FINAL

RECOVERY PLAN FOR THE SPERM WHALE

(Physeter macrocephalus)

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

December 2010

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Prepared by:

Office of Protected Resources
National Marine Fisheries Service

Approved: ______________________
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National Oceanic and Atmospheric Administration

Date: DEC 21 2010

PREFACE

Congress passed the Endangered Species Act of 1973 (16 USC 1531 *et seq*) (ESA) to provide a means to conserve the ecosystems upon which endangered and threatened species depend, to provide a program for the conservation of such endangered and threatened species, and to take such steps as may be appropriate to achieve the purposes of the treaties and conventions that conserve such species. The National Marine Fisheries Service (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 Recovery 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, nongovernmental organizations, and individuals will be required throughout the recovery period.

DISCLAIMER

Recovery plans delineate such reasonable actions as may be necessary, based upon the best scientific and commercial data available, for the conservation and survival of listed species. Plans are published by NMFS, sometimes prepared with the assistance of recovery teams, contractors, State agencies, and others. Recovery plans do not necessarily represent the views, official positions or approval of any individuals or agencies involved in the plan formulation, other than NMFS. They represent the official position of NMFS only after they have been signed by the Assistant Administrator. Recovery plans are guidance and planning documents only; identification of an action to be implemented by any public or private party does not create a legal obligation beyond existing legal requirements. Nothing in this plan should be construed as a commitment or requirement that any Federal agency obligate or pay funds in any one fiscal year in excess of appropriations made by Congress for that fiscal year in contravention of the Anti-Deficiency Act, 31 U.S.C. 1341, or any other law or regulation. 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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National Marine Fisheries Service. 2010. Recovery plan for the sperm whale (*Physeter macrocephalus*). National Marine Fisheries Service, Silver Spring, MD. 165pp.

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

ACKNOWLEDGMENTS

The National Marine Fisheries Service gratefully acknowledges Randall R. Reeves and Gregory K. Silber for the initial preparation of this recovery plan. NMFS also acknowledges the subsequent contribution of the following people for updating the recovery plan, including providing access to unpublished information and reviewing the manuscript to produce this final plan: Jay Barlow, Robert Brownell, Jr., Monica DeAngelis, Sarah Mesnick, and Barbara Taylor.

Special thanks goes to Simona Perry, the lead author of the "The Great Whales: History and Status of Six Species Listed as Endangered Under the U.S. Endangered Species Act of 1973" (Perry *et al*., 1999), which proved very useful in drafting this document. Additional thanks go to the following for their technical assistance, editing, and review: Kyle Baker, Shannon Bettridge, Phillip Clapham, Don Croll, Christina Fahy, Dan Goodman, Bob Kenney, Naomi Littlefield, Mike Newcomer, Larissa Plants, Susan Pultz, Amy Scholik-Schlomer, Bernie Tershy, Mason Weinrich, Andrew Wright, Hal Whitehead, and Chris Yates.

TERM AND ACRONYM LIST

The following is a list of acronyms, abbreviations, and terms used throughout the recovery plan.

ATOC	Acoustic Thermometry of Ocean Climate
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
dB	decibels
Delisting	removal from the list of Endangered and Threatened Wildlife and Plants
Downlisting	considered for reclassification from endangered to threatened under the ESA
DPS	Distinct Population Segment
EEZ	Exclusive Economic Zone
ESA	Endangered Species Act
FR	Federal Register
Hz	hertz
IWC	International Whaling Commission
kHz	kilohertz
LFA	Low Frequency Active (for sonar)
LNG	Liquefied Natural Gas
m	meters
MMPA	Marine Mammal Protection Act
mtDNA	Mitochondrial Deoxyribonucleic acid
μPa	micro Pascal
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
PCB	Polychlorinated Biphenyls
SPLASH	Structure of Populations, Levels of Abundance and Status of Humpbacks
SURTASS	Surveillance Towed Array Sensor System
SWSS	Sperm Whale Seismic Study

EXECUTIVE SUMMARY

Current Species Status: Sperm whales, *Physeter macrocephalus*, are currently globally 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 of 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 long history of whaling and the complex social structure and reproductive behavior of sperm whales have confounded assessments of population status and structure. 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.

Sperm whales have a global distribution and can be found in the Atlantic, Pacific, and Indian Oceans. 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. Populations are often divided on an ocean basin level. Therefore, this Recovery Plan is organized, for convenience, by ocean basin and discussed in three sections, those sperm whales in the Atlantic Ocean/Mediterranean Sea, including the Caribbean Sea and Gulf of Mexico, those in the Pacific Ocean and its adjoining seas and gulfs, and those in the Indian Ocean. An improved understanding of the genetic differences between populations would allow better estimates of abundance and more effective management of the species. Although there is new information, existing knowledge of population structure for this nearly continually distributed species remains poor.

Habitat Requirements and Limiting Factors: Populations in the Atlantic Ocean/ Mediterranean Sea, Pacific Ocean, and Indian Ocean have been legally protected from commercial whaling for the last twenty or more years, and this protection continues. Although the main direct threat to sperm whales was addressed by the IWC whaling moratorium on commercial whaling, several potential threats remain. Among the current potential threats are collisions with vessels, reduced prey abundance due to climate change, the possibility that illegal whaling or resumed legal whaling will cause removals at biologically unsustainable rates, contaminants and pollutants, and, possibly, the effects of increasing anthropogenic ocean noise.

Recovery Strategy: The primary purpose of this Recovery Plan is to identify and take actions that will minimize or eliminate effects of human activities that are detrimental to the recovery of sperm whale populations. Immediate objectives are to identify factors that may be limiting abundance/recovery/ productivity, and cite actions necessary to allow the populations to increase. The main threats to sperm whale populations include collisions with vessels, direct harvest, and possibly competition for resources, loss of prey base due to climate change, and disturbance from anthropogenic noise. 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. Because sperm whales move freely across international borders, it would be unreasonable to confine recovery efforts to U.S. waters, and this Recovery Plan stresses the importance of a multinational approach to management. Ideally, both research and conservation should be undertaken at oceanic rather than national levels.

Recovery Goals and Criteria: The goal of this Recovery Plan is to promote recovery of sperm whales to a point at which they can be downlisted 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 recovery criteria presented in this Recovery Plan were based on the *Report of the Workshop on Developing Recovery Criteria for Large Whales Species* (Angliss *et al.* 2002). The sperm whale is currently listed as a single species on a global scale.

Downlisting Criteria:

Sperm whales will be considered for reclassifying from endangered to threatened when all of the following criteria are met:

1. Given current and projected threats and environmental conditions, the sperm whale population in each ocean basin in which it occurs (Atlantic Ocean/Mediterranean Sea, Pacific Ocean, and Indian Ocean) satisfies the risk analysis standard for threatened status (has no more than a 1% chance of extinction in 100 years) *and* the global population has at least 1,500 mature, reproductive individuals (consisting of at least 250 mature females and at least 250 mature males in each ocean basin). Mature is defined as the number of individuals known, estimated, or inferred to be capable of reproduction. Any factors or circumstances that are thought to substantially contribute to a real risk of extinction that cannot be incorporated into a Population Viability Analysis will be carefully considered before downlisting takes place.

and

2. None of the known threats to sperm whales are known to limit the continued growth of populations. Specifically, the factors in 4(a)(l) of the ESA are being or have been addressed: A) the present or threatened destruction, modification or curtailment of a species' habitat or range; B) overutilization for commercial, recreational or educational purposes; C) disease or predation; D) the inadequacy of existing regulatory mechanisms; and E) other natural or manmade factors. See Section III, Recovery Goals, Objectives, and Criteria, for specific threats-based criteria.

Delisting Criteria:

Sperm whales will be considered for removal from the list of Endangered and Threatened Wildlife and Plants under the provisions of the ESA, when all of the following criteria are met:

1. Given current and projected threats and environmental conditions, the total sperm whale population in each ocean basin in which it occurs (Atlantic Ocean/Mediterranean Sea, Pacific Ocean, and Indian Ocean) satisfies the risk analysis standard for unlisted status (has less than a 10% probability of becoming endangered (has more than a 1% chance of extinction in 100 years) in 20 years). Any factors or circumstances that are thought to substantially contribute to a real risk of extinction that cannot be incorporated into a Population Viability Analysis will be carefully considered before delisting takes place.

and

2. None of the known threats to sperm whales are known to limit the continued growth of populations. Specifically, the factors in 4(a)(l) of the ESA are being or have been addressed: A) the present or threatened destruction, modification or curtailment of a species' habitat or range; B) overutilization for commercial, recreational or educational purposes; C) disease or predation; D) the inadequacy of existing regulatory mechanisms; and E) other natural or manmade factors. See Section III, Recovery Goals, Objectives, and Criteria, for specific threats-based criteria.

This recovery plan identifies the following actions needed to achieve recovery of sperm whales:

1. Coordinate state, federal, and international actions to implement recovery action and maintain international regulation of whaling for sperm whales;

2. Develop and apply methods to estimate population size and monitor trends in abundance;

3. Determine population discreteness and population structure of sperm whales;

4. Conduct risk analyses;

5. Identify, characterize, protect, and monitor habitat important to sperm whale populations in U.S. waters and elsewhere;

6. Investigate causes of and reduce the frequency and severity of human-caused injury and mortality;

7. Determine and minimize any detrimental effects of anthropogenic noise in the oceans;

8. Maximize efforts to acquire scientific information from dead, stranded, and entangled sperm whales; and

9. Develop post-delisting monitoring plan.

Estimated Cost of Actions Necessary to Achieve Recovery, Including All Three Ocean Basins (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[1]
Atlantic (2025)	1,500	43,990	3,000	200	6,500	7,500	2,500	1,352	*	66,542
Pacific (2025)	1,500	32,160	3,000	200	6,500	12,500	2,500	1,352	*	59,712
Indian (2035)	2,500	27,490	1,500	200	6,000	8,000	2,000			47,690
Total for Task Duration	**5,500**	**103,670[2]**	**7,500**	**600**	**19,000**	**28,000**	**7,000**	**2,704**	*****	**173,974**

[1] Total reflects cost of recovery for ocean basin.
[2] Total reflects an additional cost of $30K that is not specific to one ocean basin.
[*] No cost associated, NMFS staff time.

ANTICIPATED DATE OF RECOVERY: The time to recovery is not predictable with the current information and global listing of sperm whales. However, minimum data needed to satisfy criterion 1 for delisting are population structure work and ocean-basin wide surveys, which are estimated to take an additional 15 years from now within the Atlantic Ocean/Mediterranean Sea and Pacific Ocean basins (date of recovery at 2025) and likely an additional 25 years from now in the Indian Ocean (date of recovery at 2035). The exact date of recovery cannot be determined as it will likely take decades. The effectiveness of many management activities is not known on a global level, 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. In the future, as more information is obtained on the threats, their impacts on sperm whales, and how they can be effectively mitigated, it should be possible to make more informative projections about the time to recovery, and its expense.

ESTIMATED COST OF RECOVERY (FIRST 5 FISCAL YEARS): $2.4 MILLION

TOTAL ESTIMATED COST OF RECOVERY FOR THREE OCEAN BASINS: $174 MILLION

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I. BACKGROUND

A. Brief Overview

The sperm whale, *Physeter macrocephalus* (Linnaeus 1758), was listed under the precursor to the Endangered Species Act (ESA), the Endangered Species Conservation Act of 1969, and remained on the list of threatened and endangered species after the passage of the ESA in 1973 (35 FR 18319, December 2, 1970). Sperm whales are widely distributed throughout the world's oceans. Although the original listing did not provide an explanation, it is understood that the main reason for listing is that most populations were depleted by modern whaling. Despite this reduction, 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), and while it is often assumed that the worldwide population of sperm whales has increased since the moratorium, there are insufficient data on population structure and abundance of inhabited ocean basins to accurately determine population trends. 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 killed 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 anthropogenic 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, Taxonomy, and Population Structure

Species Description

The sperm whale is a 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), ranging between 60°N and 70°S (Leatherwood and Reeves 1983). 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 age distribution of the sperm whale population is unknown, but sperm whales are believed to live at least 60 years, with females potentially living up to 80 years (Whitehead 2003). Sperm whale annual mortality rates are thought to vary by age, but previous estimates of mortality rates for juveniles and adults are considered unreliable (IWC 1980).

Sperm whales have a disproportionately large head, one quarter to one third of their total body length (Rice 1989). Their 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. Their eyes are relatively small. Sperm whales are generally dark gray in color, with white lips and often white areas on the belly and flanks. Their dorsal fin is low in profile, thick, and not pointed or curved, followed by knuckles along its spine. 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). They have the largest brain of any animal on Earth, and their blunt snout houses a large reservoir of spermaceti, a high-quality oil.

Hearing and Vocalizations

The anatomy of the sperm whale ear indicates that it hears in the same functional acoustic division as bottlenose dolphins and appears tailored for ultrasonic (>20 kilohertz (kHz)) reception (Ketten 1994, 1997). The odontocete inner ear is primarily adapted for echolocation, and the ears have exceptional frequency discrimination abilities. The sperm whale may also possess better low frequency hearing than some of the other odontocetes, although not as low as many baleen whales (Ketten 1992). Southall *et al*. (2007) recently put sperm whales in the same hearing group (mid-frequency cetaceans), as "dolphins," toothed whales, beaked whales, and bottlenose whales (estimated hearing range 150 Hz to 160 kHz). The only data on the hearing range of sperm whales are evoked potentials from a stranded male neonate, which suggest that neonatal sperm whales respond to sounds from 2.5 to 60 kHz, with best sensitivity at 5, 10, and 20 kHz.

Sperm whales produce several types of click sounds: patterned clicks (codas), usual clicks, creaks, and slow clicks (Weilgart and Whitehead 1988). Codas are associated with social behavior and interactions within social groups (Weilgart and Whitehead 1993). When sperm whales are socializing, they tend to repeat codas, which follow a precise rhythm and may last for hours (Watkins and Schevill 1977). Codas are shared between individuals of a social unit and are considered to be primarily for intragroup communication (Weilgart and Whitehead 1997; Rendell and Whitehead 2004). Usual clicks have interclick periods of 0.4 to 1 seconds and are heard most often when sperm whales engage in foraging/diving behavior (Whitehead and Weilgart 1991; Miller *et al.* 2004; Zimmer *et al.* 2005). These may be echolocation clicks used in feeding, contact calls (communication), and orientation during dives. Creaks are a series of very rapid clicks and are thought to be produced by sperm whales as they are closing on a food item. Slow clicks have interclick periods greater than 5 seconds and are believed to be made only by adult males in the context of mating.

Generally, most of the acoustic energy from sperm whales is present at frequencies below 4 kHz, although diffuse energy up to and past 20 kHz has been reported (Thode *et al.* 2002), with source levels up to 236 dB re 1 μPa-m (Møhl 2003). Other studies indicate sperm whales' wide-band clicks contain energy between 0.1 and 20 kHz (Weilgart and Whitehead 1993, 1997; Goold and

Jones 1995). These have source levels estimated at 171 dB re 1 μPa (Levenson 1974). Current evidence suggests that the disproportionately large head of sperm whales is an adaptation to produce these vocalizations (Norris and Harvey 1972; Clarke 1979; Cranford 1992). This suggests that the production of these loud, low-frequency clicks, is extremely important to the survival of individual sperm whales. The function of these vocalizations is relatively well-studied (Weilgart and Whitehead 1993, 1997; Goold and Jones 1995). Long series of monotonous regularly spaced clicks are associated with feeding and are thought to be produced for echolocation.

Taxonomy

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) using 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).

Population Structure

In the United States, sperm whales are managed under three constructs, all with different objectives and therefore, different terminology for population structure: the Marine Mammal Protection Act (MMPA), the IWC, and the ESA. Roughly, the MMPA protects marine mammal species with a goal of maintaining marine mammal population "stocks" as functioning elements of their ecosystem, the IWC manages whales with a goal of maintaining healthy stocks while authorizing harvest to meet aboriginal (and potentially commercial catches), 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.

Both the MMPA and the IWC use the term "stocks" to refer to units to conserve. In this document, we use the term "stocks" in the context of MMPA or IWC stocks, and use the more generic term "populations" when referring to subunits of the same species in other contexts. The stock concept has been the subject of much discussion among biologists and natural resource managers. The MMPA defines "stock" as "a group of marine mammals of the same species or smaller taxa in a common spatial arrangement, that interbreed when mature." 16 U.S.C. § 1362(11). A recent working interpretation of this definition 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 for 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.

The population structure of sperm whales has not been adequately defined. Most existing models have assigned arbitrary boundaries, often based on patterns of historic whaling activity and catch reports, rather than on biological evidence. In discussions of sperm whales, populations are often divided and discussed on an ocean basin level. An improved understanding of the genetic differences between populations would allow better estimates of abundance and more effective management of the species. Although there is new information, existing knowledge of population structure for this nearly continuously distributed species remains poor.

Over the past decade, several authors have investigated population structure in sperm whales using sequence variation within the mitochondrial DNA (mtDNA) and/or polymorphic nuclear loci (*e.g.,* 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 distinct geographic basins such as the Mediterranean Sea and Gulf of Mexico (Dillon 1996; Lyrholm and Gyllensten 1998; Mesnick *et al.* 1999a; Bond 1999; Lyrholm *et al.* 1999; Engelhaupt 2004). However, several factors complicate these studies, such as low sample sizes, low mtDNA haplotypic diversity, and sex biased patterns of dispersal, which alone and together reduce the power to detect population structure.

The low mtDNA diversity in sperm whales requires that studies using this marker have large sample sizes. 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. Mesnick *et al.* (2005) compiled over 2,473 tissue samples and 1,038 mtDNA sequences from a global consortium of investigators. This compilation found 28 haplotypes worldwide, defined by 24 variable sites. The three most common haplotypes ("a", "b," and "c") comprised 82% of the total, with haplotype "a" comprising 39% of the total. Several hypotheses for the lack of diversity have been proposed, such as an historic bottleneck effect on population size (Lyrholm *et al.* 1996), dissimilar environmental conditions experienced by separate matrilineal groups causing disparity of fecundities (Tiedemann and Milinkovitch 1999) and cultural "hitchhiking" in matrilineal species (Whitehead 1998).

Additional information on population structure can be found in data sets derived from historical, demographic, behavioral, morphological, and acoustic sources (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, breed at different times than those in the California Current system (B.L. Taylor, pers. comm. 2006). To address the potential bias due to relatedness within groups, novel analytical approaches are needed.

It is likely that population structuring exists among sperm whales. Although sperm whales are found throughout the world's waters, it appears that only males penetrate to truly arctic waters, having been observed to move towards colder waters in the summer feeding seasons and return to warmer water to breed. Lyrholm and Gyllensten (1998) found that the dispersal of females was limited, suggesting the possibility of the development of genetic differentiation. However, Discovery Mark data from the days of commercial whaling (260 recoveries with location data) show extensive movements of both males and females from U.S. and Canadian coastal waters into the Gulf of Alaska and Bering Sea (Omura and Ohsumi 1964; Ivashin 1967; Ivashin and Rovnin 1967; Ohsumi and Masaki 1975; Wada 1980; Kasuya and Miyashita 1988; Mizroch, pers. comm. 2008). While no firm boundaries can be drawn, there is likely very limited movement among the Atlantic/Mediterranean Sea, the Pacific, and the Indian Oceans. 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 areas. Research currently underway will improve our understanding of the sperm whale's population structure and genetic differences.

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; Jaquet *et al.* 2003; Engelhaupt 2004). 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."

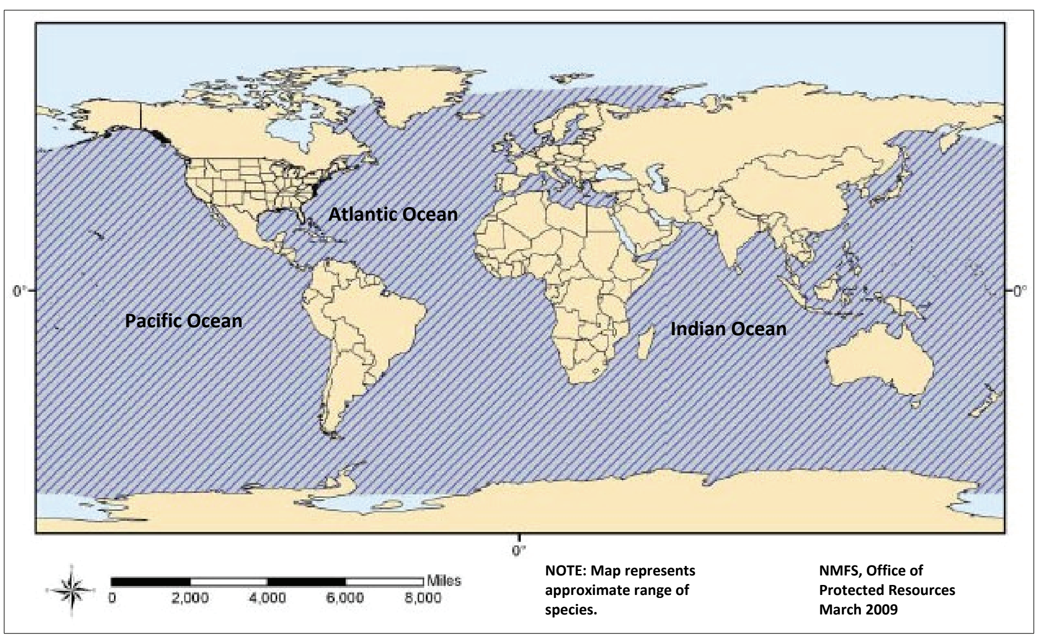

Figure 1. Sperm whale global range.

