Conduct risk analyses***							
4.1	Atlantic and Pacific	2(1?)	TBD	NMFS, States, DOS	100	100		200
4.2	Indian	2(1?)	TBD	NMFS, DOS			200	200

Action Number	Action Description	Priority	Task Duration (years)	Agencies/ Organizations Involved/ Potentially Involved	Atlantic Ocean (2021)	Pacific Ocean (2021)	Indian Ocean (2021)	Total
Objective 5	***Identify and Protect Habitat Essential to the Survival and Recovery of Populations in U.S. Waters and Elsewhere***							
5.1	Promote action to define, identify, and protect important habitat in U.S. waters.	2(1?)	Ongoing	NMFS, States, NOS	375	375		750
5.2	Promote action to define, identify, and protect important habitat in foreign or international waters.	2	Ongoing	NMFS, DOS			375	375
5.3	Improve knowledge of sperm whale feeding ecology.	2	Ongoing	NMFS	150	150	100	400
5.4	Improve Knowledge about the characteristics of important sperm whale habitat, and how these whales use such areas.							
Objective 6	***Investigate Causes and Reduce the Frequency and Severity of Human-caused Injury and Mortality***							

Action Number	Action Description	Priority	Task Duration (years)	Agencies/ Organizations Involved/ Potentially Involved	Atlantic Ocean (2021)	Pacific Ocean (2021)	Indian Ocean (2021)	Total
6.1	Identify areas where concentrations of sperm whales coincide with significant levels of maritime traffic, fishing, or pollution.	2	Ongoing	NMFS, USCG, NOS	40	40	20	100
6.2	Investigate the significance of mortality and serious injury from ship collisions, interactions with fishing gear including the extent of depredation, and retaliatory actions by fishermen.	2	Ongoing	NMFS, USCG, States	75	75	50	200
6.3	As appropriate following 6.2, implement measures to reduce the frequency and severity of these kinds of human-whale interaction.	2	Ongoing	NMFS, NOS, USCG, DOS	20	20	10	50
6.4	Conduct studies of environmental pollution that may affect sperm whale populations and their prey.	2	5	EPA, NMFS	250	250	100	650
Objective 7	***Determine and Minimize Any Detrimental Effects of Artificial Sound in the Oceans***							

Action Number	Action Description	Priority	Task Duration (years)	Agencies/ Organizations Involved/ Potentially Involved	Atlantic Ocean (2021)	Pacific Ocean (2021)	Indian Ocean (2021)	Total
7.1	Support ongoing and additional studies to evaluate the effects of sound on sperm whales.	3	5	NMFS, USN	500	500	400	1400
7.2	Implement appropriate regulations on sound-production activities which are found to be detrimental to sperm whales.	3	5	NMFS, ACOE, USN, USCG, MMS	20	20	10	50
Objective 8	***Maximize Efforts to Acquire Scientific Information from Dead, Stranded, and Entangled or Entrapped Sperm Whales***							
8.1	Maintain the system for reporting dead, entangled, or entrapped sperm whales.	3	Ongoing	NMFS, NOS, States	1875	1875		3750
8.2	Improve the existing programs to maximize data collected from dead sperm whales.	3	Ongoing	NMFS, NOS, States	750	750		1500
Objective 9	***Develop Post-Delisting Monitoring Plan***				75	75		150

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