A striking feature of the sperm whale's life history is the difference in migratory behavior between adult males and females. Typically adult males move into the higher latitudes and all age classes and both sexes range throughout tropical and temperate seas. However, there are areas where at least some individual males and females are present year-round in the higher latitudes (Mellinger *et al.* 2004; Mizroch pers. comm. 2009). Discovery Mark data from the days of commercial whaling (260 recoveries with location data) show extensive movements of both males and females from U.S. and Canadian coastal waters into the Gulf of Alaska and Bering Sea (Omura and Ohsumi 1964; Ivashin and Rovnin 1967; Ohsumi and Masaki 1975; Wada 1980; Kasuya and Miyashita 1988, Mizroch, pers. comm. 2009) although, of nearly 60,000 sperm whales killed in the North Pacific above 50°N, approximately 57,000 were males (Mizroch and Rice 2006). Sperm whale calls have been detected year-round in the Gulf of Alaska (Mellinger *et al.* 2004). Male sperm whales are widely dispersed along the Antarctic ice edge from December to March (austral summer) (Gosho *et al.* 1984). 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 inter-oceanic 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 (Bond 1999; Lyrholm *et al.* 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 extensive "Offshore" and "On the Line" whaling grounds between the Galapagos 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 low, to determine the reason(s).

In this Recovery Plan we separate description of the data into three sections: Atlantic Ocean/Mediterranean Sea, Pacific Ocean, and Indian Ocean. 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 to use the equator as a boundary, as well-known populations are known to span this artificial 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 seasonal movements towards colder waters in the summer feeding seasons has been observed by at least the males. Therefore, while no firm boundaries can be drawn, there is likely very limited movement between the Atlantic Ocean/Mediterranean Sea, the Pacific, and the Indian Ocean. The Recovery Criteria in this Recovery Plan, therefore, use these three large oceanic regions. All three of these oceanic regions must meet the recovery criteria. Careful consideration should be given to the meaning of "significant," as used in the phrase "significant portion of its range," (per the definition of endangered and threatened which states that the species is endangered or threatened "throughout all or a significant portion of its range") in light of our poor understanding of population structure.

D. Life History – Atlantic Ocean/Mediterranean Sea Population

D.1 Population Structure

In U.S. waters, the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) recognizes two MMPA stocks of sperm whales: 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 Sea and the North Atlantic Ocean. Engelhaupt (2004) examined genetic variation among samples collected in the Gulf of Mexico, Mediterranean Sea, North Sea, and North Atlantic Ocean using mtDNA and nuclear genetic markers. Both studies found that all Mediterranean Sea 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 Sea) 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). Recently, Gero *et al.* (2008) investigated patterns of association within a social unit of sperm whales from the eastern Caribbean, and contrary to previous findings, found that the patterns of association among members of this unit were heterogeneous and that individuals had preferred associations or avoidances with specific individuals. Furthermore, it was determined that the intra-unit social complexity of a group, when the variation in sociability is controlled, is based on genetic relatedness, as individuals associated more with their close relative.

D.2 Distribution and Habitat Use

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 attached to a male sperm whale's body 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; Aguilar 1985; Sigurjønsson 1985). Tagging data have also shown that sperm whales make substantial latitudinal movements across the equator (Ivashin 1967).

Sperm whales inhabit the entire 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 whale 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 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.

There has been an increase in the number of reported sperm whales in European continental shelf waters since the mid-1970s (Dunlop and Mellor 2008). Most available information on the presence of sperm whales in the United Kingdom and Ireland has come from stranding events along the north and west coasts of Ireland (Berrow *et al.* 1993) and from visual sighting records (Evans 1997; Evans *et al.* 2003; Reid 2003). Sperm whales are widely distributed throughout the deep waters of the North Atlantic and occur in small numbers along the shelf break north and west of the British Isles and Ireland (Dunlop and Mellor 2008). Visual and acoustic surveys conducted by Weir *et al.* (2001) indicate a small sperm whale population located in deeper waters northwest of Scotland and that sperm whales are typically found along the continental shelf and along the 1,000 m isobath throughout the entire year. In comparison, Weir *et al.* (2001) observed few animals off the west and northwest coasts of Ireland. Dunlop and Mellor's (2008) acoustic survey indicates that the sperm whale range could potentially extend towards the north coast of Ireland more frequently than is currently acknowledged.

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 of Mexico 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 of Mexico, sperm whales are especially common near the Mississippi Canyon, where they are present year-round (Davis *et al.* 1998), and 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 of Mexico, with some animals using deeper oceanic waters. Satellite tag deployments also have indicated large scale movements of individuals out of the Gulf of Mexico. The SWSS research provided detailed information on the habitat preferences and population structure of Gulf of Mexico sperm whales (Jochens and Biggs 2004; Jochens *et al.* 2008).

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; Scott and Sadove 1997; Waring *et al.* 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. Most sperm whales are found in very deep waters (>3000m) but feed at 500–1000 m depths (where most of the food is found). As far as it 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 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 squid, the list of documented food items is fairly long and diverse. Prey items include other cephalopods, such as octopus, and medium-and large-sized demersal fish, 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 consumed by sperm whales in the Denmark Strait (Martin and Clarke 1986).

D.4 Competition

May *et al.* (1979) provided a relatively simple example, using male sperm whales, squid, and krill in the Antarctic, to show how complex competition 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 (*Hyperoodon ampullatus*, *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 (Whitehead 2003).

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 are organized in groups in which adult females (some related to each other and some not) travel with their sub-adult offspring. Mature female and immature sperm whales of both sexes are found in more temperate and tropical waters from the equator to around 45^{o}N throughout the year. North Pacific Discovery Mark data indicate that females were caught well above 50^{o}N and over 3,000 female sperm whales were killed above that latitude (Mizroch and Rice 2006). Sexually mature males join these groups throughout the winter. During the summer, mature male and some female sperm whales are thought to move north into the Aleutian Islands, Gulf of Alaska, and the Bering Sea. Based mostly on sighting surveys or land station whaling data, it is thought that they are often concentrated around oceanic islands in areas of upwelling, and along the outer continental shelf, continental slope, and mid-ocean waters (Hain *et al.* 1985; Kenney and Winn 1987; Waring *et al.* 1993; Waring and Finn 1995; Gannier 2000; Gregr and Trites 2001; Waring *et al*. 2001). However, based on pelagic whaling data, sperm whales were found in large numbers in a broad band around 40^{o}N in the northeastern North Pacific and a broad band around 30^{o}N in the northwestern Pacific (Mizroch and Rice 2006).

Sperm whales mature slowly. Females usually begin ovulating at 7–13 years of age and usually conceive at about age 9 (Rice 1989). 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. 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 calving interval is estimated to be about four to six years (Best *et al.* 1984) and female sperm whales rarely become pregnant after the age of 40 (Whitehead 2003).

The peak breeding season for sperm whales in the North Atlantic occurs during the spring (March/April to June) 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, as mentioned above (Best *et al.* 1984), for prime-aged females and apparently much longer for 40+ year-olds. Presumably the peak breeding season in the South Atlantic occurs in the austral spring.

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 eventually leave these family groups after which they live in "bachelor schools." The cohesion among males within a bachelor school declines as the animals age, although bonding is evident as males have mass stranded (Bond 1999). During their prime breeding period 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

Known non-anthropogenic threats to sperm whales include predation, competition, and disease; however, there are many documented cases of strandings for which the cause is unknown. Sperm whales can live to ages in excess of 60 years (Rice 1989). 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). Despite an observation off California showing 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), the paucity of documented attacks by killer whales indicates that predation risk to sperm whales is low. New hypotheses have been developed on how predation by killer whales has influenced marine mammal populations, including sperm whales (Springer *et al.* 2003; Mizroch and Rice 2006). However, while evidence indicates that predation by killer whales has been, and is still, a source of natural mortality for sperm whales (Pitman *et al*. 2001), the extent of impact on sperm whale populations is expected to be small based on the fact that few observations have occurred. Sperm whale calves are subject to predation by killer whales (Arnbom *et al.* 1987) and possibly large sharks (Best *et al.* 1984). 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 (Palacios and Mate 1996; Weller *et al.* 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 standings 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, possibly 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).

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. Using Whitehead's methods, abundance in the Atlantic Ocean is approximately 90,000–134,000 sperm whales. Assuming that the population is growing at about 1.1%/year[1], Whitehead also estimated that the global population is at about 32% of historical numbers. Since the Atlantic kills from 1940–1970 were less extreme than those in the Pacific (*i.e.,* much less intensive whaling in the North Atlantic during this time than in the Pacific and Southern Oceans), the current status in the Atlantic is likely better than the global estimate (of 32%).

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 eastern coast of the United States (western North Atlantic) is 4,804 (CV=0.38) based upon two vessel surveys and an aerial survey conducted during the summer of 2004; northern U.S. Atlantic is 2,697 (CV=0.57), and southern U.S. Atlantic is 2,197 (CV=0.47) (Waring *et al.* 2009). This joint estimate is considered best because together these two surveys have the most complete coverage of the species' habitat. These estimates were not corrected for dive time, and thus are likely downwardly biased and an underestimate of actual abundance (Waring *et al*. 2009).

The estimate pertains to waters from Florida to the Gulf of Maine within the U.S. Exclusive Economic Zone (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 km^2) 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 2003–2004 resulted in a combined estimate of 1,665 (CV=0.20) (Mullin 2007) for the oceanic northern Gulf of Mexico (Mullin and Fulling 2004). Although some surveys correct for missed animals, the survey estimates for the Gulf of Mexico are negatively biased, as they do not account for the

[1] From Whitehead (2002): Maximum rate of increase: best r = 1.1%; reasonable range 0.7 to 1.5%. The population parameters used by the IWC (1982) suggest r = 0.9% for a population with stable age distribution, but these include very uncertain, and probably overestimated, mortality rates, and no changes with age in either fecundity or adult mortality. It may be more realistic to use the well-established mortality schedule of killer whales (Olesiuk *et al.* 1990) and an age-specific pregnancy rate taken from the data presented by Best *et al.* (1984; pregnancy rate for mature females = 0.257 – 0.0038 × Age in years), in which case the annual rate of increase with stable age distribution is 1.1% yr–1.

long submergence time of sperm whales. Furthermore, the bias associated with a given estimate can be highly variable, depending on the survey platform.

Sperm whales are rare in deep Atlantic waters offshore from Iceland and Norway south to the Iberian Peninsula, and east into the Mediterranean Sea. When observed, sperm whales are mainly seen around Iceland and off western Norway (Andenes), the west coast of Portugal, the north coast of Spain, and the Azores. In coastal North European waters, sperm whales are mainly reported from July to December. 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 Sigurjønsson 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.* (2002) 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).

Although there is no complete abundance estimate for the Mediterranean Sea, estimates in smaller studies together with information on distribution and frequency of sightings were used to infer that there are fewer than 2,500 mature adults. Gannier *et al.* (2002) reported the highest encounter rates in the northwestern portions of the Mediterranean, especially near the Gulf of Lions, and in eastern coastal areas of the Ionian Sea, especially off the Greek Islands. Estimated abundance for the Ionian Sea in 2003, based on surveys combining visual and acoustic techniques, was 66 individuals (with 95% lognormal confidence limits 28–156) (Lewis *et al.* 2006). No sperm whales were observed on-transect during a survey of the Strait of Sicily (Lewis *et al.* 2006). These results are consistent with the number of photo-identified sperm whales along the Hellenic Trench (see below). Preliminary results from a survey of a large portion of the western basin (from Gibraltar to Sicily and bounded on the north by a line from the Balearics east to Sardinia) in Summer 2003 indicate a sperm whale detection rate roughly eight times that in the Ionian Sea (T. Lewis, IFAW, pers. comm.). This suggests that sperm whale numbers are significantly higher in the western basin than in the Ionian Sea, but still are likely to be only in the low to mid hundreds. Gannier *et al.* (2002) provided sperm whale visual and acoustic encounter rates for a large portion of the Mediterranean Sea, however, no absolute abundance estimates can be derived from their data. About 1500 individuals have been photo-identified in the Mediterranean Sea during the last decade (NAMSC 2004).

E. Life History–Pacific Ocean Population

E.1 Population Structure

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, NMFS recognizes three MMPA stocks in U.S. EEZ waters in the Pacific—California/Oregon/Washington, Hawaii, and Alaska stocks (Carretta *et al.* 2009). 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. However, Mizroch (pers. comm. 2009) indicates that there is likely no stock separation in the North Pacific based on Discovery Mark data and the northward movements of those whales currently separated into the Hawaii stock. 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.* (1999a; 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 (B.L. Taylor pers. comm. 2008). The authors analyzed variation in mtDNA and nuclear (microsatellite) loci and found significant north to 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) and Mesnick *et al.* (2008) addressed the question of cultural philopatry by examining mtDNA 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 Analysis of Molecular Variance and partial Mantel tests showed greater genetic subdivision among vocal clans than putative populations based on geography (Chile/Peru, Galapagos/Ecuador, and the Southwest Pacific). Currently, efforts are underway to define North Pacific stock structure based on 300 samples collected throughout the northeastern, southeastern, and central North Pacific using mtDNA and nuclear markers which, for the first time, will include the use of single nucleotide polymorphisms or SNPs to improve the power to detect structure (Mesnick *et al.* 1999a; S. L. Mesnick, pers. comm. 2008).

Rice (1977), Wade and Gerrodette (1993), and Dufault and Whitehead (1995) also suggested that a separate equatorial Pacific sperm whale population exists. Rendell and Whitehead (2003) determined that in the South Pacific, female sperm whales appeared quite clearly structured into sympatric cultural clans, each with a distinctive dialect. 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 not be geographical separation between Galapagos and

Ecuador/ North Peru whales as previously indicated (Dufault and Whitehead 1995), as recent photo identification information shows several matches between the Galapagos and Ecuador/Peru and also some to Chile, although the genetics has yet to be verified.

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 acoustic detections using various recordings. The northern limit of adult male sperm whales in the North Pacific Ocean is estimated to extend 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: (l) 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). Sperm whale calls have been detected year-round in the Gulf of Alaska (Mellinger *et al.* 2004). Discovery Mark data from the days of commercial whaling (260 recoveries with location data) show extensive movements of both males and females from U.S. and Canadian coastal waters into the Gulf of Alaska and Bering Sea and the coast of Japan Ground and Bonin Islands Ground (Omura and Ohsumi 1964; Ivashin and Rovnin 1967; Ohsumi and Masaki 1975; Wada 1980; Kasuya and Miyashita 1988, Mizroch, pers. comm. 2008). Rice (AFSC-NMML, retired, pers. comm. in Angliss and Allen 2009) marked 176 sperm whales during U.S. survey cruises from 1962–1970, mostly between 32° and 36°N off the California coast. Seven of those marked whales were observed in locations ranging from offshore California, Oregon, and British Columbia waters to the western Gulf of Alaska. A whale marked by Canadian researchers moved from near Vancouver Island, British Columbia to the Aleutian Islands near Adak. A whale marked by Japanese researchers moved from the Bering Sea just north of the Aleutians to waters off Vancouver Island, British Columbia (Mizroch pers. comm. 2009). Based on these data, there appear to be movements along the U.S. west coast into the Gulf of Alaska and Bering Sea/Aleutian Islands region. 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). Of the nearly 60,000 sperm whales killed in the North Pacific above 50°N, approximately 57,000 were males (Mizroch and Rice 2006 appendix).

A 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 off Oregon and Washington in all seasons except mid-winter (Dec.–Feb.) (Green *et al.* 1992). Figure 1 illustrates the location of sperm whales seen during NMFS' Southwest Fisheries Science Center surveys in the eastern North Pacific from 1986 through 2005.

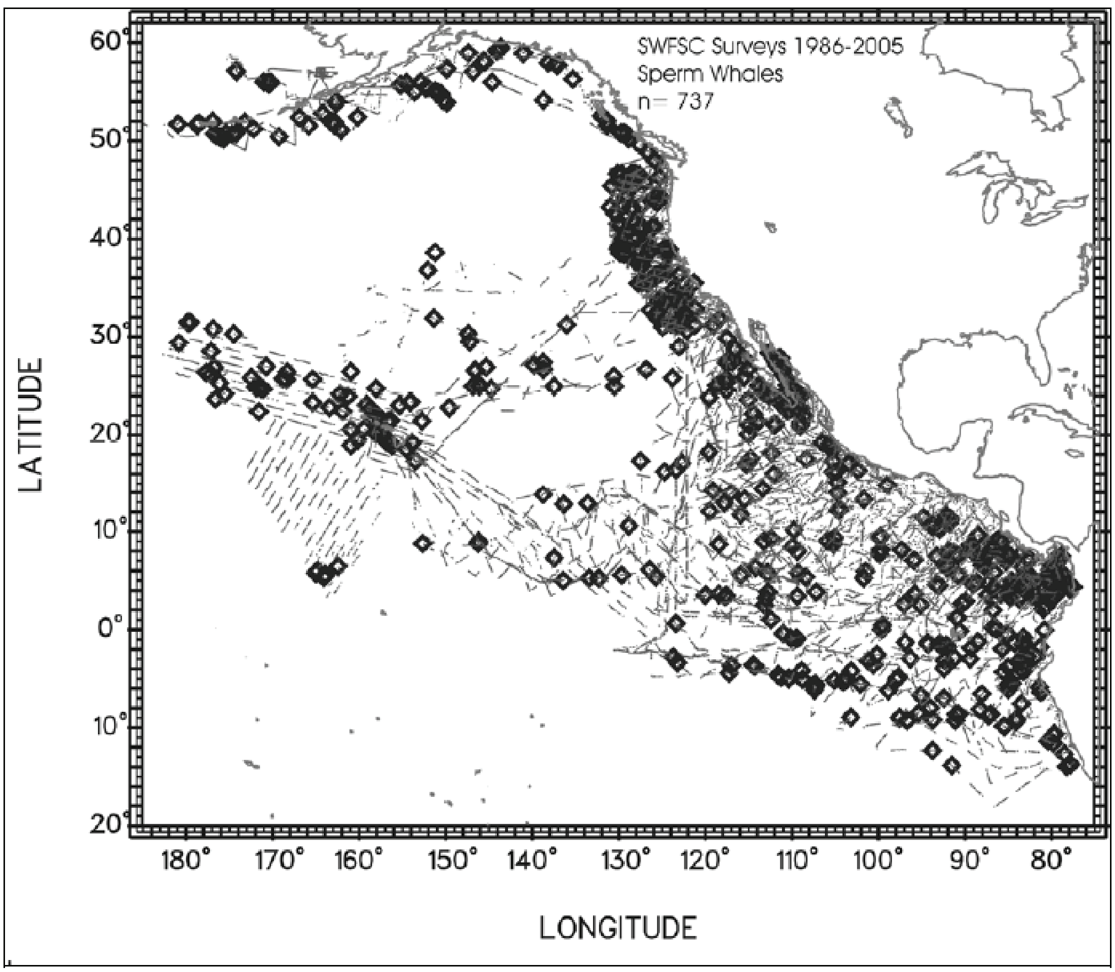

Figure 2. Location of sperm whales (b) seen on Southwest Fisheries Science Center surveys in the eastern North Pacific (1986–2005). Fine lines represent track lines surveyed during those years.

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. This study found such structure to be weak in comparison to other non-geographically defined structures, but it is suggested that, if applied more intensively and on a larger geographic scale, this method could help elucidate the possible existence of a process of population differentiation in sperm whales. While latitudinal movements of mature males are believed to be seasonal (Best 1979), there is little evidence for this and seasonal components of female movement are even less clear (Whitehead 2003). While the following conclusions about sperm whales' movements derived in the Whitehead *et al.* (2008) study refer only to the tropical Pacific, they are consistent with some data from other oceans using other methods (Kasuya and Miyashita 1988; Best 1979). Results of Whitehead *et al.* (2008) indicated that social units and groups of females/immature animals in the tropical Pacific adapted their movements over a range of temporal and spatial scales to the distribution of resources (Whitehead *et al.* 2008). In addition, Whitehead *et al.* (2008) suggested home ranges spanning 2000 km that may be related to the amount of habitat that an individual or social unit can keep track of, although occasional long-distance movements by a few individuals spanned about 4000 km.

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, including the Gulf of Alaska where they reportedly take fish from gear set along the ocean bottom 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 reduction in 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 compared to 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

The density of sperm whales (individuals per 1000 km^2) 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); 1.7 off the U.S. West Coast (Barlow and Forney 2007); 3.4 to 4.2 in the eastern temperate Pacific (Barlow and Taylor 2005); and 2.82 in the Hawaiian EEZ (Barlow 2006). 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. Abundance in the Pacific is approximately 152,000–226,000 using Whitehead's methods. Assuming that the population is growing at about 1.1%/year[2], Whitehead also estimated that the global population is at about 32% of historical numbers. Since the Pacific kills from 1940–1970 were most extreme in the Pacific (hunting was not uniform across sperm whale habitats; the Atlantic was exploited before the Pacific and Indian Ocean areas and thus during this time period, more hunting of sperm whales was occurring in the Pacific Ocean than in the Atlantic Ocean), the current status there is likely worse than the global level (of 32%).

Rice (1989) provided a crude estimate of 1,260,000 for the total pre-exploitation abundance of sperm whales in the North Pacific. 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.

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 km^2) in California coastal waters (within 300 nautical miles 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

[2] From Whitehead (2002): Maximum rate of increase: best r = 1.1%; reasonable range 0.7 to 1.5%. The population parameters used by the IWC (1982) suggest r = 0.9% for a population with stable age distribution, but these include very uncertain, and probably overestimated, mortality rates, and no changes with age in either fecundity or adult mortality. It may be more realistic to use the well-established mortality schedule of killer whales (Olesiuk *et al.* 1990) and an age-specific pregnancy rate taken from the data presented by Best *et al.* (1984; pregnancy rate for mature females = 0.257 – 0.0038 × Age in years), in which case the annual rate of increase with stable age distribution is 1.1% yr–1.

(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).

In the eastern North Pacific, a shipboard line-transect survey for sperm whales, using combined visual and acoustic methods, was conducted in a 7.8 million km^2 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, and the two estimates were not significantly different (Barlow and Taylor 2005). Barlow (2006) estimated sperm whale abundance in the U.S. EEZ waters surrounding Hawaii as 6,900 (CV=0.81). There are no available estimates for sperm whales in Alaskan waters and no recent estimates of abundance for the entire North Pacific.

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 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).

F. Life History-Indian Ocean Population

F.1 Population Structure

In the western Indian Ocean, there is evidence 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; James 1979). In the central Indian Ocean, concentrations of sperm whales have been recorded to the north of St. Paul and Amsterdam Islands in the austral summer (Gosho *et al.* 1984).

F.2 Distribution and Habitat Use

See Atlantic and Pacific sections. The Indian Ocean Sanctuary was created in 1979, under Article v(l)(c) of the International Whaling Convention for the Regulation of Whaling, and all commercial whaling was prohibited within its boundaries. This boundary extends from the Antarctic continent north to 55°S and from 20°E to 130°E.

F.3 Feeding and Prey Selection

See Atlantic Ocean section.

F.4 Competition

See Atlantic and Pacific Oceans sections.

F.5 Reproduction

See Atlantic and Pacific Oceans sections.

F.6 Natural Mortality

See Atlantic and Pacific Oceans sections.

F.7 Abundance and Trends

No estimate of density, abundance or trends are available based on surveys in the Indian Ocean. 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. If we use Whitehead's methods, then abundance in the Indian Ocean is approximately 62,000–92,000 sperm whales. Assuming that the population is growing at about 1.1%/year[3] (in Whitehead 2002), Whitehead also estimated that the global population is at about 32% of historical numbers.

G. Threats

A threat is defined as any factor that could represent an impediment to recovery. In this recovery plan all threats, those that are natural and those that are human-related, are considered. The rankings were developed relative to each other, and put into one of four categories: high, medium, low, and unknown (*i.e.*, further research is needed to determine whether it falls into high, medium, or low). Relative Impact to Recovery, which is defined in the last column in the threats table (Table 1) and at the end of each subsection, is a combination of the severity (magnitude, scope, and relative frequency with which the threat is expected to occur) and uncertainty of information for each. There are different types of uncertainty relating to threats. For example, there may be uncertainty about the extent to which something affects sperm whales (*e.g.*, ship strikes); whether a factor affects sperm whales negatively or positively (*e.g.*, climate change); or how a factor affects sperm whales (*e.g.*, anthropogenic noise). Therefore, how severity and uncertainty interact (to produce Relative Impact to Recovery ranking) is unique by situation. Threats to sperm whales are summarized in Table 1.

G.1 Fishery Interactions – LOW

The vulnerability of sperm whales to incidental capture in fishing gear, especially gillnets set in deep water for pelagic fish (*e.g.*, sharks, billfish, and tuna) and bottom-set longline gear, is well documented (Di Natale and Notarbartolo di Sciara 1994; Haase and Felix 1994; Felix *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 (described in detail in following sections) fish off fishing gear. Thus, it is possible that the increased strandings frequency in the Atlantic noted in Section D.7 could be related to fishery

[3] From Whitehead (2002): Maximum rate of increase: best r = 1.1%; reasonable range 0.7 to 1.5%. The population parameters used by the IWC (1982) suggest r = 0.9% for a population with stable age distribution, but these include very uncertain, and probably overestimated, mortality rates, and no changes with age in either fecundity or adult mortality. It may be more realistic to use the well-established mortality schedule of killer whales (Olesiuk *et al.* 1990) and an age-specific pregnancy rate taken from the data presented by Best *et al.* (1984; pregnancy rate for mature females = 0.257 – 0.0038 × Age in years), in which case the annual rate of increase with stable age distribution is 1.1% yr–1.

bycatch (whales having drowned in gear) (Evans 1997). Direct action taken by fishermen to protect their catch and gear from depredation by sperm whales could result in serious injuries or mortality. The ranking of the threat posed by the incidental capture of animals by global gillnet and longline fishing practices to sperm whale recovery was based on the assertion that although there is low severity and medium uncertainty with regard to impacts to individual animals, the impact to the recovery of sperm whale populations due to these fishing practices is considered low (Table 1).

G.1.1 Atlantic Ocean/Mediterranean Sea – LOW

In U.S. east-coast waters, bycatch of sperm whales has been documented in the pelagic drift gillnet fishery, which targeted primarily swordfish and tuna (Waring *et al.* 1997). In 1990, one whale was found entangled and was released in "injured" condition on Georges Bank. In June 1995, one sperm whale was entangled with gear "in/around several body parts," then released injured from a pelagic drift gillnet haul located on the shelf edge on Georges Bank. In addition to pelagic gear, in August 1993, a dead sperm whale, with longline gear wound tightly around the jaw, was found floating about 20 miles off Mt. Desert Rock, Maine. In October 1994, one sperm whale was successfully disentangled from a fine-mesh gillnet in Birch Harbor, Maine. There was one recorded death by entanglement in longline gear in the Caribbean (Northridge 1996). The pelagic drift gillnet fishery closed in 1997 and the use of drift gillnets prohibited in 1999. In May 1997, a sperm whale entangled in a net with three buoys trailing was sighted 130 nm northwest of Bermuda, but no information on the status of that animal was provided. There have been no recent interactions between sperm whales and commercial fishing gear in the Gulf of Mexico (Waring *et al.* 2005). It is possible that some mortality and injury occurs in offshore fisheries without being documented, such as that resulting from "ghost fishing" by lost or discarded gear, but the level is unknown. During 2001–2005, human-caused mortality was estimated at 0.2 sperm whales per year (0.0 sperm whales per year from fisheries and 0.2. from ship strikes) off the east coast of the U.S. (Waring *et al.* 2009).

In the North Atlantic, depredation has been recorded in waters around Norway, the southern coast of Greenland and the Davis Strait between Newfoundland and Greenland in fisheries targeting Greenland halibut (*Reinhardtius hippoglossoides*), Atlantic halibut (*Hippoglossus hippoglosuss*), Atlantic cod (*Gadus morhua*) and Greenland cod (*Gadus ogac*) (Dyb 2006; Nils Oien and Paul Winger, pers. comm. in Mesnick *et al.* 2008). In the Flemish Cap region, Karpouzli and Leaper (2004) recorded interactions with deep-water trawlers, where sperm whales appeared during hauling operations targeting Greenland halibut, and one case of entanglement in the trawl was reported. Between 2001 and 2005, no sperm whales were known to be killed due to fishery interactions in the U.S. Gulf of Mexico (Waring *et al.* 2009).

In the Southern Atlantic Ocean interactions with sperm whales involve demersal longline fisheries for Patagonian toothfish (*Dissostichus eleginoides*). There are records of depredation or possible depredation occurring at several locations (Falkland, South Georgia) (CCAMLR 1994; Crespo *et al.* 1997; Nolan and Liddle 2000; Northridge 1996; Purves *et al.* 2004). In the Falkland Islands (Nolan and Liddle 2000; Yates and Brickle 2007) and in the Crozet Islands (Jerome Maison, pers. comm. in Mesnick *et al.* 2008) aggressive competition between sperm and killer whales for a spot at the hauling station of longliners was reported. Entanglements in longline fishing gear have been observed in South Georgia (Purves *et al.* 2004) and the Falklands

Islands (Helen Otley, pers. comm. in Mesnick *et al*. 2008). The threat posed by demersal longline fisheries was ranked as low based on the assertion that there is low uncertainty with regard to the extent the fishing practice may have on sperm whales and that the severity of the threat to the overall population was low (Table 1).

Such results indicate that current fishing practices pose a low threat to the recovery of sperm whale populations in the Atlantic Ocean. However, levels of mortality and injury due to entanglement in lost or discarded gear and the number of cases of entanglement in fisheries that were not reported are unknown. The threat posed by pelagic drift gillnet fishing was ranked as low based on the assertion that there is low uncertainty with regard to the extent the fishing practice may have on sperm whales and that the severity of the threat to the overall population was low (Table 1).

The Mediterranean Sea is an exception to this threat being considered low in severity. Should this population be later considered separately from the Atlantic Ocean basin, sperm whale entanglement is known to be a high risk factor in the swordfish drift gillnet fishery. The primary indication that this population is likely to have declined substantially is based on a reduced stranding rate where most strandings indicated entanglement mortality. Although the fishery is now illegal, fisheries entanglements continue.

G.1.2 Pacific Ocean – LOW

The offshore drift gillnet fishery targeting swordfish and sharks off Oregon, California, and Baja California (Mexico) is a recognized threat to sperm whales. While the California/Oregon drift gillnet fishery killed/seriously injured several sperm whales in the 1990s, since the creation of a leatherback sea turtle (*Dermochelys coriacea*) conservation area was implemented in 2001 off central California and Oregon (66 FR 44549), no sperm whales have been observed taken in this fishery. No estimates of mortality/serious injury are available for the Mexican drift gillnet fisheries (Carretta *et al.* 2009). Palacios and Gerrodette (1996) noted that sperm whales are at least occasionally killed in artisanal gillnet fisheries targeting 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). One sperm whale stranded dead in 2004 with 5 to 6-inch mesh nylon netting found in its stomach and two sperm whales stranded dead in 2008 with a variety of netting in their stomachs (U.S. Department of Commerce 2009, J. Cordaro, NMFS-SWR, pers. comm., 2009). The fishery source of those nets is unknown, but is currently being analyzed to determine the type and source (country/area). Mean annual takes for these "unknown" fisheries are based on 2002–2006 data (Carretta and Chivers 2004; Carretta *et al.* 2005a, 2005b; Carretta and Enriquez 2006, 2007). This results in an average estimate of 0.2 (CV = not available) sperm whale deaths per year attributed to all fisheries. The threat posed by the drift gillnet fishery was ranked as low based on the assertion that there is a low uncertainty with regard to the extent of impact the fishing practice may have on sperm whales and that the severity of the threat to the overall population was low (Table 1).

In the North Pacific, longline depredation is a localized phenomenon, occurring mainly in the central and eastern Gulf of Alaska, occasionally in the western Gulf of Alaska and Aleutian Islands, and absent in the Bering Sea (Sigler *et al*. 2008). In this region, depredation occurs in the sablefish (black cod) (*Anoplopoma fimbria*) and Pacific halibut fishery (*Hippoglossus stenolepis*) (Hill *et al.* 1999; Straley *et al.* 2005; Sigler *et al.* 2008). Investigations have been conducted to document rates of depredation, to understand how sperm whales manage to find vessels and remove fish from the gear, and to quantify the amount of prey removed and record the frequency of resulting mortality or serious injury due to entanglement. For instance, in 2006, the "Symposium on Fisheries Depredation by Killer and Sperm Whales: Behavioural Insights, Behavioural Solutions," was held in British Columbia. Reports of depredation were first noted in 1978, in the Gulf of Alaska, and from 1989–2003, 38 surveyed stations recorded sperm whale predation on longline catch (Angliss and Outlaw 2005). However, from 1998 to 2004, neither sperm whale presence nor depredation rate increased significantly (Sigler *et al*. 2008). In collaboration with fishermen, research using genetic, acoustic, and fishing behavior studies has 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. In Alaska there are reports of fishermen throwing seal bombs in the water and yelling at the whales when they depredate their gear. Reports of fishermen shooting whales with guns and harpoons in the artisanal fishery off Southeast Chile represent potentially fatal threats provoked by frustration with reduced catches due to sperm whale depredation (González and Olivarría 2002).

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, however, from 2001–2005, there have been no observed serious injuries or mortalities in federally observed Alaska fisheries (Angliss and Outlaw 2007). However, in 2006, there were three observed serious injuries in the Gulf of Alaska sablefish longline fishery, which extrapolates to 10 estimated serious injuries for that fishery for that year. Total estimated total annual takes is 2.01 (CV=0.49) animals (Angliss and Allen 2009).

The threat by North Pacific fishing practices in Alaska from the sablefish fishery to sperm whale recovery was ranked as low since only a small proportion of the population, when compared to the global population, depredates the sablefish fishery in Alaska. The severity and uncertainty of this threat are ranked as low.

The average 5-year estimate within the Hawaiian Islands of annual mortality and serious injury is zero (between 1998–2002). Since 2001, the Hawaii-based long line fishery has undergone a series of regulatory changes, primarily to protect sea turtles, but the potential impacts of these regulatory changes on the rate of sperm whale interaction in unknown. The Hawaii-based longline fishery was ranked as low since few whales have interacted with these fisheries and the severity and uncertainty of these interactions is low (the one animal that was observed caught in longline gear was apparently able to free itself and not considered seriously injured) (Forney 2004).

Sperm whales may become entangled in fishing gear (recorded most often in demersal longline gear) while attempting to depredate fish off of the gear (Warner *et al.* 2005). Southern Pacific

Ocean interactions involve demersal longline fisheries for Patagonian toothfish (*Dissostichus eleginoides*). There are records of depredation or possible depredation occurring in Chile (Oporto and Brieva 1994; Ashford *et al.* 1996; González 2001; González *et al.* 2001; Olivarría 2002; Hucke-Gaete *et al.* 2004). 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 Chile (Ashford *et al.* 1996). 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 (González 2001). In addition, Haase and Felix (1994) recorded two instances in which sperm whales were killed after becoming trapped in tuna purse-seine nets off Ecuador. The ranking of the threat posed by the incidental capture of animals by these fishing practices to sperm whale recovery was listed under the global population/stock, reference G.1 (Table 1).

G.1.3 Indian Ocean – UNKNOWN

Indian Ocean interactions with fishing gear involve demersal longline fisheries for Patagonian toothfish. There are records of depredation or possible depredation occurring at several locations (Crozet, and Kerguelen Islands; Capdeville 1997; CCAMLR 1994). In Crozet Island aggressive competition between sperm and killer whales for a spot at the hauling station of longliners were reported (S. Mesnick, pers. comm. 2006). Deepwater gillnets are still prevalent in the Indian Ocean and there is risk for entanglements with whales.

The threat by Indian Ocean fishing practices to sperm whale recovery was ranked as unknown because of the high uncertainty with regard to the extent of impact the fishing practices may have on sperm whales and the unknown severity of the threat to the overall population.

G.2 Anthropogenic Noise – UNKNOWN

Humans have introduced sound intentionally and unintentionally into the marine environment for underwater communication, navigation, and research. Noise exposure can result in a multitude of impacts, ranging from those causing little or no impact to those being potentially severe, depending on level and on various other factors. Response to noise varies due to many factors, including type and characteristics of the noise source, distance between the source and the receptor, receptor characteristics (*e.g.*, sensitivity, behavioral context, age, sex, and previous experience with sound source) and time of the day or season. Noise may be intermittent or continuous, steady or impulsive, and may be generated by stationary or transient sources. As one of the potential stressors to marine mammal populations, noise may seriously disrupt marine mammal communication, navigational ability, and social patterns. Marine mammals use sound to communicate, navigate, locate prey, and sense their environment. Both anthropogenic and natural sounds may cause interference with these functions.

The effects of anthropogenic noise are difficult to ascertain and research on this topic is ongoing. The possible impacts of the various sources of anthropogenic noise, described below, have not all been well studied on sperm whales. The threat occurs at an unknown severity and there is a high level of uncertainty associated with the evidence described below. Thus, the relative impact of anthropogenic noise to the recovery of sperm whales is ranked as unknown (Table 1).

Types of Noise

Ambient and Discrete Sources

Ambient or background noise levels are an important consideration in assessing acoustic impacts. Natural (*e.g.*, wind, biologics) and anthropogenic sources contribute significantly to ambient noise levels as a whole (*i.e.*, composite of all sources together) (Wenz 1962). These sound sources can occur locally or contribute from afar, like distant shipping (Curtis *et al*. 1999; Andrew *et al*. 2002; McDonald *et al*. 2006; McDonald *et al*. 2008). The ambient noise level of an environment can be quite complicated and vary from location to location (deep versus shallow water), from day to day, within a day, and/or from season to season. For example, the amount of noise from shipping can be correlated to amount of traffic (*e.g.*, major shipping lanes are louder than other areas outside shipping lanes; Hatch *et al*. 2008). In addition to describing the ambient acoustic environment, sound can be described as discrete sources (*e.g.*, individual seismic vessel, individual tactical sonar, individual ship). More information on sound produced by discrete sources is provided later in this section.

Hearing Damage or Impairment

The potential effects of continuous or impulse noise sources on sperm whales are of particular concern. Intense sound transmissions in the marine environment (*i.e.*, explosives) may impact sperm whales by causing damage to body tissue or gross damage to ears, causing a permanent threshold shift (PTS) or a temporary threshold shift (TTS), if the animal is in close range of a sound source or exposed for a long duration. Additionally, 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

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, the obscuring of sounds of interest by interfering sources (generally at similar frequencies), occurs when noise interferes with a marine animal's ability to hear a sound of interest. Marine mammals use acoustic signals for a variety of purposes, which differ among species, but include communication between individuals, navigation, foraging, reproduction, and learning about their environment (Erbe and Farmer 2000; Tyack 2000). "Auditory Interference," or masking, generally occurs when the interfering noise is louder than, and of a similar frequency to, the auditory signal received by the animal. Masking these acoustic signals can disturb the behavior of individual animals, groups of animals, or entire populations.

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 (Richardson *et al.* 1995; Foote *et al*. 2004). Masking is influenced by the amount of time that the noise is present, as well as the spectral characteristics of the noise source (*i.e.*, overlap in time, space, and frequency characteristics between noise and receiver). There are still many uncertainties regarding how masking affects marine mammals. For example, it is not known how loud acoustic signals must be for animals to recognize or respond to another animal's vocalizations (NRC 2003). It is also unknown if animals listen/respond to all the sounds they can hear or can be selective about what they will listen to. Richardson *et al*. (1995) argued that the maximum radius of influence of an industrial noise (including broadband low frequency sound transmission) on a marine mammal, is the distance from the source to the point at which the noise can barely be heard. This range is determined by either the hearing sensitivity of the animal or the background noise level present. Masking of industrial noise is likely to affect some species' ability to detect communication calls and natural sounds (*i.e.*, surf noise, prey noise, etc.; Richardson *et al*. 1995).

Animals may try to minimize masking by changing their behavior. These behavior changes may include producing more calls, producing longer calls, or shifting the frequency of the calls. For example, it has been demonstrated that mysticetes, like the North Atlantic right whale (Parks *et al*. 2007; Parks *et al*. 2009) and blue whale (Di Iorio and Clark 2009) alter their vocalizations (call parameters or timing of calls) in response to background noise levels.

The echolocation calls of toothed whales are subject to masking by high frequency sound. Human data indicate low frequency sound can mask high frequency sounds (*i.e.*, upward masking). Studies on captive odontocetes (not sperm whales) (Au *et al.* 1974, 1985; Au 1993) indicate that some species may use various processes to reduce masking effects (*e.g.*, adjustments in echolocation call intensity or frequency as a function of background noise conditions). There is also evidence that the directional hearing abilities of odontocetes are useful in reducing masking at the high frequencies used for echolocation, but not at the low-moderate frequencies used for communication (Zaitseva *et al.* 1980).

There are still many uncertainties regarding how masking affects marine mammals, including sperm whales. The potential impacts that masking may have on individual survival, the behaviors marine mammals may exhibit to avoid masking, and the energetic costs of changing behavior to reduce masking, are poorly understood.

Behavioral Response

Behavioral reactions can vary not only among individuals but also for a given individual, depending on previous experience with a sound source, hearing sensitivity, sex, age, reproductive status, geographic location, season, health, social behavior, or context. The severity of the response can also vary depending on characteristics of the sound source (*e.g.*, whether it is moving or stationary, number of sound sources) and/or the surrounding environment (*e.g.*, how close to shore, region where animals may be unable to avoid exposure, propagation characteristics the area either enhancing or reducing exposure) (Richardson *et al*. 1995; NRC 2003, 2005). As one of the potential stressors to marine mammal populations, noise and acoustic influences may seriously disrupt marine mammal communication, navigational ability, and social patterns.

Most observations of behavioral responses of marine mammals to noise have been limited to short-term behavioral responses, which included the cessation of feeding, resting, or social interactions.

Relationships between specific sound sources, or anthropogenic sound in general, and the responses of marine mammals to those sources are still subject to scientific investigation, but no clear patterns have emerged (see Southall *et al*. 2007 for a review). Animals may adapt by altering vocalizations, but interruption of normal vocalizing behavior or other behaviors could be acutely changed for a period of time or slightly modified, which could have efficiency and energetic consequences[4]. Sensitization (increased behavioral or physiological responsiveness over time) to noise could also exacerbate other effects, and habituation (decreased behavioral responsiveness over time) to chronic noise could cause animals to remain close to noise sources. 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, fishing gear, predation, etc. (Richardson *et al.* 1995).

It is important to recognize the difficulty of measuring behavior in free-ranging whales. The cumulative effects of habitat degradation are difficult to define and almost impossible to evaluate. Additionally, there is a lack of information on how short-term behavioral responses to noise translate into long-term or population-level effects (Wartzok *et al.* 2004; NRC 2003, 2005). Responses of sperm whales to anthropogenic noises probably depend on the age and sex of animals being exposed, as well as other factors. There is evidence that many individuals respond to certain sound sources, provided the received level is high enough to evoke a response, while other individuals do not. Studies mentioned in the previous section on Masking suggest that the behavioral responses of sperm whales to anthropogenic noises are highly variable, but do not appear to result in the death or injury of individual whales or result in reductions in the fitness of individuals involved. For more specific information on potential impacts of noise associated with vessel traffic, oil and gas exploration, and military activities, see sections below.

G.2.1 Ship Noise – UNKNOWN

Sound emitted from large vessels, particularly in the course of transit, is a principal source of noise in the ocean today, primarily due to the properties of sound emitted by cargo vessels. Ship propulsion and electricity generation engines, engine gearing, compressors, bilge and ballast pumps, as well as hydrodynamic flow surrounding a ship's hull and any hull protrusions and vessel speed contribute to a large vessels' noise emission into the marine environment. Prop-driven vessels also generate higher frequency noise through cavitations, which accounts for approximately 85% or more of the noise emitted by a large vessel. Larger vessels tend to generate lower frequency sounds and are louder (Polefka 2004).

Surface shipping is the most widespread source of anthropogenic, low frequency (0 to 1,000 Hz) noise in the oceans (Simmonds and Hutchinson 1996). Ross (1976) estimated that between 1950 and 1975, shipping had caused a rise in ambient noise levels of 10 dB. He predicted that this would increase by another 5 dB by the beginning of the 21st century. The National Research Council (2003) estimated that the background ocean noise level at 100 Hz has been increasing by about 1.5 dB per decade since the advent of propeller-driven ships and others have estimated that the increase in background ocean noise is as much as 3 dB per decade in the Pacific (Andrew *et*

[4] Tyack (2008) speaks to the costs associated with marine mammals adjusting their vocalizations to compensate with noise in their environment. In birds, energetic costs have been reported with singing louder (Oberweger and Goller 2001).

al. 2002; McDonald *et al.* 2006, 2008). At this point, the severity of the threat of ship noise to sperm whales is unknown and uncertainty of the threat is high. Therefore, the relative impact to recovery of sperm whales due to this threat is ranked as unknown (Table 1).

Other Miscellaneous Sound Sources

There is some evidence of disruptions of sperm whale clicking and behavior from exposure to pingers (Watkins and Schevill 1975), the Heard Island Feasibility Test (Bowles *et al*. 1994), and the Acoustic Thermometry of Ocean Climate (ATOC) at Pioneer Seamount off Half Moon Bay, California (Costa *et al.* 1998). Sperm whales have been observed to frequently stop echolocating in the presence of underwater pulses made by echosounders, such as pingers, at 6 to 13 kHz (Watkins and Schevill 1975). Goold (1999) reported six sperm whales that were driven through a narrow channel using ship noise, echosounder, and fishfinder emissions from a flotilla of 10 vessels. They also stop vocalizing for brief periods when codas are being produced by other individuals, perhaps because they can hear better when not vocalizing themselves (Goold and Jones 1995).

G.2.2 Oil and Gas Exploration– UNKNOWN

Drilling for oil and gas generally produces low-frequency sounds with strong tonal components. There are few recent studies 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 undetectable alongside the platform at Beaufort scale sea states of three or above. The strongest tones were at very low frequencies near 5 Hz (Richardson *et al*. 1995).

Oil and gas exploration, including seismic surveys, typically operate with marine mammal observers as part of required mitigation measures. There have been no reported seismic-related or industry ship-related mortalities or injuries to sperm whales in areas where marine mammal observers are present, such as the Gulf of Mexico. However, the severity of this threat is unknown and the uncertainty of this threat is high. Therefore, the relative impact to recovery of sperm whales due to this threat is ranked as unknown (Table 1).

Geophysical and Other Exploration

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 appreciable sound energy into the water and operate at low frequencies.

Published reports identify instances in which sperm whales may have responded to an acoustic source and other instances in which they did not appear to respond behaviorally when exposed to seismic surveys. Sperm whales in the Gulf of Mexico apparently moved away, possibly by 50+ km, when seismic surveys began (Mate *et al.* 1994; Davis *et al.* 1995). However, Davis *et al*. (2000) noted that sighting frequency did not differ significantly among the different acoustic levels examined in the northern Gulf of Mexico, contrary to what Mate *et al*. (1994) reported. In one DTAG deployment in the northern Gulf of Mexico, researchers documented that the tagged whale moved away from an operating seismic vessel once the seismic pulses were received at the tag at roughly 137 dB re 1 μPa (Johnson and Miller 2002). Preliminary data from an experimental study of sperm whale reactions to seismic surveys in the Gulf of Mexico and a study of the movements of sperm whales with satellite-linked tags in relation to seismic surveys show that during two controlled exposure experiments in which sperm whales were exposed to seismic pulses at received levels up to 148 dB re 1 μPa, the whales did not avoid the vessel or change their feeding efficiency (NRC 2003). Miller *et al.* (2009) found similar results, from eight sperm whales exposed to airgun arrays in the Gulf of Mexico that did not exhibit avoidance reactions to the airguns, but suggest the animals were affected at ranges beyond those currently regulated, due to more subtle effects on their foraging behavior. Some 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-ATOC "Heard Island Feasibility Test" (Bowles *et al.* 1994). Stone (2003) summarized the responses of marine mammals to seismic surveys off the United Kingdom and found that sperm whales showed no noticeable avoidance response. Although the sample size is small (4 whales in 2 experiments), the results are consistent with those off northern Norway (described below). Weir (2008) recently reported that sperm whales encounter rates were similar when airguns were firing compared to when they were off, as well as no incidences of overtly observable responses to airgun sound.

Captive odontocetes (bottlenose dolphin and beluga whale) exhibited changes in behavior when exposed to a seismic watergun (Finneran et al. 2002). Behavioral changes typically involved what appeared to be deliberate attempts to avoid the location of the exposure site during subsequent tests or vocalizations after exposure, which began at ~187 dB 1 μPa_{rms} for the beluga whale and 207 dB 1 μPa_{rms} for the bottlenose dolphin. The relevance of these data to free-ranging odontocetes is uncertain. In the wild, cetaceans sometimes avoid sound sources well before they are exposed to the levels listed above, and reactions in the wild may be more subtle than those described during captive studies.

A recent study offshore of northern Norway indicated that sperm whales continued to call when exposed to pulses from a distant seismic vessel. Received levels of the seismic pulses were up to 146 dB re 1 μPa peak-to-peak (Madsen *et al*. 2002). Similarly, a study conducted off Nova Scotia that analyzed recordings of sperm whale sounds at various distances from an active seismic program did not detect any obvious changes in the distribution or behavior of sperm whales (McCall Howard 1999). Seismic work off Angola found no difference in encounter rates of sperm whales or obvious behavioral changes due to air gun activity (Weir *et al.* 2001). Recent data from vessel-based monitoring programs in United Kingdom waters suggest that sperm whales in that area may have exhibited some changes in behavior in the presence of operating seismic vessels) (Stone 1997, 1998, 2000, 2001, 2003), but the compilation and analysis of the data led the author to conclude that seismic surveys did not result in observable effects to sperm whales (Stone 2003). However, there may have been adverse effects that this study did not detect, due to the difficulty of making surface observations for a species that spend relatively less time at the surface (Stone 2003). Nonetheless, the results from these surveys from the programs in United Kingdom waters are similar to previously mentioned studies and seem to show that some sperm whales tolerate seismic surveys.

Very little systematic information is available regarding the reactions of toothed whales to impulsive noises, like seismic pulses. 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. However, some energy in seismic pulses at higher frequencies has been recorded (Madsen et al. 2006). 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 WÜrsig 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. Furthermore, because of sperm whales' apparent role as important predators of mesopelagic squid and fish, changes in their abundance could affect the distribution and abundance of other marine species.

Explosives

Studies identify instances in which sperm whales did not respond (by altering behavior or click rate) to anthropogenic or impulse sounds such as the use of explosives. Sperm whales did not alter their vocal activity when exposed to levels of 173 dB re 1 μPa (peak equivalent root mean square) from impulsive sounds produced by 1 g TNT detonators (Madsen and Mohl 2000).

Liquefied Natural Gas

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 a LNG facility could negatively impact marine mammals migrating through the area. For more information on vessel impacts, see section G.3.

G.2.3 Military Sonar and Explosives – UNKNOWN

Military training activities by the U.S. Navy and the navies of other countries regularly occur in the Atlantic (including the Gulf of Mexico and Mediterranean Sea), Indian, and Pacific Oceans. These activities include anti-submarine warfare exercises, surface warfare exercises, anti-surface mine warfare exercises, missile exercises, sinking exercises, and aerial combat exercises. In addition to these training activities, the U.S. Navy conducts ship shock trials, which involve detonations of high explosive charges, and operates several permanent and temporary (portable) undersea warfare training ranges that employ acoustic sensors.

These activities introduce a variety of sounds into the marine environment, but most studies have focused on the potential effects of active sonar, which has been associated with several marine mammal stranding events. The U.S. Navy employs several low-frequency (<1,000 Hz), mid-frequency (1,000–10,000 Hz), and high-frequency (>10,000 Hz) active sonar systems. The U.S. Navy employs several mid-frequency sonar systems that range from large systems mounted on the hulls of ships (*e.g.*, AN/SQS-53 and -56), to smaller systems that are deployed from helicopters and fixed-wing aircraft, sonobuoys, and torpedoes. The primary low-frequency sonar active sonar system is the Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar system, which produces loud signals in the 100–500 Hz range, and has operated in the western and central Pacific Ocean. These sonar systems can produce loud sounds at frequencies of between 1 and 10 kHz and higher (Evans and England 2001; U.S. Department of the Navy 2008).

For decades, sperm whales have been exposed to sounds associated with these training activities in waters off the Atlantic Coast (including portions of the Gulf of Mexico), off Southern California, in waters off the main Hawaiian Islands, the Mariana Islands, and off the coasts of Washington, Oregon, and Alaska. This pattern of exposure is likely to continue into the foreseeable future. What is largely unknown is how sperm whales respond to this type of exposure and what the consequences of that exposure could be on the longevity and reproductive success of sperm whales.

Although no audiograms are available for sperm whales, they are expected to have good, high frequency hearing because their inner ear resembles that of most dolphins, and appears tailored for ultrasonic (>20 kHz) reception (Ketten 1994). The only data on the hearing range of sperm whales are evoked potentials[5] from a stranded neonate, which suggest that neonatal sperm whales respond to sounds from 2.5 to 60 kHz. Sperm whales vocalize in high- and mid-frequency ranges; most of the energy of sperm whales clicks is concentrated at 2 to 4 kHz and 10 to 16 kHz. Other studies indicate sperm whales' wide-band clicks contain energy between 0.1 and 20 kHz (Weilgart and Whitehead 1993, Goold and Jones 1995). Ridgway and Carder (2001) measured low-frequency, high amplitude clicks with peak frequencies at 500 Hz to 3 kHz from a neonate sperm whale. Based on the limited information on their hearing sensitivities and assuming that their vocalizations provide some insight into their hearing, sperm whales would be expected to hear high- and mid-frequency sounds, but would have limited sensitivity to low-frequency sounds.

Sperm whales have been reported to have reacted to military sonar, apparently produced by a submarine, by dispersing from social aggregations, moving away from the sound source, remaining relatively silent and becoming difficult to approach (Watkins *et al.* 1985). Captive bottlenose dolphins and a white whale exhibited changes in behavior when exposed to 1 sec pulsed sounds at frequencies similar to those emitted by multi-beam sonar that is used in geophysical surveys (Ridgway *et al.* 1997, Schlundt *et al.* 2000), and to shorter broadband pulsed signals (Finneran *et al.* 2000, 2002). Behavioral changes typically involved what appeared to be deliberate attempts to avoid the sound exposure or to avoid the location of the exposure site during subsequent tests (Schlundt *et al.* 2000, Finneran *et al.* 2002). Dolphins exposed to 1-sec intense tones exhibited short-term changes in behavior above received sound levels of 178 to 193 dB re 1 μPa rms and belugas did so at received levels of 180 to 196 dB and above. Received levels necessary to elicit such reactions to shorter pulses were higher (Finneran *et al.* 2000, 2002). Test animals sometimes vocalized after exposure to pulsed, mid-frequency sound from a watergun (Finneran *et al.* 2002). In some instances, animals exhibited aggressive behavior

[5] An evoked potential is a test to evaluate the electrical activity of brain waves.

toward the test apparatus (Ridgway *et al.* 1997, Schlundt *et al.* 2000). The relevance of these data to free-ranging odontocetes is uncertain. In the wild, cetaceans sometimes avoid sound sources well before they are exposed to the levels listed above, and reactions in the wild may be more subtle than those described by Ridgway *et al.* (1997) and Schlundt *et al.* (2000).

There is some evidence of disruptions of clicking and behavior from sonars (Goold 1999, Watkins and Scheville1975, Watkins *et al.* 1985), pingers (Watkins and Scheville 1975), the Heard Island Feasability Test (Bowles *et al.* 1994), and the Acoustic Thermometry of Ocean Climate (Costa *et al.*1998). Sperm whales have been observed to frequently stop echolocating in the presence of underwater pulses made by echosounders (Watkins and Scheville 1975). Goold (1999) reported six sperm whales that were driven through a narrow channel using ship noise, echosounder, and fishfinder emissions from a flotilla of 10 vessels. Watkins and Scheville (1975) showed that sperm whales interrupted click production in response to pinger (6 to 13 kHz) sounds. They also stopped vocalizing for brief periods when codas were being produced by other individuals, perhaps because they can hear better when not vocalizing themselves (Goold and Jones 1995).

Other studies identify instances in which sperm whales did not respond to anthropogenic sounds. Sperm whales did not alter their vocal activity when exposed to levels of 173 dB re 1 μPa from impulsive sounds produced by 1 g TNT detonators (Madsen and Mohl 2000). Richardson *et al.* (1995) citing a personal communication with J. Gordon suggested that sperm whales in the Mediterranean Sea continued calling when exposed to frequent and strong military sonar signals. When Andre *et al.* (1997) exposed sperm whales to a variety of sounds to determine what sounds may be used to scare whales out of the path of vessels, sperm whales were observed to have startle reactions to 10 kHz pulses (180 db re 1 μPa at the source), but not to the other sources played to them.

Published reports suggest that sperm whales might respond to sounds produced by seismic surveys in some instances and ignore the sounds in other instances. Mate *et al.* (1994) reported an opportunistic observation of the number of sperm whales to have decreased in an area after the start of airgun seismic testing. However, Davis *et al.* (2000) noted that sighting frequency did not differ significantly among the different acoustic levels they examined in the northern Gulf of Mexico, contrary to what Mate *et al.* (1994) reported. In one DTAG deployment in the northern Gulf of Mexico on July 28, 2001, the tagged sperm whale moved away from an operating seismic vessel once the seismic pulses were received at the tag at roughly 137 dB re 1 μPa (Johnson and Miller 2002). Sperm whales may also have responded to seismic airgun sounds by ceasing to call during some (but not all) times when seismic pulses were received from an airgun array >300 km away (Bowles *et al.* 1994).

A recent study offshore of northern Norway indicated that sperm whales continued to call when exposed to pulses from a distant seismic vessel. Received levels of the seismic pulses were up to 146 dB re 1 μPa peak-to-peak (Madsen *et al.* 2002). Similarly, a study conducted off Nova Scotia that analyzed recordings of sperm whale sounds at various distances from an active seismic program did not detect any obvious changes in the distribution or behavior of sperm whales (McCall Howard 1999). Recent data from vessel-based monitoring programs in United Kingdom waters suggest that sperm whales in that area may have exhibited some changes in behavior in the presence of operating seismic vessels (Stone 1997, 1998, 2000, 2001, 2003). However, the compilation and analysis of the data led the author to conclude that seismic surveys did not result in observable effects to sperm whales (Stone 2003). The results from these waters seem to show that some sperm whales tolerate seismic surveys.

During two controlled exposure experiments in the Gulf of Mexico, four sperm whales were exposed to seismic pulses (300 Hz and 3 kHz) at received levels up to 147 dB re 1 μPa (rms). The sperm whales did were not reported to have avoided the vessel or to have changed their feeding efficiency (Madsen *et al*. 2006, Jochens *et al*. 2008). Although the sample size is small (4 whales in 2 experiments), the results are consistent with those off northern Norway.

Captive bottlenose dolphins and a beluga whale exhibited changes in behavior when exposed to 1 second pulsed sounds at frequencies similar to those emitted by tactical sonar (Ridgway *et al.* 1997; Schlundt *et al.* 2000). In this case, behavioral changes typically involved what appeared to be deliberate attempts to avoid the sound exposure or to avoid the location of the exposure site during subsequent tests (Schlundt *et al.* 2000).

Underwater detonations associated with military training activities range from large high explosives such as those associated sinking exercises or ship shock trials, to missile exercises, gunnery exercises, mine warfare, disposal of unexploded ordnance, and grenades. Detonations produce shock waves and sound fields of varying size. Animals that occur close to a large detonation might be killed or seriously injured; animals that are further away might suffer lesser injury (*i.e.,* tympanic membrane rupture, or slight to extensive lung injury); while animals that are even further away might experience physiological stress responses or behavioral disturbance whose severity depends on their distance from the detonation.

Various measures are being developed to prevent sperm whales from being exposed to active sonar transmissions or underwater detonations. For example, the SURTASS LFA sonar system employs a high-frequency active sonar that allows the U.S. Navy to detect large and most small cetaceans and shut down sonar transmissions until whales have moved away from the sonar source; tests of this sonar system suggest that it detects more than 96 percent of the whales that occur within 1 kilometer of the sonar system. As another example, the suite of monitoring protocols the U.S. Navy developed during the ship shock trial on the U.S.S. Winston Churchill were effective at preventing fin whales, other cetaceans, and sea turtles from being exposed to the shock wave associated with those detonations. Other measures are being developed and tested to reduce the probability of exposing sperm whales and other cetaceans to active sonar transmissions and shock waves of underwater detonations.

The relatively large spatial scale, frequency, duration, and diverse nature of these training activities in areas in which sperm whales also occur suggests that these activities have the potential to adversely affect sperm whales. However, the severity of the effect of military sonar and detonations on sperm whales and the effectiveness of measures that avoid any adverse effects remains largely unknown and the uncertainty of our knowledge is high. Therefore, the relative impact to recovery of sperm whales due to this threat is ranked as unknown (Table 1).

G.3 Vessel Interactions

G.3.1 Ship Strikes – UNKNOWN BUT POTENTIALLY LOW

Laist *et al.* (2001), Jensen and Silber (2004), Vanderlaan and Taggart (2007), and Van Waerebeek and Leaper (2008) compiled information available worldwide regarding documented collisions between ships and large whales (baleen whales and sperm whales). Of 292 recorded strikes contained in the Jensen and Silber database (2004), 17 were of sperm whales.

Sperm whales spend long periods (typically up to 10 minutes) "rafting" and socializing at the surface between deep dives (Jaquet *et al.* 1998; Whitehead 2003). This could make them vulnerable to ship strikes. There were also instances in which sperm whales approached vessels too closely and were cut by the propellers. Within specified areas of U.S. waters in the Atlantic, NMFS has established ship speed restrictions, mandatory ship reporting systems, recommended routes, and an extensive sighting advisory system to protect right whales. While these measures were designed to protect right whales specifically, they are expected to also reduce the risk of ship strikes to other marine mammals, including sperm whales (NMFS 2008a).

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). André *et al.* (1997) in Laist *et al.* (2001), reports a case in the Canary Islands in which a high speed ferry collided with and killed a sperm whale while traveling at 45 knots.

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). In May 1994, a ship-struck sperm whale was observed south of Nova Scotia (Reeves and Whitehead 1997) and in May 2000, a merchant shop reported a strike in Block Canyon (off the central east coast of the U.S.) (Waring *et al.* 2009). In the spring, Block Canyon is a major pathway for sperm whales entering southern New England continental shelf waters in pursuit of squid (CETAP 1982; Scott and Sadove 1997). From 2001–2003 one stranded sperm whale was reported struck by a naval vessel, and another whale was reported struck by a merchant vessel near Rhode Island (Waring *et al.* 2005). During 2001–2005, mortality from ship strikes off the east coast of the U.S. was estimated at 0.2 sperm whales per year (Waring *et al.* 2009). 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 than some other species).

More than 6% (7) of 111 sperm whales stranded in Italy (1986–1999) and Greece (1982–2001) had died after being struck by a vessel, and 6% of 51 photo-identified individuals (39 in Greece and 22 in Italy) bore wounds or scars that were clearly caused by a collision (Pesante *et al.* 2002).

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). In 2005, two sperm whales were struck by a ship, but it is not known if these ship strikes resulted in a mortality or injury (U.S. Department of Commerce 2009). In 2007 a sperm whale calf was struck and killed off of Florence, Oregon

(U.S. Department of Commerce 2007). There were 14 unidentified whales struck by ships in California from 1982–2008 (California Marine Mammal Stranding Network Database, U.S. Department of Commerce 2009). While there have been some reports of sperm whales struck by ships, it does not appear that ship strikes are a significant threat to sperm whales (Whitehead 2003). However, quantifying the effects of ship strikes in the U.S. is not possible, at this time.

The possible impact of ship strikes on recovery of sperm whale populations is not well understood. 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. Because many ship strikes go unreported or undetected for various reasons and the offshore distribution of sperm whales may make ship strikes less detectable than for other species, the estimates of serious injury or mortality should be considered minimum estimates. The threat occurs at a medium severity and there is a medium level of uncertainty associated with the evidence above. While the number of sperm whale ship strikes is likely greater than those reported, the relative impact of this threat to recovery of the population is not considered significant. Thus, the relative impact to recovery of sperm whales due to ship strikes is ranked as unknown but potentially low (Table 1).

G.3.2 Disturbance from Whale Watching and Other Vessels – LOW

Several investigators reported behavioral responses to close approaches by vessels suggesting that individual whales might experience a stress response (Watkins *et al.* 1981; Baker *et al.* 1983; Malme *et al.* 1983; Bauer 1986; Bauer and Herman 1986; Baker and Herman 1987; Richardson *et al.* 1995; Jahoda *et al.* 2003). Others suggest that there is mounting evidence that wild animals respond to human disturbance in the same way that they respond to predators (Harrington and Veitch 1992; Lima 1998; Gill and Sutherland 2000; Gill *et al.* 2001; Frid and Dill 2002; Beale and Monaghan 2004; Romero 2004). These responses have been associated with the abandonment of sites (Bartholomew Jr., 1949; Allen 1991; Sutherland and Crockford 1993), reduced reproductive success (Giese 1996; Müllner *et al.* 2004), and the death of individual animals (from expending energy and thus compromising their survival) (Feare 1976; Daan *et al.* 1996).

With regard to sperm whales' behavioral responses to tour vessels, Richter *et al.* (2006) found that sperm whales in Kaikoura, New Zealand respond to whale-watching activities with small changes in ventilation and vocalization patterns. These changes may not be of biological importance; however, compared to resident whales, transients, which receive less whale-watching effort, respond differently, and usually more strongly to whale-watching boats. This appears to be consistent with Gordon *et al.* (1992) who also examined the effects of whale-watching and approaching boats off the coast of Kaikoura, New Zealand on sperm whales' behavior and found that sperm whales spent less time at the surface and adjusted their breathing intervals and acoustic behavior. 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. 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). 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 (Loup *et al.* 2005). It is not known 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). When Andre *et al*. (1997) exposed sperm whales to a variety of sounds to determine what sounds may be used to scare whales out of the path of vessels, sperm whales were observed to have startle reactions to 10 kHz pulses (180 dB re 1 μPa at the source), but not to the other sources played to them.

The potential for injury or disturbance to cetaceans from military ships is also a concern. NMFS conducted an assessment in its Biological Opinion on Rim of the Pacific (RIMPAC) exercises, focusing on ship traffic and mid-frequency sonar, and concluded that sperm whales in the action area were likely to respond to ship traffic associated with the maneuvers (NMFS 2008b).

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. Based on this information, the threat occurs at a low severity and there is a medium level of uncertainty. Thus, the relative impact to recovery of sperm whales due to disturbance from vessels and tourism is ranked as low (Table 1).

G.4 Contaminants and Pollutants – UNKNOWN

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).

A potential human-caused source of mortality is from accumulation of stable pollutants (*e.g.*, polychlorobiphenyls (PCBs)), chlorinated pesticides (DDT, DDE, dieldrin, etc.), polycyclic aromatic hydrocarbons (PAHs), and heavy metals in long lived, high -trophic level animals. (NMFS 2005a). Holsbeek *et al.* (1999) analyzed tissue samples obtained from 21 sperm whales that mass-stranded in the North Sea in 1994/1995. Their results indicated that mercury, PCB, DDE, and PAH levels were low and similar to levels reported for other marine mammals. However, cadmium levels were high, and double the reported levels in North Pacific sperm whales. While these strandings were not attributable to contaminant burdens, Holsbeek et al. (1999) do suggest that the stable pollutants might affect the health or behavior of North Atlantic sperm whales.

Levels of organochlorine contaminants in sperm whales that stranded dead 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 ^{60}Co bio-accumulates in sperm whales (from their diet that includes mesopelagic cephalopods). The authors proposed that ^{60}Co is dispersed in surface waters when the whales defecate there. The implications for the overall health of sperm whales were not considered.

In a review of organochlorine and metal pollutants in marine mammals from Central and South America, Borrell and Aguilar (1999) note that organochlorine levels in marine mammals (based on studies of franciscana dolphins (*Pontoporia blainvillei*) from Argentina and spotted dolphins (*Stenella attenuata*) from the eastern tropical Pacific) suggest low levels of exposure compared to other regions of the world. Indeed, although data are extremely scarce, concentrations of organochlorines in the tropical and equatorial fringe of the northern hemisphere and throughout the southern hemisphere are low or extremely low in marine mammals, and organochlorine concentrations in marine mammals off South America, South Africa and Australia are invariably low (Aguilar *et al.* 2002). The lowest organochlorine concentrations are found in the polar regions of both hemispheres. However, due to the systematic long-term transfer of airborne pollutants from warmer to colder regions, it is expected that the Arctic and, to a lesser extent, the Antarctic will become major sinks for organochlorines in the future, warranting long-term monitoring of polar regions (Aguilar *et al.* 2002).

The highest concentrations of organochlorines found in marine mammals are in the Mediterranean Sea. High concentrations of organochlorines in marine mammals also occur, although to a lesser extent, along the Pacific coast of the U.S. and generally in other mid-latitudes in the northern hemisphere (Aguilar *et al.* 2002). Fossi *et al.* (2003) state that concentrations in the Mediterranean could have an effect on reproductive rates of sperm whales, warranting further study (Fossi *et al.* 2003).

Recently, Ocean Alliance, Inc. completed a five-year research voyage to collect baseline data on contaminants in the oceans. The team collected 955 sperm whale biopsy samples in 18 regions across the globe, with the goal of using sperm whales as global indicators of ocean contamination. The study will analyze levels of PCBs, DDT, and hexachlorobenzene (HCB) in samples collected. Analysis of toxic metals contained in the samples revealed high levels of aluminum in all samples, with more significant levels in the Atlantic and Indian Oceans than in the Pacific Ocean or Mediterranean Sea. The range of chromium levels found in the sperm whale samples was much higher than previously reported for wildlife, and was higher in the Pacific and Indian Oceans than in the Atlantic Ocean or Mediterranean Sea. Previous to this study, aluminum and chromium were not considered to be major health concerns. Mercury and selenium were detected in the samples, but mercury levels were not considered to be toxic to the whales. Also detected in the samples were lead and cadmium (Ocean Alliance 2010).

Oil Spills

Oil spills that occur 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. Long term ingestion of pollutants, including oil residues, could affect reproductive success, but data is lacking to determine how oil may fit into this scheme for sperm whales.

Little is known about the possible long-term and trans-generational effects of exposure of sperm whales to pollutants. It is not known if high levels of heavy metals, persistent organic pollutants such as PCBs, and organochlorines found in prey species accumulate with age and are transferred through nursing, as demonstrated in other marine mammals, such as killer whales. It is also not known if exposure to oil from an oil spill will have a detrimental effect on sperm whales.

In general, the threat from contaminants and pollutants occurs at an unknown severity and there is a high level of uncertainty. Thus, the relative impact to recovery of sperm whales due to contaminants and pollution is ranked as unknown (Table 1). However, this ranking may need to be revised if future data indicate reproductive rates are indeed impacted by exposed to contaminants or pollution. For instance, we may obtain new information based on the 2010 Gulf of Mexico oil spill that leads us to reevaluate threats from contaminants in general.

G.5 Disease – LOW

Disease presumably plays a role in natural mortality of sperm whales, but little is known. While serological studies on North Pacific and North Atlantic sperm whales indicate that these whales are carriers of and infected by calciviruses and papillomavirus (Smith and Latham 1978; Lambertsen *et al.* 1987), 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 effect on sperm whales is largely unknown. Although parasites may have little effect on otherwise healthy animals, effects could become significant if combined with other stressors. Pollutants such as PCBs are known to suppress immune system function in some marine mammals, but there is considerable uncertainty in applying this knowledge to estimate how pollutants might increase disease susceptibility (Marine Mammal Commission 1999). Currently, there is no evidence of an increased level of disease in sperm whales, so the severity of this threat is considered to be low. However, given the potential but unknown effect of pollutants on immune suppression, the uncertainty in this determination is considered to be medium. Thus, the relative impact to recovery of sperm whales due to disease is ranked as low (Table 1).

G.6 Injury from Marine Debris – LOW

Harmful marine debris consists of plastic garbage washed or blown from land into the sea, fishing gear lost or abandoned by recreational and commercial fishers, 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 serious internal injuries.

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 do ingest marine debris (Lambertsen 1997). The consequences can be debilitating and even fatal. In 1989, a necropsy on a stranded sperm whale carcass indicated that its death was caused by a stomach obstruction following accidental ingestion of plastic bags and sheets in the Lavezzi Islands of the Tyrrhenian Sea (Viale *et al.* 1992). In addition, one of 32 sperm whales examined for pathology in Iceland had a lethal illness thought to have been caused by the complete obstruction of the gut with plastic marine debris (Lambertsen 1990).

Observational studies cannot fully evaluate the potential for entanglement because many entangled animals may die at sea and thus not be seen or reported. Although instances of stomach obstruction caused by marine debris have been documented in sperm whales, these are few and it is not believed to be a major threat to the species, thus the severity of this threat is ranked as low. However, given the potential but unknown effect of entanglement and ingestion of marine debris on sperm whales, the uncertainty in this determination is considered to be medium. Thus, the relative impact to recovery of sperm whales due to marine debris is ranked as low (Table 1).

G.7 Research – LOW

Sperm whales have been the subject of field studies for decades. The primary objective of many of these studies has generally been monitoring populations to gather data for behavioral and ecological studies. Existing permits authorize investigators to make close approaches of endangered whales for photographic identification, behavioral observations, passive acoustic recording, aerial photogrammetry, and underwater observations. Reported responses of gray whales to research activities ranged from no visible responses to short-term behavioral responses; however, the consequences of these levels of close approaches on the population ecology of listed species remains unknown (Moore and Clarke 2002). Research on sperm whales is likely to continue and increase in the future, especially oceanographic surveys, collection of genetic information, photographic studies, and acoustic studies.

The effects of research not directly associated with sperm whales are addressed in other subsections of the threats section of this Recovery Plan, such as vessel interactions, anthropogenic noise, contaminants and pollutants, oil and gas exploration and other industrial activities, and military sonar and explosives.

Research activities could result in disturbance, but are closely monitored and evaluated in an attempt to minimize any impacts of research necessary for the recovery of sperm whales. Specifically, the National Environmental Policy Act requires the development of environmental impact statements to assess the potential impact of a project on protected species, and ESA and MMPA permits are required for any incidental take of sperm whales. The threat occurs at a low severity and a medium level of uncertainty, as the potential does exist for unobserved mortality to occur following the completion of research activities. Thus, the relative impact to recovery of sperm whales due to this threat is ranked as low (Table 1).

G.8 Predation and Natural Mortality – LOW

Sperm whale calves are subject to predation by killer whales (Arnbom *et al.* 1987) and possibly large sharks (Best *et al.* 1984). However, other age classes are also targeted, as an observation off the coast of 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 that could be attributed to avoidance of some type of threat. Large sharks are sometimes observed around sperm whales, particularly when newborn calves are present, and scars from shark bites have been observed on calves (Best *et al.* 1984). Sperm whale remains have been found in the stomachs of sharks, but these were probably from eating carcasses rather than preying on live animals (Rice 1989). There are also reports of pilot whales (*Globicephala* spp.) and false killer whales (*Pseudorca crassidens*) harassing and attacking sperm whales (Palacios and Mate 1996; Weller *et al.* 1996). In none of these cases were there fatalities, although pieces of flesh were observed in the water after the false killer whale incident, suggesting that this species may cause some of the marks and scars seen on sperm whales' bodies (Palacios and Mate 1996).

The potential impact of predation by killer whales on the dynamics of the North Pacific marine ecosystem over the last several decades has received substantial attention within the scientific community in recent years. Information on killer whale abundance, diet, and movements has increased, and new hypotheses have been developed within the scientific community on how predation by killer whales has influenced the dynamics of marine mammal populations. Evidence indicates that predation by killer whales has been, and still is, a source of natural mortality for sperm whales: however, the extent of natural mortality and predation is not known, as few observations have occurred. Thus, the relative impact to recovery from predation and natural mortality is ranked as low, based on low severity and medium uncertainty (Table 1).

G.9 Direct Harvest – LOW

Direct harvest was the main cause of the initial depletion of sperm whales and other large whales. The IWC's moratorium on commercial whaling has largely mitigated this threat, however, the possibility of resumed whaling remains and has the potential to affect sperm whale populations. 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 also valuable byproducts of sperm whales. 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 greatly expanded after World War II as it was used in the manufacture of cosmetics and soaps and as machine oil (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— 1) the open-boat, sailing-vessel, hand-harpooning period from about 1715 to 1925; and 2) the modern period from about 1910 to the early 1980s (Best *et al.* 1984).

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 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 inaccurate, and it seems likely that the officially reported data from other areas will prove to be equally unreliable.

The IWC's moratorium on commercial whaling for sperm whales throughout the North Atlantic and North Pacific has been in place for two decades, and it has almost certainly had a positive effect on the species' recovery. There is currently no legal commercial whaling for sperm whales by IWC member nations party to the moratorium. 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 whaling for sperm whales 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. Norway[6] and Iceland have formally objected to the IWC ban on commercial whaling and are therefore under no obligation to refrain from hunting, but neither country has expressed interest in taking 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

[6] In 1982, the IWC adopted a temporary moratorium on the commercial whaling of all whale species, effective from 1986. Norway formally reserved its position on the moratorium, but nevertheless introduced a temporary ban on minke whaling pending more reliable information on the state of stocks. The Norwegian government unilaterally decided to resume whaling in 1993. Norway's legal right to hunt minke whales is not disputed, as Norway reserved its position on the temporary moratorium when it was adopted by the IWC.

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.

As mentioned previously in the Reproduction section of this Recovery Plan, selective killing of large males by whalers could have had the residual effect of reducing reproductive rates (Whitehead *et al.* 1997) and the maximal rate of increase in reproduction is very low, perhaps no more than one or two percent per year. No new information is available regarding the direct harvest of sperm whales. Although historical whaling activities were responsible for the depletion of sperm whales worldwide, they are now hunted only by Japan and in small numbers (the 2008 program proposed the taking of 10 sperm whales in the western North Pacific), and therefore, the threat of overutilization by direct harvest is currently low. However, if the IWC's moratorium on commercial whaling was ended, direct harvest could again become a threat to sperm whales, so direct harvest was addressed in this plan. The relative impact of direct harvest to recovery of sperm whales was ranked as low (Table 1).

G.9.1 Direct Harvest – Atlantic Ocean/Mediterranean Sea

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. 198la).

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 Avila 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.9.2 Direct Harvest – Pacific Ocean

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; Hegarty 1959; Best 1983). European whalers also hunted 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-based 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 Kuril 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). From 1968 to 1972, the whaling fleets moved further south and took large catches of sperm whales in the whaling grounds along the Subarctic Boundary (ca. 42°N). By 1973, there were almost no whale catches north of 50°N. There was a peak in sperm whale catches in 1969. Mizroch and Rice (2006) noted that whale catches from 1946 to 1967 showed a high density of sperm whale catches in the traditional whaling areas through 1967, and then from 1968 to 1987, sperm whale catches shifted much farther south, starting in 1968. There were no sperm whale catches in most of the areas north of 50°N after 1967. Based on official statistics after 1947, the overall male-to-female ratio in the catches was about 3 to 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 versus 9.6 times, respectively. It is clear that previously reported totals and sex ratios for North Pacific sperm whale catches are wrong.

The NMFS 2007 Stock Assessment Report states: "…a total of at least 436,000 sperm whales were taken between 1800 and the end of commercial whaling for this species in 1987. Of this grand total, an estimated 33,842 were taken by Soviet and Japanese pelagic whaling operations in the eastern North Pacific from the longitude of Hawaii to the U.S. West coast, between 1961 and 1976 (Allen 1980, IWC statistical Areas II and III), and 965 were reported taken in land-base U.S. West coast whaling operations between 1947 and 1971 (Ohsumi 1980). In addition, 13 sperm whales were taken by shore whaling stations in California between 1919 and 1926 (Clapham et al. 1997). Some of the whales taken during the whaling era were certainly from a population or populations that occur within Hawaiian waters" (Carretta *et al.* 2007).

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.9.3 Direct Harvest – Indian Ocean

The Indian Ocean sperm whale populations were almost exterminated from areas such as the Seychelles back in the 19th Century by Yankee whalers, and by the latter half of the 20th Century, modern whaling had brought all large whale species to the point of near biological collapse. It was recently revealed that illegal whaling activity by the Soviets in Omani waters in the 1960s, devastated the humpback, Bryde's (*Balaenoptera edeni)*, and sperm whale populations. At that time, most Indian Ocean populations of large whales had been devastated by commercial whaling activities. In the 1970s, the Soviet fleets continued to reduce sperm whale populations that were not protected by the ban on factory ship whaling north of 40 degrees south latitude. The widespread slaughter included thousands of females and family groups together with juveniles. This widespread whaling likely destroyed intact social groups of sperm whales in the area. Gradual reductions and restrictions were implemented leading up to the global moratorium. Whaling by factory ships ended in 1980.

A proposal by the Republic of the Seychelles at the 1979 meeting of the IWC was adopted, creating the Indian Ocean Sanctuary (IWC 1980). This Sanctuary consists of those waters of the Northern Hemisphere from the coast of Africa east to 100°E (including the Red and Arabian Seas and the Gulf of Oman) and those waters of the Southern Hemisphere between 20°E and 130°E from the equator to 55°S. The Indian Ocean Sanctuary offers protection from commercial whaling to the great whales (IWC 1980), including sperm whales.

The Southern Ocean, consisting of most of the area south of 40^{o}S latitude, was declared a whale sanctuary by the IWC in 1994 under a proposal by France. The main argument in favor of the Southern Ocean Sanctuary was to protect the Indian Ocean's whales when they migrated south to feed in Antarctic waters. Japan continues to whale in the Southern Ocean Sanctuary for scientific purposes, mainly for minke whales (*Balaenoptera acutorostrata*). Some of these whales are believed to migrate north into the Indian Ocean in winter.

For most countries, the declaration of the Indian and Southern Ocean Sanctuary has begun a new era in cetacean studies and has since stimulated a great deal of research in this least known of the three large oceans.

G.10 Competition for Resources – LOW

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. The effect on sperm whales' foraging efficiency resulting from disruption of large prey aggregations due to commercial fishing is not well known. Commercial removal of prey species may have a limited effect on sperm whales, particularly if a large biomass remains unharvested and accessible. Furthermore, the disruption of large aggregations of prey into multiple smaller aggregations by fishing activity could enhance sperm whale foraging success. The species-specific duration and degree of prey disruption due to commercial harvest are also unknown and it is not known what impact switching to alternate prey may have on sperm whales. Other threats that could be confounded with fisheries are environmental variability and inter-specific competition. Research is needed to reduce these uncertainties. The severity of this threat was ranked as low and the uncertainty was ranked as medium, thus the relative impact to recovery of sperm whales due to this threat is ranked as low (Table 1).

G.11 Loss of Prey Base Due to Climate and Ecosystem Change – UNKNOWN

Although the future consequences of climate and ecosystem change are not understood, it is possible that sperm whale prey bases may be affected. 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 Decadal 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 could be 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 (ACIA 2004; IPCC Climate Change 2007). The potential impacts of climate and oceanographic change on sperm whales will likely affect 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 climate change will reduce the productivity of at least some sperm whale populations (Whitehead 1997). Any changes in these factors could render currently used habitat areas unsuitable. Changes to climate and oceanographic processes may also lead to decreased productivity, different patterns of prey distribution, and changes in prey availability. Such changes could affect sperm whales that are dependent on those affected prey.

The feeding range of sperm whales is likely one of the greatest of any species on earth, and consequently, it is likely that the sperm whale may be more resilient to climate change, should it affect prey, than a species with a narrower range. The severity of the threat posed by environmental variability to sperm whale recovery was ranked as unknown due to the oceanographic and atmospheric conditions that have changed over the last several decades, and the uncertainty was ranked as high due to the unknown potential impacts of climate and ecosystem change on sperm whale recovery and regime shifts on sperm whale prey; therefore the relative impact to recovery was ranked as unknown (Table 1).

G.12 Cable Laying – LOW

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. The severity of this threat was ranked as low and the uncertainty was ranked as low, thus the relative impact to recovery of sperm whales due to this threat is ranked as low (Table 1).

The following table provides a visual synopsis of the text regarding threats to sperm whales, the sources of these threats, and populations that are affected (where information is available). For each threat, the table describes the severity, including the magnitude, scope, and relative frequency with which the threat is expected to occur; the uncertainty of information or effects; and the relative impact to recovery, which is a combination of the severity and uncertainty of each threat. The rankings were developed relative to each other, and put into one of four categories: high, medium, low, and unknown (further research is needed to determine whether it falls into high, medium, or low). Ranking assignments were determined by an expert panel with contributions from reviewers.

Table 1. Sperm whale threats analysis table.

Reference	Ocean Basin/ Population	Threat	Source	Severity (Unknown, Low, Med., High)	Uncertainty (Unknown, Low, Med., High)	Relative Impacts to Recovery (Unknown, Low, Med., High)
		Fishery Interactions:				
G.1	All	Injury or mortality from gillnet gear entanglement	Gillnet gear	Low	Medium	Low
G.1	All	Injury or mortality from longline gear entanglement	Longline gear	Low	Medium	Low
G.1.1	Atlantic – North	Injury or mortality from pelagic drift gillnet	Pelagic drift gillnet fishery	Low[7]	Low	Low
G.1.1	Atlantic – Northern Gulf of Mexico	Injury or mortality from longline gear and entanglement	Demersal longline fishery	Low	Low	Low
G.1.2	Pacific – CA/OR/WA	Injury or mortality from drift gillnet entanglement	CA/OR thresher shark/swordfish gillnet (> 14 in. mesh)	Low	Low	Low

[7] Sperm whale entanglement is known to be a high risk factor in the swordfish drift gillnet fishery in the Mediterranean Sea, but this threat is considered "low severity" for the Atlantic as a whole.

Reference	Ocean Basin/ Population	Threat	Source	Severity (Unknown, Low, Med., High)	Uncertainty (Unknown, Low, Med., High)	Relative Impacts to Recovery (Unknown, Low, Med., High)
G.1.2	Pacific – HI	Injury or mortality from longline gear and entanglement	Hawaii-based longline fishery	Low	Low	Low
G.1.2	Pacific – North	Injury or mortality from longline gear and entanglement	AK Gulf of Alaska sablefish longline	Low	Low	Low
G.1.3	Indian Ocean	Injury or mortality from longline and gillnet fishing gear entanglement	Demersal longline and gillnet fisheries	Unknown	High	Unknown
G.2		Anthropogenic Noise:				
G.2.1	All	Ship Noise	Ships	Unknown	High	Unknown
G.2.2	All	Oil and Gas Exploration Activities	Seismic surveys, noise from construction and operation of oil exploration work, LNG facilities	Unknown	High	Unknown
G.2.3	All	Military Sonar and Explosives	Ship shock trials, low and mid-frequency sonar	Unknown	High	Unknown
G.3		Vessel Interactions:				
G.3.1	All	Ship Strikes	Areas of high vessel traffic and/or high speed vessel traffic	Medium	Medium	Unknown but Potentially Low
G.3.2	All	Disturbance from Whale Watching and Other Vessels	Whale watching and military vessels	Low	Medium	Low
G.4	All	Contaminants and Pollutants	Heavy metals, PCBs, organochlorines, oil spills	Unknown	High	Unknown

Reference	Ocean Basin/ Population	Threat	Source	Severity (Unknown, Low, Med., High)	Uncertainty (Unknown, Low, Med., High)	Relative Impacts to Recovery (Unknown, Low, Med., High)
G.5	All	Disease	Parasites, myocardial infarction, other vectors	Low	Medium	Low
G.6	All	Injury from Marine Debris	Plastic garbage from land, lost/abandoned fishing gear, non-biodegradable garbage from ships	Low	Medium	Low
G.7	All	Disturbance due to Research	Oceanographic surveys and genetic, photographic, and acoustic studies	Low	Medium	Low
G.8	All	Predation and Natural Mortality	Killer whales, sharks, bone necrosis	Low	Medium	Low
G.9	All	Direct Harvest	Japanese scientific whaling; West Indies artisanal whaling; illegal whaling	Low	Medium	Low
G.10	All	Competition for Resources	Other whales, human fisheries	Low	Medium	Low
G.11	All	Loss of Prey Base due to Climate and Ecosystem Change or Shifts in Habitat	Climate and Ecosystem Change	Unknown	High	Unknown
G.12	All	Cable Laying	Submarine cable	Low	Low	Low

H. Conservation Measures

Although minimum size limits of 38 feet for male and 35 feet for female sperm whales were imposed 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 of sperm whale products occurs across international borders.

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II. RECOVERY STRATEGY

The primary purpose of this Recovery Plan is to identify and take actions that will minimize or eliminate effects of human activities that are detrimental to the recovery of sperm whale populations. Immediate objectives are to identify factors that may be limiting abundance/recovery/ productivity, and cite actions necessary to allow the populations to increase. The main threats to sperm whale populations include collisions with vessels, direct harvest, and possibly competition for resources, loss of prey base due to climate change, and disturbance from anthropogenic noise. Other potential (but likely low impact) threats include entanglement in fishing gear, habitat degradation, disturbance from vessels and tourism, contaminants and pollutants, disease, disturbance due to research, predation and natural mortality, and cable laying (see Table 1) .

The original direct threat to sperm whales was addressed by the IWC's 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.

Because sperm whales move freely across international borders, it would be unreasonable to confine recovery efforts to U.S. waters, and this Recovery Plan stresses the importance of a multinational approach to management. This Recovery Plan recognizes the limits imposed by the national nature of protective legislation. As demonstrated by work on humpback whales (Structure of Populations, Levels of Abundance and Status of Humpbacks (SPLASH) (Calambokidis *et al.* 2008) 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, this Recovery Plan is also expected to help achieve the MMPA's purpose of maintaining marine mammal populations at optimum sustainable levels.

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III. RECOVERY GOALS, OBJECTIVES, 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 "de-list," or 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. Objectives and Criteria

The two main objectives for sperm whale recovery are to 1) achieve sufficient and viable populations in all ocean basins, and 2) ensure significant threats are addressed. Likewise, recovery criteria take two forms: 1) those that reflect the status of the species itself and 2) those that indicate effective management or elimination of threats. The former criterion may explicitly state a certain risk of extinction as a threshold for downlisting or delisting and uses models based on at least abundance and trends in abundance to assess whether this threshold has been reached. Since sperm whales are currently globally listed, all ocean basins where sperm whales occur would need to meet these criteria.

Guidance on appropriate levels of risk for down-listing and de-listing decisions was developed in a workshop for large cetaceans (Angliss *et al.* 2002). This guidance was employed in the North Atlantic Right Whale Recovery Plan criteria (NMFS 2005b) and is also appropriate here. The following framework was suggested:

- A large cetacean species shall no longer be considered endangered when, given current and projected conditions, the probability of quasi-extinction is less than 1% in 100 years;
- 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 (in the case of the sperm whale the period of 25 years is considered necessary given imprecise abundance estimates);
- Recurrence of threats that brought the species to the point that warranted listing and current threats to the species have been addressed.

B.1 Downlisting Objectives and Criteria

Objective 1: Achieve sufficient and viable populations in all ocean basins.

Criterion:
Given current and projected threats and environmental conditions, the sperm whale population in each ocean basin in which it occurs (Atlantic Ocean/Mediterranean Sea, Pacific Ocean, and Indian Ocean) satisfies the risk analysis standard for threatened status (has no more than a 1% chance of extinction in 100 years) *and* the global population has at least 1,500 mature,

reproductive individuals (consisting of at least 250 mature females and at least 250 mature males in each ocean basin). Mature is defined as the number of individuals known, estimated, or inferred to be capable of reproduction. Any factors or circumstances that are thought to substantially contribute to a real risk of extinction that cannot be incorporated into a Population Viability Analysis will be carefully considered before downlisting takes place.

Objective 2: Ensure significant threats are addressed.

Criteria:
Factors that may limit population growth (*i.e.*, those that are identified in the threats analysis under relative impact to recovery as high or medium or unknown) 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)(l) of the ESA are being or have been addressed as follows:

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

- Effects of reduced prey abundance due to climate change continue to be investigated and action is being taken to address the issue, as necessary.
- Effects of anthropogenic noise continue to be investigated and actions taken to minimize potential effects, as necessary.
- Competition with fisheries for resources is being addressed through fishery management plans and other measures.
- Effects of oil spills and contaminants are determined to not affect the potential for continued growth or maintenance of sperm whale populations.

Factor B: Overutilization for commercial, recreational, or educational purposes.

- Management measures are in place to ensure that any direct harvest (commercial, subsistence, and scientific) is at a sustainable level.

Factor C: Disease or Predation.

There are no criteria for this factor because there are no data to indicate that disease or predation are threats.

Factor D: The inadequacy of existing regulatory mechanisms.

- Ship collisions continue to be investigated and actions taken to minimize potential effects, as necessary.

Direct harvest is addressed under Factor B.

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

No other factors are known to be limiting the recovery of sperm whales.

B.2 Delisting Objectives and Criteria

Objective 1: Achieve sufficient and viable populations in all ocean basins

Criterion:
Given current and projected threats and environmental conditions, the sperm whale population in each ocean basin in which it occurs (Atlantic Ocean/Mediterranean Sea, Pacific Ocean, and Indian Ocean) satisfies the risk analysis standard for unlisted status (has less than a 10% probability of becoming endangered (has more than a 1% chance of extinction in 100 years) in 20 years). Any factors or circumstances that are thought to substantially contribute to a real risk of extinction that cannot be incorporated into a Population Viability Analysis will be carefully considered before delisting takes place.

Objective 2: Ensure significant threats are addressed

Criteria:
Factors that may limit population growth (those that are identified in the threats analysis as high or medium or unknown) 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)(l) of the ESA are being or have been addressed as follows:

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

- Effects of reduced prey abundance due to climate change have continued to be investigated and any necessary action being taken to address the issue are shown to be effective or this is no longer believed to be a threat.
- Effects of anthropogenic noise have continued to be investigated and actions being taken to address the issue are shown to be effective or this is no longer believed to be a threat. Competition with fisheries for resources continues to be addressed through fishery management plans and other measures or is no longer believed to be a threat.
- Effects of oil spills and contaminants are determined to not affect the potential for continued growth or maintenance of the sperm whale population and actions taken or having been taken to minimize potential effects have been proven effective.

Factor B: Overutilization for commercial, recreational, or educational purposes.

- Management measures are in place that ensure that any direct harvest (commercial, subsistence, and scientific) is at a sustainable level.

Factor C: Disease or Predation.

There are no criteria for this factor because there are no data to indicate that disease or predation are threats.

Factor D: The inadequacy of existing regulatory mechanisms.

- Ship collisions have been investigated and action being taken to address the issue are shown to be effective or this is no longer believed to be a threat.

Direct harvest is addressed under Factor B.

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

No other factors are known to be threats.

IV. RECOVERY PROGRAM

A. Recovery Action Outline

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

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

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

2.1 *Determine the best methods for assessing sperm whale status and trends.*

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

2.2.1 Continue to estimate abundance and monitor trends in the Atlantic Ocean, Gulf of Mexico, and Pacific Ocean.

2.2.2 Estimate abundance and monitor trends in the Indian Ocean and Mediterranean Sea.

3.0 Determine Population Discreteness and Population Structure of Sperm Whales.

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

3.1.1 Continue to collect biopsy samples off the Atlantic, Gulf of Mexico, and Pacific coasts of North America.

3.1.2 Collaborate with foreign agencies and researchers to obtain sufficient samples at the ocean basin scale.

3.1.3 Perform genetic analyses on preserved samples from whales killed by the whaling industry in the past.

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

3.2.1 Continue/conduct telemetry and photo-identification studies of sperm whales in the Atlantic Ocean/Mediterranean Sea.

3.2.2 Continue/conduct telemetry and photo-identification studies of sperm whales in the Pacific Ocean.

3.2.3 Continue/conduct telemetry and photo-identification studies of sperm whales in the Indian Ocean.

3.2.4 Establish and maintain a central repository for sperm whale photographs.

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

4.0 Conduct Risk Analyses

4.1 *Conduct risk analyses for the Atlantic Ocean /Mediterranean Sea.*

4.2 *Conduct risk analyses for the Pacific Ocean.*

4.3 *Conduct risk analyses for the Indian Ocean.*

5.0 Identify, Characterize, Protect, and Monitor Habitat Important to Sperm Whale Populations in U.S. Waters and Elsewhere.

5.1 *Characterize sperm whale habitat.*

5.1.1 Conduct research to characterize sperm whale habitat in the Atlantic Ocean.

5.1.2 Conduct research to characterize sperm whale habitat in the Pacific Ocean.

5.1.3 Conduct research to characterize sperm whale habitat in the Indian Ocean and Mediterranean Sea.

5.2 *Monitor important habitat features and sperm whale use patterns to assess potentially detrimental shifts in these features that might reflect disturbance or degradation of habitat.*

5.3 *Promote actions to protect important habitat in U.S. waters.*

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

5.5 *Improve knowledge of sperm whale feeding ecology.*

5.6 *Investigate the impacts of climate change on sperm whales and seek strategies to reduce those impacts found to be detrimental to sperm whales and their habitat.*

5.6.1 Conduct studies and perform analyses to assess the effects of climate change on the distribution, behavior, reproduction, and productivity of sperm whales.

5.6.2 Seek strategies to reduce any detrimental impacts of climate change on sperm whales and their prey and habitats (identified in action 5.6.1).

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

6.1 *Investigate and reduce injury and mortality caused by fisheries and fishing equipment and reduce depredation.*

6.1.1 Conduct a systematic review of data on sperm whale interactions with fishing operations.

6.1.2 Promote studies that investigate the ingestion of fishing gear (and the target species/bait) by sperm whales and develop methods to reduce sperm whale ingestion of fishing gear.

6.1.3 Investigate the development of a system to non-lethally deter sperm whales from fishing gear.

6.1.4 Conduct studies of gear modifications that reduce the likelihood of entanglement and depredation, mitigate the effects of entanglements, and enhance the possibility of disentanglement. Determine whether measures to reduce entanglement and depredation are effective.

6.1.5 Develop and implement schemes to reduce the rate at which gear is lost, and improve the reporting of lost gear, in conjunction with studies in 6.1.2, 6.1.3, 6.1.4, and 6.1.6.

6.1.6 Continue to review, evaluate, and act upon reports from fishermen and fishery observers of fishery interactions with sperm whales.

6.2 *Investigate and reduce mortality and serious injury from vessel collisions.*

6.2.1 Identify areas where concentrations of sperm whales coincide with significant levels of maritime traffic.

6.2.2 Identify specific areas where recorded ship strikes of sperm whales have occurred (for example, the Canary Islands) and conduct studies to identify ecosystem-based traits that could support an assemblage of predictive tools.

6.2.3 Once areas in 5.0 and 6.2.1 are identified, and in conjunction with information derived and resulting predictive tools from 6.2.2, conduct analyses of shipping routes and important sperm whale habitat areas to determine the risk of ship collisions with sperm whales.

6.2.4 Develop a system to encourage, collect, and appropriately analyze opportunistic sightings of sperm whales from fishing vessels, whale-watching vessels, charter vessels, etc.

6.2.5 Work with mariners, the shipping industry, and appropriate state, federal, and international agencies to develop and implement regionally-based measures to reduce the threat of ship strikes. Assess the effectiveness of ship strike measures and adjust, as necessary.

6.2.6 Explore possible mechanisms to encourage vessels that have struck a whale to report the incident.

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

6.3.1 Identify areas where concentrations of sperm whales coincide with significant levels of pollution (including marine debris).

6.3.2 Conduct studies on individual health and body condition as they may be related to accumulated contaminants.

6.3.3 Take steps to minimize adverse effects from pollutants, if necessary.

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

7.1 *Conduct studies to assess the effects of anthropogenic noise on the distribution, behavior, and productivity of sperm whales.*

7.2 *Take steps to minimize anthropogenic noises that are found to be potentially detrimental to sperm whales.*

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

8.1 *Respond effectively to strandings of sperm whales in U.S. waters.*

8.1.1 Continue and improve programs to maximize data collected from necropsy of sperm whale carcasses.

8.1.2 Maintain and review, and if needed improve, the system for reporting dead, stranded, or entangled sperm whales.

8.1.3 Improve, or as necessary, develop and implement protocols for securing and retrieving stranded (on land) or floating (at sea) sperm whale carcasses.

8.2 *Review, analyze, and summarize data on stranded sperm whales on an annual basis.*

8.3 *Develop protocols for handling live-stranded sperm whales.*

8.4 *Establish reliable sources of funding for rescue, necropsy, tissue collection, and analysis efforts.*

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 Recovery 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.

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 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 upon 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).

2.0 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.

2.1 *Determine the best methods for assessing sperm whale status and trends.*

Considerable effort has been made to gather information on sperm whales in the North Atlantic and North Pacific, but very little in the Indian Ocean. An assessment of the level and distribution of survey efforts required to achieve optimal assessment results for the three ocean basins is essential to ensure that the entire population of sperm whales is surveyed and that field work is as efficient and cost-effective as possible. This may be achieved through a workshop or other means.

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

Broad international participation, including support from governments, and researchers from other countries should be supported. Sperm whale abundance should be estimated at least once every three years (depending on results of the workshop recommendations in 2.1). Population modeling should be conducted to assess status, trends, abundance, and vital rates, including reproduction and survivorship. As necessary, the development and implementation of other programs (*i.e.,* improved assessment techniques, alternative analysis methods identified) necessary for population monitoring should be supported.

2.2.1 Continue to estimate abundance and monitor trends in the Atlantic Ocean, Gulf of Mexico, and Pacific Ocean.

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.

2.2.2 Estimate abundance and monitor trends in the Indian Ocean and Mediterranean Sea.

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 3.0 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 and extended periods of ship-based surveys on large research vessels. A primary goal should be to foster an international collaboration and cooperation in the study and protection of the worldwide population of sperm whales. It is likely than within the next five years, autonomous acoustic buoys can be developed to estimate sperm whale abundance and trends and as a result, costs to accomplish this objective could be reduced considerably. Other potential cost savings include combining this objective with other large ship-based research projects in the same area and other objectives listed in this Recovery Plan.[8]

3.0 Determine Population Discreteness and Population Structure of Sperm Whales.

Existing knowledge of the population structure of sperm whales is insufficient, and a more comprehensive understanding is essential for determining populations status and trends and developing strategies to promote recovery.. In addition, in 1996, NMFS and FWS published the Policy Regarding the Recognition of Distinct Vertebrate Population Segments (DPS) (61 FR 4722). This policy interpreted the term "DPS" for the purposes of listing and delisting and reclassifying vertebrates under the ESA. It is possible that sperm whales could be more appropriately listed as DPSs, which would require an evaluation of discreteness and significance among populations.

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 Recovery 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. Models of sperm whale movement (3.2 below) are necessary to understand population structure, both genetically (3.1 below) and socially (3.3 below), and to manage the effects of human activities on this species (Dufault *et al.* 1999; Whitehead *et al.* 2008). NMFS proposes three interrelated research initiatives to assess population structure described in detail below: the first, 3.1, uses genetic analysis to determine population structure and discreteness; the second, 3.2, uses telemetry and photo-identification to assess movement; and the third 3.3, investigates the complex social structure of sperm whales.

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[8] In the Implementation Schedule, the daily cost of an ocean class University-National Oceanographic Laboratory System (UNOLS) ship was estimated to be about $35K per day. This estimate does not account for inflation factors such as fuel costs. It was also assumed that the cost of the ship would mainly be split between Actions 3.1, 3.2, 2.2, and 5.1. These actions were assumed to be split in the following proportions for ship time: Action 3.2 at 80%, Action 5.1 at 15%, and Actions 3.1 and 3.2 totaling 5%. The task duration was rounded up to the nearest 6 or 12 month period for ease of estimating costs. Action 3.2 represents the total cost for the ship time. Other actions items where ship time may be necessary are also included in the total cost, but the proportion of ship time that would be used was less than what is reported here for action items 3.1, 3.2, 2.2, and 5.1 and thus, those specific actions are not discussed in detail.

3.1 *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, and scarring patterns. To address the potential bias due to relatedness within groups, novel analytical approaches are needed. 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, Indian Ocean, 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; Amos 1999; Whitehead 1999; Tiedemann and Milinkovitch 1999; Hyde *et al.* 2001).

3.1.1 Continue to collect biopsy samples off the Atlantic, Gulf of Mexico, and Pacific coasts of North America.

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.

3.1.2 Collaborate with foreign agencies and researchers to obtain sufficient samples at the ocean basin scale.

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 contaminant analyses (item 6.4.1). A central repository for sperm whale tissue samples would facilitate research.

3.1.3 Perform genetic analyses on preserved samples from whales killed by the whaling industry in the past.

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.

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

Telemetry studies using satellite-linked and VHP 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). 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.

3.2.1 Continue/conduct telemetry and photo-identification studies of sperm whales in the Atlantic Ocean/Mediterranean Sea.

3.2.2 Continue/conduct telemetry and photo-identification studies of sperm whales in the Pacific Ocean.

3.2.3 Continue/conduct telemetry and photo-identification studies of sperm whales in the Indian Ocean.

3.2.4 Establish and maintain a central repository for sperm whale photographs. A single, 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).

3.3 *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) and Mesnick *et al*. (2008) examined mtDNA variation among vocal clans of sperm whales from social groups sampled from three broad areas of the Pacific (Chile/Peru, Galapagos/Ecuador, and the Southwest Pacific). The authors found that acoustic dialect showed greater genetic structure than geography, and that 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. Sperm whales have a complex social structure with the observed “groups” 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).

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 for sperm whales, 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. A workshop may be needed to address this.

4.1 *Conduct risk analyses for Atlantic Ocean /Mediterranean Sea.*

Conduct simulations to estimate risk of extinction. Required data are minimum abundance estimates for a significant portion of the range together with estimates on trends in abundance.

4.2 *Conduct risk analyses for the Pacific Ocean.*

Conduct simulations to estimate risk of extinction. Required data are minimum abundance estimates for a significant portion of the range together with estimates on trends in abundance.

4.3 *Conduct risk analyses for the Indian Ocean.*

Conduct simulations to estimate risk of extinction. Required data are minimum abundance estimates for a significant portion of the range together with estimates on trends in abundance. No data currently exist for a risk analysis (*e.g.*, minimum abundance estimates and trends) so the analysis is anticipated to occur at a much later date than for the Atlantic and Pacific Oceans and Mediterranean Sea.

5.0 Identify, Characterize, Protect, and Monitor Habitat Important to Sperm Whale Populations in U.S. Waters and Elsewhere.

Identifying important habitat and reducing direct and indirect threats to sperm whale habitat is integral to recovery. Important habitat may or may not qualify as critical habitat under the ESA. Information is needed on environmental factors that influence sperm whale distribution. In addition, adequate protective measures are needed to reduce or eliminate human-related impacts to sperm whale habitat.

5.1 *Characterize sperm whale habitat.*

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. Compile or collect relevant physical, chemical, biological, meteorological, fishery, and other data to characterize features of important habitats and potential sources of human-caused destruction and degradation of what are determined to be important areas for sperm whales. Habitat characterization also 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, is an important component of habitat characterization. Researchers in many different areas have begun to explore the correlations between sperm whale occurrence and habitat features (Waring *et al.* 1993; Jaquet and Whitehead 1996; Jaquet *et al.* 1996, 1998; Davis *et al.* 1998; Hooker *et al.* 1998), but 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. Only with information on the ecological needs of the species will managers be able to provide necessary protections.

5.1.1 Conduct research to characterize sperm whale habitat in the Atlantic Ocean.

There has recently been extensive work on the movements and habitat use of sperm whales in the Northern Gulf of Mexico, by the 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 of Mexico, with some animals using deeper oceanic waters. Satellite tag deployments also have indicated large scale movements of individuals out of the Gulf of Mexico. The SWSS research provided detailed information on the habitat preferences and population structure of Gulf of Mexico sperm whales (Jochens and Biggs 2004; Jochens *et al.* 2008).

5.1.2 Conduct research to characterize sperm whale habitat in the Pacific Ocean.

While there have been many studies on sperm whale distribution in the Pacific Ocean, more work is needed on characterizing habitat in this ocean.

5.1.3 Conduct research to characterize sperm whale habitat in the Indian Ocean and Mediterranean Sea.

More research is needed on characterizing sperm whale habitat in the Indian Ocean and in the Mediterranean Sea.

5.2 *Monitor important habitat features and sperm whale use patterns to assess potentially detrimental shifts in these features that might reflect disturbance or degradation of habitat.*

After baseline data are obtained and analyzed, ongoing studies should be done to determine if shifts are occurring in essential habitat components. Sperm whale habitat should be assessed periodically through surveys and GIS analysis. Shifts in distribution or habitat use should be analyzed as potentially resulting from anthropogenic sources of habitat degradation or disturbance. If shifts are detected and are linked to human activities, actions may be taken to modify the activity to reduce or eliminate the cause.

5.3 *Promote actions to protect important habitat in U.S. waters.*

Support efforts to collect and compile data on habitat use patterns for the sperm whale population in U.S. waters. Once 5.1 and 5.2 are determined, mitigate for actions that may disturb or degrade important habitat. Validate those areas where sperm whales are thought to occur and determine if those areas are important areas warranting habitat protection.

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

Sperm whale range is transboundary. Collaborative efforts should be made with foreign governments to protect sperm whale habitat within their EEZ's, and to join multi-national efforts on behalf of marine habitat protection. International efforts to collect and compile data on habitat use patterns for the sperm whale population should be supported. Actions that have impacts on sperm whales should be mitigated, and the U.S. should support and endorse such efforts. Validation of those areas where sperm whales are thought to occur and protection of those areas that are determined as important areas warranting habitat protection should be supported. Due to 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 (see 6.4) and protect resources on the high seas may be key to the long-term conservation of sperm whale populations.

5.5 *Improve knowledge of sperm whale feeding ecology.*

Improved knowledge of sperm whale feeding ecology would be useful for evaluating or predicting interactions with fisheries. 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 Galapagos 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. 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) and sperm whales in the Gulf of Mexico, North and South Pacific, and Atlantic (Santos *et al*. 2002; Ruiz-Cooley *et al*. 2006; Gomez-Villota 2007; Marcoux *et al*. 2007) and these should be augmented with additional biopsy samples collected (see 3.1.1). It is expected that this objective could be accomplished in conjunction with surveys conducted to achieve actions 3.2 and 5.1, and thus reduce costs.

5.6 *Investigate the impacts of climate change on sperm whales and seek strategies to reduce these impacts.*

5.6.1 Conduct studies and perform analyses to assess the effects of climate change on the distribution, behavior, and productivity of sperm whales.

In addition to the information collected in 5.1, 5.2, and 5.5, improved knowledge of the effects of climate change on sperm whale feeding ecology and habitat use would be informative for evaluating or predicting shifts in prey abundance or distribution caused by climatic fluctuations. Investigating the degree of overlap between distributions of different species, the environmental factors influencing their distributions, and the effect of spatial scale on the significance of different environmental predictors should be supported to improve knowledge on the potential effects of climate change on sperm whales. Although the natural absorption of carbon dioxide (CO_2) by the world's oceans helps mitigate the climatic effects of anthropogenic emissions of CO_2, it is believed that the resulting decrease in pH will have negative consequences. While the full ecological consequences of these changes are not known, organisms, such as sperm whales, may suffer adverse effects, either directly as reproductive or physiological effects or indirectly through negative impacts on their food resources.

5.6.2 Seek strategies to reduce any detrimental impacts of climate change on sperm whales and their prey and habitats (identified in action 5.6.1).

Strategies developed through international efforts to mitigate and minimize the effects of climate change should be followed for the benefit of sperm whales as well as other ecosystem components.

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

Known or suspected causes of anthropogenic mortality and injury in sperm whales include vessel strikes, ingestion of marine debris, and entanglement in fishing gear or debris. Studies of the circumstances leading to collisions with ships and entanglement in fishing gear are required before appropriate measures can be developed to reduce the impacts on sperm whales. 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 (Loup *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.

6.1 *Investigate and reduce injury and mortality caused by fisheries and fishing equipment and reduce depredation.*

6.1.1 Conduct a systematic review of data on sperm whale interactions with fishing operations.

In the Atlantic Ocean, the threat posed by pelagic drift gillnet and longline fishing was ranked as low, however sperm whale entanglement is known to be a high risk factor in the swordfish drift gillnet fishery in the Mediterranean Sea and thus further research is needed in this area. There is high uncertainty about threat by Indian Ocean fishing practices to sperm whale recovery, and more information about fishing interactions in this region is needed. A thorough understanding of where sperm whales and fishing gear coincide will help guide management efforts to reduce the threat of entanglement and depredation.

After a systematic review, it should be possible to make a preliminary evaluation of what types of fisheries and fishing gear pose the greatest risk to sperm whales and the nature of the interaction. Data from areas outside U.S. waters could be useful for strengthening inferences and extrapolations.

6.1.2 Promote studies that investigate the ingestion of fishing gear (and the target species/bait) by sperm whales and develop methods to reduce sperm whale ingestion of fishing gear.

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.

6.1.3 Investigate the development of a system to non-lethally deter sperm whales from fishing gear.

6.1.4 Conduct studies of gear modifications that reduce the likelihood of entanglement and depredation, mitigate the effects of entanglements, and enhance the possibility of disentanglement. Determine whether measures to reduce entanglement and depredation are effective.

Current and ongoing research on possible modifications to fishing gear that facilitate an entangled whale freeing itself once entangled should be continued.

These studies might include assessing the potential use of biodegradable lines, studying ways to reduce the number and length of vertical lines in the water column, designing breakaway lines for heavy gear, and researching acoustic deterrents.

6.1.5 Develop and implement schemes to reduce the rate at which fishing gear is lost, and improve the reporting of lost gear, in conjunction with studies in 6.1.2, 6.1.3, 6.1.4, and 6.1.6.

6.1.6 Continue to review, evaluate, and act upon reports from fishermen and fishery observers of fishery interactions with sperm whales.

6.2 *Investigate and reduce mortality and serious injury from vessel collisions.*

6.2.1 Identify areas where concentrations of sperm whales coincide with significant levels of maritime traffic.

The possible impacts of ship strikes on recovery of sperm whale populations are not well understood. While relatively rare, there are reports of ships colliding with sperm whales in the Atlantic Ocean, Pacific Ocean, Gulf of Mexico and Mediterranean, and while there are no reports of collisions in the Indian Ocean, they likely occur there as well. Many ship strikes go unreported or undetected and the offshore distribution of sperm whales may make ship strikes less detectable than for other species, thus the estimates of serious injury or mortality should be considered minimum estimates. Studies are needed to identify areas where high ship traffic densities and sperm whale densities overlap to assist with management efforts to reduce the occurrence of ship strikes.

6.2.2 Identify specific areas where recorded ship strikes of sperm whales have occurred (for example, the Canary Islands) and conduct studies to identify ecosystem-based traits that could support an assemblage of predictive tools.

Building upon information compiled in action 6.2.1, the above would assist in the determination of when sperm whales may be present, why sperm whales are present in the area at that time, and whether the presence of ships alters the ecosystem in such a way that sperm whales become more susceptible to a strike. It is expected that this objective could be accomplished in conjunction with surveys conducted to achieve actions 3.2, 5.1, and 5.5, and thus reduce costs.

6.2.3 Once areas in 5.0 and 6.2.1 are identified, and in conjunction with information derived and resulting predictive tools from 6.2.2, conduct analyses of shipping routes and important sperm whale habitat areas to determine the risk of ship collisions with sperm whales.

6.2.4 Develop a system to encourage, collect, and appropriately analyze opportunistic sightings of sperm whales from fishing vessels, whale-watching vessels, charter vessels, etc.

6.2.5 Work with mariners, the shipping industry, and appropriate State, Federal, and International agencies to develop and implement regionally-based measures to reduce the threat of ship strikes. Assess the effectiveness of ship strike measures and adjust, as necessary.

The practicality and effectiveness of options to reduce ship strikes, 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.

6.2.6 Explore possible mechanisms to encourage vessels that have struck a whale to report the incident.

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

The inconclusive, but troublesome, 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 and on their prey. Research should be extended to include studies of metabolic pathways and the influence on contaminant burdens of sex, reproductive condition, and geographic origin.

6.3.1 Identify areas where concentrations of sperm whales coincide with significant levels of pollution (including marine debris).

In a review of organochlorine and metal pollutants in marine mammals from Central and South America, Borrell and Aguilar (1999) note that organochlorine levels in marine mammals suggest low levels of exposure compared to other regions of the world. Although data are extremely scarce, concentrations of organochlorines in the tropical and equatorial fringe of the northern hemisphere and throughout the southern hemisphere are low or extremely low in marine mammals, and organochlorine concentrations in marine mammals off South America, South Africa and Australia are invariably low (Aguilar *et al.* 2002). The highest concentrations of organochlorines found in marine mammals are in the Mediterranean Sea. High concentrations of organochlorines in marine mammals also occur, although to a lesser extent, along the Pacific coast of the U.S. and generally in other mid-latitudes in the northern hemisphere (Aguilar *et al.* 2002).

6.3.2 Conduct studies on individual health and body condition as they may be related to accumulated contaminants.

Biopsy samples collected under items 3.1.1 and 3.1.2 (above) will be usable for some of this work. The Ocean Alliance collected over 900 sperm whale biopsy samples during the five-year, round-the-world voyage of the RV Odyssey, and plans analyzed 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.

6.3.3 Take steps to minimize adverse effects from pollutants, if necessary.

If studies indicate that contaminants in the marine environment are adversely affecting sperm whales, steps should be taken to reduce the sources of such contaminants.

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

Sperm whales are among the cetaceans 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 surveys), 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 *Conduct studies to assess the effects of anthropogenic noise on the distribution, behavior, and productivity of sperm whales.*

As discussed in section G.2, some research has addressed questions about the effects of noise on sperm whales, and little of this work has been conclusive in regard to the biological significance of observed effects. Studies are needed to assess potential adverse effects of underwater noise (including ship noise) on sperm whales, including, but not limited to, disturbance of intraspecific communication, disruption of vital functions mediated by sound, distributional shifts, and stress from chronic or frequent exposure to loud sound. Noise sources studied should include, but not be limited to, industrial and shipping activities, oceanographic experiments, military related activities, and other human activities.

7.2 *Take steps to minimize anthropogenic noises that are found to be potentially detrimental to sperm whales.*

If studies of the kind mentioned in item 7.1 indicates that particular types of underwater noise have adverse effects on sperm whales (either by masking their sounds or by damaging their auditory organ systems), or add physiological stress to their lives, implement appropriate regulatory measures on sources of the threat.

8.0 Maximize Efforts to Acquire Scientific Information from Dead, Stranded, and Entangled 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 *Respond effectively to strandings of sperm whales in U.S. waters.*

8.1.1 Continue and improve programs to maximize data collected from necropsy of sperm whale carcasses.

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.

8.1.2 Maintain and review, and if needed improve, the system for reporting dead, stranded, or entangled sperm whales.

8.1.3 Improve, or as necessary, develop and implement protocols for securing and retrieving stranded (on land) or floating (at sea) sperm whale carcasses.

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. In areas where protocols do not exist, they should be developed. The responsibilities of all relevant agencies, organizations, and individuals should be clearly defined.

Sperm whales may die at sea and not be detected or reported. Mariners, including Navy and Coast Guard personnel, commercial and recreational boaters, and fishermen might observe carcasses at sea, but not recognize the importance of their observation. Mariners should be educated about the importance of reporting carcasses so that as much information as possible can be collected from them.

8.2 *Review, analyze, and summarize data on stranded sperm whales on an annual basis.*

Current and complete data on stranding events and the data derived from them is essential to developing protective measures. Summaries should include, but not be limited to, assessments of the cause of death and, where applicable, the types of fishing gear, if fishing operations resulted in the death of the animal.

8.3 *Develop protocols for handling live-stranded sperm whales.*

Disentanglement readiness, contingencies, and programs are essential. When feasible, and with maximum regard for human safety, efforts should be made to free entangled whales. Therefore, clearly defined strategies should be in place. Disentanglement response teams should be trained and efforts to expand disentanglement response should be considered to ensure coverage is adequate. Studies of possible advances of disentanglement gear should be conducted to improve disentanglement efforts.

Rehabilitation of live-stranded sperm whales may be feasible in very limited circumstances. Attempting and effecting rehabilitation requires advanced planning including decisions regarding appropriate facilities, logistics, and equipment to be used. These are likely regionally specific and should be developed in advance with responsibilities clearly defined.

8.4 *Establish reliable sources of funding for rescue, necropsy, tissue collection, and analysis efforts.*

As noted, collection of information from sperm whale carcasses is essential to recovery efforts. Therefore, identifying and committing predictable sources of funding for completing these tasks is also critical.

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 conducted prior to delisting, and will continue for a minimum of 1.5 generations, although it may be continued for longer.

V. IMPLEMENTATION SCHEDULE

The implementation schedule that follows is used to estimate costs to direct and monitor implementation and completion of recovery tasks set forth in this Recovery Plan. It is a guide for meeting recovery goals outlined in this Recovery Plan. The Implementation Schedule indicates the action numbers, action descriptions, action priorities, duration of the action, the parties responsible for the actions, and estimated costs. Parties with authority, responsibility, or expressed interest to implement a specific recovery action are identified in the Implementation Schedule.

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 or to identify those actions necessary to prevent extinction.

Each action is listed under that section which best describes the intent of that action. However, a single action may have multiple consequences. For instance, many of the actions described in *Action 5* (*Identify, Characterize, Protect, and Monitor Habitat Important to Sperm Whale Populations in U.S. Waters and Elsewhere.*) also have an impact on the threats identified in *Action 6* (*Investigate Causes and Reduce the Frequency and Severity of Human-caused Injury and Mortality*) as important habitat areas may coincide with areas with significant human influences. While this is of little consequence to the overall goal of recovering sperm whales, readers should note that because actions are linked, the total cost of achieving the single action will include the cost of actions completed in other sections. Hence, while the total cost of recovery described in the Implementation Schedule reflects the cost of recovering the species, individual actions, or the costs of completing the goals of individual actions, may be understated when actions are viewed in isolation. 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. In addition, the listing 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). The cost of actions within each category is assigned to the subsection of that action which encompasses those described under that subsection (*i.e.,* costs in subsection 6.1 include those costs incurred in actions 6.1.1, 6.1.2, 6.1.3, 6.1.4, and 6.1.5). For each, sub-totals are given as a whole in ***bold italics***. Some costs are listed as discrete (*e.g.*, 5 years) and some are until time to recovery (*i.e.*, “TBD” and “Ongoing”). Thus, “TBD” and “ongoing” were treated equally and both were assumed to equal the time to recovery for cost purposes (2024 for Atlantic Ocean/Mediterranean Sea and Pacific Ocean and 2034 for the Indian Ocean) and costs that were discrete, were calculated for that discrete time period.

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 Recovery 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. 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).

Current NMFS practice is to conduct multi-species marine mammal surveys. The estimates for survey costs in this implementation table reflect the cost to conduct sperm whale specific research, and therefore are the estimated upper limit.

Table 2. Sperm Whale Implementation Schedule by Fiscal Year

Action Number	Action Description	Priority	Task Duration (years)	Agencies/ Organizations Potentially Involved	Cost Estimates by FY (thousands of dollars)						
					FY11	FY12	FY13	FY14	FY15	FY16 +[9]	Total/yr. x Task Duration
1.0	***Coordinate State, Federal, and International Actions to Implement Recovery Actions and Maintain International Regulation of Whaling for Sperm Whales.***	2	Ongoing	NMFS, IWC, Department of State (DOS)	300	300	300	300	300	4,000	5,500
TOTAL 1					***300***	***300***	***300***	***300***	***300***	***4,000***	***5,500***
2.0	***Develop and Apply Methods to Estimate Population Size and Monitor Trends in Abundance.***										
2.1	Determine the best methods for assessing sperm whale status and trends.	2	1	NMFS, International Partners	30						30
2.2 See text for explanation of cost. Costs include 2.2 sub-actions	Conduct surveys to estimate abundance and monitor trends worldwide.	2	One survey[10]	NMFS, International Partners							

[9] Few actions are expected to be undertaken in the first five fiscal years of this plan.
[10] Using two ships for approximately 4.5 months/year. The task duration was rounded up to the nearest 6 or 12 month period for ease of estimating costs. Task Duration is one survey and for the Atlantic Ocean, one survey is expected to last 4.6 years. Rounding the value up to coincide with the nearest 6th or 12th month, the total annual cost is the total cost in thousands of a sperm-whale specific survey ($43,990), divided by 5 years = $8,798. For the Pacific Ocean, one survey is expected to last 3.4 years. Rounding the value up to coincide with the nearest 6th or 12th month, the total annual cost is the total cost in thousands of a sperm-whale specific survey ($32,160), divided by 3.5 years = $9,189. For the Indian Ocean, one survey is expected to last 2.8 years. Rounding the value up to coincide with the nearest 6th or 12th month, the total annual cost is the total cost in thousands of a sperm-whale specific survey ($27,490), divided by 3 years = $9,163.

Action Number	Action Description	Priority	Task Duration (years)	Agencies/ Organizations Potentially Involved	Cost Estimates by FY (thousands of dollars)						
					FY11	FY12	FY13	FY14	FY15	FY16 +[9]	Total/yr. x Task Duration
2.2.1	Continue to estimate abundance and monitor trends in the Atlantic Ocean, Gulf of Mexico, and Pacific Ocean.	2	One survey (see footnote 9)	NMFS, International Partners						76,150	76,150
2.2.2	Estimate abundance and monitor trends in the Indian Ocean.	2	One survey (see footnote 9)	NMFS, International Partners						27,490	27,490
TOTAL 2					***30***	***n/a***	***n/a***	***n/a***	***n/a***	***103,640***	***103,670***
3.0	***Determine Population Discreteness and Population Structure of Sperm Whales.***										
3.1 See text for explanation of cost. Costs include 3.1 sub-actions.	Support existing studies and initiate new studies to investigate population discreteness and population structure of sperm whales using genetic analyses.	2	5	NMFS, IWC, International Partners						2,500	2,500
3.1.1	Continue to collect biopsy samples off the Atlantic, Gulf of Mexico, and Pacific coasts of North America.	2	5	NMFS							
3.1.2	Collaborate with foreign agencies and researchers to obtain sufficient samples at the ocean basin scale.	2	5	NMFS, IWC, International Partners							
3.1.3	Perform genetic analyses on preserved samples from whales killed by the whaling industry in the past.	2	5	NMFS, IWC, International Partners							

Action Number	Action Description	Priority	Task Duration (years)	Agencies/ Organizations Potentially Involved	Cost Estimates by FY (thousands of dollars)						
					FY11	FY12	FY13	FY14	FY15	FY16 +[9]	Total/yr. x Task Duration
3.2 See text for explanation of cost. Costs include 3.2 sub-actions.	Assess daily and seasonal movements and inter-area exchange using telemetry and photo-identification.	2	5	NMFS, International Partners							
3.2.1	Continue/conduct telemetry and photo-identification studies of sperm whales in the Atlantic Ocean/Mediterranean Sea.	2	5	NMFS, International Partners						1,000	1,000
3.2.2	Continue/conduct telemetry and photo-identification studies of sperm whales in the Pacific Ocean.	2	5	NMFS						1,000	1,000
3.2.3	Continue/conduct telemetry and photo-identification studies of sperm whales in the Indian Ocean.	2	5	NMFS, International Partners						500	500
3.2.4	Establish and maintain a central repository for sperm whale photographs.	3	Ongoing	NMFS							
3.3	Support ongoing studies and initiate new studies to investigate social structure and how it influences population structure.	2	10	NMFS, International Partners						2,500	2,500
TOTAL 3										***7,500***	***7,500***
4.0	***Conduct Risk Analyses.***										
4.1	Conduct risk analyses for the Atlantic Ocean/ Mediterranean Sea.	2	2	NMFS, International Partners						200	200
4.2	Conduct risk analyses for the Pacific Ocean.	2	2	NMFS						200	200
4.3	Conduct risk analyses for the Indian Ocean.	2	2	NMFS, International Partners						200	200

Action Number	Action Description	Priority	Task Duration (years)	Agencies/ Organizations Potentially Involved	Cost Estimates by FY (thousands of dollars)						
					FY11	FY12	FY13	FY14	FY15	FY16 +[9]	Total/yr. x Task Duration
TOTAL 4					*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*600*	*600*
5.0	***Identify, Characterize, Protect, and Monitor Habitat Important to Sperm Whale Populations in U.S. Waters and Elsewhere.***										
5.1 See text for explanation of cost	Characterize sperm whale habitat.	2	10	NMFS, International Partners							
5.1.1	Conduct research to characterize sperm whale habitat in the Atlantic Ocean.	2	10	NMFS						5,000	5,000
5.1.2	Conduct research to characterize sperm whale habitat in the Pacific Ocean.	2	10	NMFS						5,000	5,000
5.1.3	Conduct research to characterize sperm whale habitat in the Indian Ocean and Mediterranean Sea.	2	10	NMFS, International Partners						5,000	5,000
5.2 See 5.1 for costs	Monitor important habitat features and sperm whale use patterns to assess potentially detrimental shifts in these features that might reflect disturbance or degradation of habitat.	2	Ongoing	NMFS, International Partners							
5.3	Promote actions to protect important habitat in U.S. waters.	3	Ongoing	NMFS, NOS	*	*	*	*	*		*
5.4	Promote actions to define, identify, and protect important habitat in foreign or international waters.	3	Ongoing	NMFS, DOS, International Partners	*	*	*	*	*		*
5.5	Improve knowledge of sperm whale feeding ecology.	2	10	NMFS						4,000	4,000

Action Number	Action Description	Priority	Task Duration (years)	Agencies/ Organizations Potentially Involved	Cost Estimates by FY (thousands of dollars)						
					FY11	FY12	FY13	FY14	FY15	FY16 +[9]	Total/yr. x Task Duration
5.6	Conduct research and perform analyses to understand the impacts of climate change on sperm whales and seek strategies to reduce these impacts.	2	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
5.6.1	Conduct studies and perform analyses to assess the effects of climate change on the distribution, behavior, and productivity of sperm whales.	2	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
5.6.2	Seek strategies to reduce any detrimental impacts of climate change on sperm whales and their prey and habitats (identified in action 5.6.1).	2	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
TOTAL 5										***19,000***	***19,000***
6.0	***Investigate Causes and Reduce the Frequency and Severity of Human-caused Injury and Mortality.***										
6.1 Costs include 6.1 sub-actions	Investigate and reduce injury and mortality caused by fisheries and fishing equipment and reduce depredation.	2	5	NMFS, USCG, NOS						13,750	13,750
6.1.1	Conduct a systematic review of data on sperm whale interactions with fishing operations.	3	TBD	NMFS, International Partners							
6.1.2	Promote studies that investigate the ingestion of fishing gear (and the target species/bait) by sperm whales and develop methods to reduce ingestion of fishing gear.	2	TBD	TBD							
6.1.3	Investigate the development of a system to non-lethally deter sperm whales from fishing gear.	2	TBD	TBD							

Action Number	Action Description	Priority	Task Duration (years)	Agencies/ Organizations Potentially Involved	Cost Estimates by FY (thousands of dollars)						
					FY11	FY12	FY13	FY14	FY15	FY16 +[9]	Total/yr. x Task Duration
6.1.4	Conduct studies of gear modifications that reduce the likelihood of entanglement and depredation, mitigate effects of entanglements, and enhance possibility of disentanglement. Determine whether measures to reduce entanglements and depredation are effective.	2	TBD	TBD							
6.1.5	Develop and implement schemes to reduce the rate at which gear is lost, and improve the reporting of lost gear, in conjunction with studies in 6.1.2, 6.1.3, 6.1.4, and 6.1.6.	3	TBD	TBD							
6.1.6	Continue to review, evaluate, and act upon reports from fishermen and fishery observers of fishery interactions with sperm whales.	2	Ongoing	NMFS, States, USCG	*	*	*	*	*		*
6.2 Costs include 6.2 sub-actions	Investigate and reduce mortality and serious injury from vessel collisions.	2	5	NMFS, USCG, States						11,250	11,250
6.2.1 In conjunction with 3.2, 5.1, and 5.5.	Identify areas where concentrations of sperm whales coincide with significant levels of maritime traffic.	2	5	NMFS							

Action Number	Action Description	Priority	Task Duration (years)	Agencies/ Organizations Potentially Involved	Cost Estimates by FY (thousands of dollars)						
					FY11	FY12	FY13	FY14	FY15	FY16 +[9]	Total/yr. x Task Duration
6.2.2	Identify specific areas where recorded ship strikes of sperm whales have occurred (for example, the Canary Islands) and conduct studies to identify ecosystem-based traits that could support an assemblage of predictive tools.	2	10	NMFS, NOS, DOS, States, International Partners							
6.2.3	Once areas in 5.0 and 6.2.1 are identified, and in conjunction with information derived and resulting predictive tools from 6.2.2, conduct analyses of shipping routes and important sperm whale habitat areas to determine the risk of ship collisions with sperm whales.	2	TBD	NMFS, DOS, International Partners							
6.2.4	Develop a system to encourage, collect, and appropriately analyze opportunistic sightings of sperm whales from fishing vessels, whale-watching vessels, charter vessels, etc.	3	TBD	NMFS, NOS, USCG, International Partners							
6.2.5	Work with mariners, the shipping industry, and appropriate state, federal, and international agencies to develop and implement regionally-based measures to reduce the threat of ship strikes. Assess effectiveness of ship strike measures and adjust, as necessary.	2	TBD	NMFS, USCG, NOS							
6.2.6	Explore possible mechanisms to encourage vessels that have struck a whale to report the incident.	3	Ongoing	NMFS, NOS, USCG, International Partners							

Action Number	Action Description	Priority	Task Duration (years)	Agencies/ Organizations Potentially Involved	Cost Estimates by FY (thousands of dollars)						
					FY11	FY12	FY13	FY14	FY15	FY16 +[9]	Total/yr. x Task Duration
6.3	Conduct studies of environmental pollution that may affect sperm whale populations and their prey.	3	5	EPA, NMFS						3,000	3,000
6.3.1 See 6.3 and 8.1 for costs	Conduct studies on individual health and body condition as they may be related to accumulated contaminants.	3	Ongoing	NMFS, NOS, States, International Partners							
6.3.2 See 6.3 for costs	Take steps to minimize adverse effects from pollutants, if necessary.	3	TBD	TBD							
TOTAL 6										***28,000***	***28,000***
7.0	***Determine and Minimize Any Detrimental Effects of Anthropogenic Noise in the Oceans.***										
7.1	Conduct studies to assess the effects of anthropogenic noise on the distribution, behavior, and productivity of sperm whales.	2	5	NMFS, U.S. Navy (USN), Bureau of Ocean Energy Management, Regulation, and Enforcement, Int'l Partners						7,000	7,000
7.2	Take steps to minimize anthropogenic noises that are found to be potentially detrimental to sperm whales.	3	TBD	NMFS, Army Corps of Engineers, USN, USCG, Bureau of Ocean Energy Management, Regulation, and Enforcement	TBD	TBD	TBD	TBD	TBD	TBD	TBD
TOTAL 7										***7,000***	***7,000***

Action Number	Action Description	Priority	Task Duration (years)	Agencies/ Organizations Potentially Involved	Cost Estimates by FY (thousands of dollars)						
					FY11	FY12	FY13	FY14	FY15	FY16 +[9]	Total/yr. x Task Duration
8.0	***Maximize Efforts to Acquire Scientific Information from Dead, Stranded, and Entangled Sperm Whales.***										
8.1	Respond effectively to strandings of sperm whales in U.S. waters.	3	Ongoing	NMFS, NOS, States	180	180	180	180	180	1,800	2,700
8.1.1 See 8.1 for costs	Continue and improve programs to maximize data collected from necropsy of sperm whale carcasses.	3	Ongoing	NMFS	*	*	*	*	*	*	
8.1.2	Maintain and review, and if needed improve, the system for reporting dead, stranded, or entangled sperm whales.	3	Ongoing	NMFS, States	*	*	*	*	*	*	*
8.1.3	Improve, or as necessary, develop and implement protocols for securing and retrieving stranded (on land) or floating (at sea) sperm whale carcasses.	3	1	NMFS, NOS, States	*	*	*	*	*	*	*
8.2	Review, analyze, and summarize data on stranded sperm whales on an annual basis.	3	Ongoing	NMFS, NOS, States	*	*	*	*	*	*	*
8.3	Develop protocols for handling live-stranded sperm whales.	2	1	NMFS		4					4
8.4	Establish reliable sources of funding for rescue, necropsy, tissue collection, and analysis efforts.	2	Ongoing	NMFS	*	*	*	*	*	*	*
TOTAL 8					***180***	***184***	***180***	***180***	***180***	***1,800***	***2,704***
9.0	***Develop Post-delisting Monitoring Plan.***	2	TBD	NMFS	*	*	*	*	*		*
TOTAL 9					*	*	*	*	*		*
TOTAL Overall					***510***	***484***	***480***	***480***	***480***	***171,540***	***173,974***

*No cost associated, NMFS staff time

Table 3. Sperm Whale Implementation Schedule by Ocean Basin

Action Number	Action Description	Priority	Task Duration (years)	Agencies/ Organizations Involved/ Potentially Involved	Cost Estimates by Ocean Basin (thousands of dollars)				
					Atlantic Ocean (2025)	Pacific Ocean (2025)	Indian Ocean (2035)	Total	Total/yr. x Task Duration
1.0	***Coordinate State, Federal, and International Actions to Implement Recovery Actions and Maintain International Regulation of Whaling for Sperm Whales.***	2	Ongoing	NMFS, IWC, Department of State (DOS)	100	100	100	300	5,500
TOTAL 1					***100***	***100***	***100***	***300***	***5,500***
2.0	***Develop and Apply Methods to Estimate Population Size and Monitor Trends in Abundance.***								
2.1	Determine the best methods for assessing sperm whale status and trends.	2	1	NMFS, International Partners				30	30
2.2 See text for explanation of cost. Costs include 2.2 sub-actions	Conduct surveys to estimate abundance and monitor trends in sperm whale populations worldwide.	2	One survey[11]	NMFS, International Partners	43,990[12]	32,160[13]	27,490[14]	103,640	103,640

[11] Using two ships for approximately 4.5 months/year. The task duration was rounded up to the nearest 6 or 12 month period for ease of estimating costs.
[12] In this case, the Task Duration is one survey and for the Atlantic Ocean, one survey is expected to last 4.6 years. Rounding the value up to coincide with the nearest 6th or 12th month, the total annual cost is the total cost in thousands of a sperm-whale specific survey ($43,990), divided by 5 years which is $8,798.
[13] In this case, the Task Duration is one survey and for the Pacific Ocean, one survey is expected to last 3.4 years. Rounding the value up to coincide with the nearest 6th or 12th month, the total annual cost is the total cost in thousands of a sperm-whale specific survey ($32,160), divided by 3.5 years which is $9,189.
[14] In this case, the Task Duration is one survey and for the Indian Ocean, one survey is expected to last 2.8 years. Rounding the value up to coincide with the nearest 6th or 12th month, the total annual cost is the total cost in thousands of a sperm-whale specific survey ($27,490), divided by 3 years which is $9,163.

Action Number	Action Description	Priority	Task Duration (years)	Agencies/ Organizations Involved/ Potentially Involved	Cost Estimates by Ocean Basin (thousands of dollars)				
					Atlantic Ocean (2025)	Pacific Ocean (2025)	Indian Ocean (2035)	Total	Total/yr. x Task Duration
2.2.1	Continue to estimate abundance and monitor trends in sperm whale populations in the Atlantic Ocean, Gulf of Mexico, and Pacific Ocean.	2	One survey (see footnote 12)	NMFS, International Partners					
2.2.2	Estimate abundance and monitor trends in sperm whale populations in the Indian Ocean and Mediterranean Sea.	2	One survey (see footnote 12)	NMFS, International Partners					
TOTAL 2					***43,990***	***32,160***	***27,490***	***103,670***	***103,670***
3.0	***Determine Population Discreteness and Population Structure of Sperm Whales.***								
3.1 See text for explanation of cost. Costs include 3.1 sub-actions.	Support existing studies and initiate new studies to investigate population discreteness and population structure of sperm whales using genetic analyses.	2	5	NMFS, IWC, International Partners	200	200	100	500	2,500
3.1.1	Continue to collect biopsy samples off the Atlantic, Gulf of Mexico, and Pacific coasts of North America.	2	5	NMFS					
3.1.2	Collaborate with foreign agencies and researchers to obtain sufficient samples at the ocean basin scale.	2	5	NMFS, IWC, International Partners					
3.1.3	Perform genetic analyses on preserved samples from whales killed by the whaling industry in the past.	2	5	NMFS, IWC, International Partners					

Action Number	Action Description	Priority	Task Duration (years)	Agencies/ Organizations Involved/ Potentially Involved	Cost Estimates by Ocean Basin (thousands of dollars)				
					Atlantic Ocean (2025)	Pacific Ocean (2025)	Indian Ocean (2035)	Total	Total/yr. x Task Duration
3.2 See text for explanation of cost. Costs include 3.2 sub-actions.	Assess daily and seasonal movements and inter-area exchange using telemetry and photo-identification.	2	5	NMFS, International Partners	200	200	100	500	2,500
3.2.1	Continue/conduct telemetry and photo-identification studies of sperm whales in the Atlantic Ocean/Mediterranean Sea.	2	5	NMFS, International Partners					
3.2.2	Continue/conduct telemetry and photo-identification studies of sperm whales in the Pacific Ocean.	2	5	NMFS					
3.2.3	Continue/conduct telemetry and photo-identification studies of sperm whales in the Indian Ocean.	2	5	NMFS, International Partners					
3.2.4	Establish and maintain a central repository for sperm whale photographs.	3	Ongoing	NMFS					
3.3	Support ongoing studies and initiate new studies to investigate social structure and how it influences population structure.	2	10	NMFS, International Partners	100	100	50	250	2,500
TOTAL 3					***500***	***500***	***250***	***1,250***	***7,500***
4.0	***Conduct Risk Analyses.***								
4.1	Conduct risk analyses for the Atlantic Ocean/ Mediterranean Sea .	2	2	NMFS, International Partners	100			100	200
4.2	Conduct risk analyses for the Pacific Ocean.	2	2	NMFS		100		100	200
4.3	Conduct risk analyses for the Indian Ocean.	2	2	NMFS, International Partners			100	100	200

Action Number	Action Description	Priority	Task Duration (years)	Agencies/ Organizations Involved/ Potentially Involved	Cost Estimates by Ocean Basin (thousands of dollars)				
					Atlantic Ocean (2025)	Pacific Ocean (2025)	Indian Ocean (2035)	Total	Total/yr. x Task Duration
TOTAL 4					***100***	***100***	***100***	***300***	***600***
5.0	***Identify, Characterize, Protect, and Monitor Habitat Important to Sperm Whale Populations in U.S. Waters and Elsewhere.***								
5.1 See text for explanation of cost	Characterize sperm whale habitat.	2	10	NMFS, International Partners					
5.1.1	Conduct research to characterize sperm whale habitat in the Atlantic Ocean.	2	10	NMFS	500			500	5,000
5.1.2	Conduct research to characterize sperm whale habitat in the Pacific Ocean.	2	10	NMFS		500		500	5,000
5.1.3	Conduct research to characterize sperm whale habitat in the Indian Ocean and Mediterranean Sea.	2	10	NMFS, International Partners			500	500	5,000
5.2 See 5.1 for costs	Monitor important habitat features and sperm whale use patterns to assess potentially detrimental shifts in these features that might reflect disturbance or degradation of habitat.	2	Ongoing	NMFS, International Partners					
5.3	Promote actions to protect important habitat in U.S. waters.	3	Ongoing	NMFS, NOS	*	*		*	*
5.4	Promote actions to define, identify, and protect important habitat in foreign or international waters.	3	Ongoing	NMFS, DOS, International Partners	*	*	*	*	*
5.5	Improve knowledge of sperm whale feeding ecology.	2	10	NMFS	150	150	100	400	4,000
5.6	Investigate the impacts of climate change on sperm whales and seek strategies to reduce these impacts.	2	TBD	TBD	TBD	TBD	TBD	TBD	TBD

Action Number	Action Description	Priority	Task Duration (years)	Agencies/ Organizations Involved/ Potentially Involved	Cost Estimates by Ocean Basin (thousands of dollars)				
					Atlantic Ocean (2025)	Pacific Ocean (2025)	Indian Ocean (2035)	Total	Total/yr. x Task Duration
5.6.1	Conduct studies and perform analyses to assess the effects of climate change on the distribution, behavior, and productivity of sperm whales.	2	TBD	TBD	TBD	TBD	TBD	TBD	TBD
5.6.2	Seek strategies to reduce any detrimental impacts of climate change on sperm whales and their prey and habitats (identified in action 5.6.1).	2	TBD	TBD	TBD	TBD	TBD	TBD	TBD
TOTAL 5					***650***	***650***	***600***	***1,900***	***19,000***
6.0	***Investigate Causes and Reduce the Frequency and Severity of Human-caused Injury and Mortality.***								
6.1 Costs include 6.1 sub-actions	Investigate and reduce injury and mortality caused by fisheries and fishing equipment and reduce depredation.	2	5	NMFS, USCG, NOS	500	1,500	750	2,750	13,750
6.1.1	Conduct a systematic review of data on sperm whale interactions with fishing operations.	2	TBD	NMFS, International Partners					
6.1.2	Promote studies that investigate the ingestion of fishing gear by sperm whales and develop methods to reduce ingestion of fishing gear.	2	TBD	TBD					
6.1.3	Investigate the development of a system to non-lethally deter sperm whales from fishing gear.	2	TBD	TBD					

Action Number	Action Description	Priority	Task Duration (years)	Agencies/ Organizations Involved/ Potentially Involved	Cost Estimates by Ocean Basin (thousands of dollars)				
					Atlantic Ocean (2025)	Pacific Ocean (2025)	Indian Ocean (2035)	Total	Total/yr. x Task Duration
6.1.4	Conduct studies of gear modifications that reduce the likelihood of entanglement and depredation, mitigate effects of entanglements, and enhance possibility of disentanglement. Determine whether measures to reduce entanglements and depredation are effective.	2	TBD	TBD					
6.1.5	Develop and implement schemes to reduce the rate at which gear is lost, and improve the reporting of lost gear, in conjunction with studies in 6.1.2, 6.1.3, 6.1.4, and 6.1.6.	2	TBD	TBD					
6.1.6	Continue to review, evaluate, and act upon reports from fishermen and fishery observers of fishery interactions with sperm whales.	2	Ongoing	NMFS, States, USCG	*	*	TBD	*	*
6.2 Costs include 6.3 sub-actions	Investigate and reduce mortality and serious injury from vessel collisions.	2	5	NMFS, States, USCG	750	750	750	2,250	11,250
6.2.1	Identify areas where concentrations of sperm whales coincide with significant levels of maritime traffic.	2	5	NMFS					
6.2.2 In conjunction with 3.2, 5.1, and 5.5.	Identify specific areas where recorded ship strikes of sperm whales have occurred (for example, the Canary Islands) and conduct studies to identify ecosystem-based traits that could support an assemblage of predictive tools.	2	10	NMFS, NOS, DOS, States, International Partners					

Action Number	Action Description	Priority	Task Duration (years)	Agencies/ Organizations Involved/ Potentially Involved	Cost Estimates by Ocean Basin (thousands of dollars)				
					Atlantic Ocean (2025)	Pacific Ocean (2025)	Indian Ocean (2035)	Total	Total/yr. x Task Duration
6.2.3	Once areas in 5.0 and 6.1.2 are identified, and in conjunction with information derived and resulting predictive tools from 6.3.1, conduct analyses of shipping routes and important sperm whale habitat areas to determine the risk of ship collisions with sperm whales.	2	TBD	NMFS, DOS, International Partners					
6.2.4	Develop a system to encourage, collect, and appropriately analyze opportunistic sightings of sperm whales from fishing vessels, whale-watching vessels, charter vessels, etc.	3	TBD	NMFS, NOS, USCG, International Partners					
6.2.5	Work with mariners, the shipping industry, and appropriate state, federal, and international agencies to develop and implement regionally-based measures to reduce the threat of ship strikes. Assess effectiveness of ship strike measures and adjust, as necessary.	2	TBD	NMFS, NOS, USCG,					
6.2.6	Explore possible mechanisms to encourage vessels that have struck a whale to report the incident.	3	Ongoing	NMFS, NOS, USCG, International Partners					
6.3	Conduct studies of environmental pollution that may affect sperm whale populations and their prey.	3	5	EPA, NMFS	250	250	100	600	3,000
6.3.1	Identify areas where concentrations of sperm whales coincide with significant levels of pollution (including marine debris).	2	5	NMFS					

Action Number	Action Description	Priority	Task Duration (years)	Agencies/ Organizations Involved/ Potentially Involved	Cost Estimates by Ocean Basin (thousands of dollars)				
					Atlantic Ocean (2025)	Pacific Ocean (2025)	Indian Ocean (2035)	Total	Total/yr. x Task Duration
6.3.2 See 6.3 and 8.1 for costs	Conduct studies on individual health and body condition as they may be related to accumulated contaminants.	3	Ongoing	NMFS, NOS, States, International Partners					
6.3.3 See 6.3 for costs	Take steps to minimize adverse effects from pollutants.	3	TBD	TBD					
TOTAL 6					***1,500***	***2,500***	***1,600***	***5,600***	***28,000***
7.0	***Determine and Minimize Any Detrimental Effects of Anthropogenic Noise in the Oceans.***								
7.1	Conduct studies to assess the effects of anthropogenic noise on the distribution, behavior, and productivity of sperm whales.	2	5	NMFS, U.S. Navy (USN), Bureau of Ocean Energy Management, Regulation, and Enforcement, Int'l Partners	500	500	400	1,400	7,000
7.2	Take steps to minimize anthropogenic noises that are found to be potentially detrimental to sperm whales.	3	TBD	NMFS, Army Corps of Engineers, USN, USCG, Bureau of Ocean Energy Management, Regulation, and Enforcement	TBD	TBD	TBD	TBD	TBD
TOTAL 7					***500***	***500***	***400***	***1,400***	***7,000***
8.0	***Maximize Efforts to Acquire Scientific Information from Dead, Stranded, and Entangled Sperm Whales.***								
8.1	Respond effectively to strandings of sperm whales in U.S. waters.	3	Ongoing	NMFS, NOS, States	90	90		180	2,700

Action Number	Action Description	Priority	Task Duration (years)	Agencies/ Organizations Involved/ Potentially Involved	Cost Estimates by Ocean Basin (thousands of dollars)				
					Atlantic Ocean (2025)	Pacific Ocean (2025)	Indian Ocean (2035)	Total	Total/yr. x Task Duration
8.1.1 See 8.1 for costs	Continue and improve programs to maximize data collected from necropsy of sperm whale carcasses.	3	Ongoing	NMFS					
8.1.2	Maintain and review, and if needed improve, the system for reporting dead, stranded, or entangled sperm whales.	3	Ongoing	NMFS, States	*	*	TBD	*	*
8.1.3	Improve, or as necessary, develop and implement protocols for securing and retrieving stranded (on land) or floating (at sea) sperm whale carcasses.	3	1	NMFS, NOS, States	*	*	TBD	*	*
8.2	Review, analyze, and summarize data on stranded sperm whales on an annual basis.	3	Ongoing	NMFS, NOS, States	*	*	*	*	*
8.3	Develop protocols for handling live-stranded sperm whales.	2	1	NMFS	2	2	TBD	4	4
8.4	Establish reliable sources of funding for rescue, necropsy, tissue collection, and analysis efforts.	2	Ongoing	NMFS	*	*	TBD	*	*
TOTAL 8					***92***	***92***		***184***	***2,704***
9.0	***Develop Post-delisting Monitoring Plan.***	2	TBD	NMFS	*	*		*	*
TOTAL 9					*	*		*	*

*No cost associated, NMFS staff time

Table 4. Estimated Cost of Action Items Listed as Priority 1, Priority 2, and Priority 3 in the Table 2 (in thousands of dollars).

ACTION ITEMS LISTED AS:	TOTAL COST
PRIORITY 1	**0**
PRIORITY 2	**168,274**
PRIORITY 3	**5,700**

NOTE: The cost above does not reflect task duration (*e.g.,* 5 years) rather all costs were estimated until time to recovery for all three ocean basins (15 years for the Atlantic Ocean/Mediterranean Sea and Pacific Ocean (2025) and 25 years for the Indian Ocean (2035)).

Table 5. Estimated Cost of Action Items by Ocean Basin in Table 2 (in thousands of dollars).

Year	Action 1	Action 2	Action 3	Action 4	Action 5	Action 6	Action 7	Action 8	Action 9	Total[1]
Atlantic (2025)	1,500	43,990	3,000	200	6,500	7,500	2,500	1,352	*	66,542
Pacific (2025)	1,500	32,160	3,000	200	6,500	12,500	2,500	1,352	*	59,712
Indian (2035)	2,500	27,490	1,500	200	6,000	8,000	2,000			47,690
Total for Task Duration	**5,500**	**103,670[2]**	**7,500**	**600**	**19,000**	**28,000**	**7,000**	**2,704**	*	**173,974**

NOTE: The cost above does not reflect task duration (*e.g.,* 5 years) rather all costs were estimated until time to recovery for each ocean basin (15 years for the Atlantic Ocean/Mediterranean Sea and Pacific Ocean (2025) and 25 years for the Indian Ocean (2035)).

[1] Total reflects cost of recovery for ocean basin.
[2] Total reflects an additional cost of $30K that is not specific to one ocean basin.
[*] No cost associated, NMFS staff time.

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VI. LITERATURE CITED

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