Sperm Whale
(Physeter macrocephalus)

5-Year Review:
Summary and Evaluation
June 2015

Source: **NOAA Northeast Fisheries Science Center**

National Marine Fisheries Service
Office of Protected Resources
Silver Spring, MD

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5-YEAR REVIEW
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1.0 GENERAL INFORMATION

1.1 Reviewers:

Lead Regional or Headquarters Office:
Therese Conant, Office of Protected Resources (OPR), 301-427-8456
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1.2 Methodology used to complete the review:

A 5-year review is a periodic analysis of a species' status conducted to ensure that the listing classification of a species as threatened or endangered on the List of Endangered and Threatened Wildlife and Plants (List) (50 CFR 17.11 – 17.12) is accurate. The 5-year review is required by section 4(c)(2) of the Endangered Species Act of 1973, as amended (ESA). To achieve this, the National Marine Fisheries Service (NMFS) Office of Protected Resources led the 5-year review with input from NMFS regional offices and science centers. The following staff provided comments on the draft: Jay Barlow, Ph.D., Southwest Fisheries Science Center; Peter Corkeron, Ph.D., Northeast Fisheries Science Center; Sally Mizroch, Alaska Fisheries Science Center; Keith Mullin, Ph.D. and Patricia Rosel, Ph.D., Southeast Fisheries Science Center; Greg Silber, Ph.D., Office of Protected Resources; Monica DeAngelis and Penny Ruvelas, West Coast Region; and Nancy Young, Pacific Islands Regional Office. We relied on the last 5 year review (NMFS 2009), final recovery plan (NMFS 2010a), peer reviewed publications, government and technical reports, conference papers, dissertations, and theses. Information was gathered *through November 2014*. The information on the sperm whale biology and habitat, threats, and conservation efforts were summarized and analyzed in light of the recovery criteria and the ESA section 4(a)(1) factors (see Section 2.3.2.1) to determine whether a reclassification or delisting is warranted (see Section 3.0). If the recovery criteria do not meet the guidelines for recovery criteria laid out in the 2006 NMFS Interim Recovery Planning Guidance or do not adequately address new threats, then we use the criteria only as a benchmark for measuring progress toward recovery.

1.3 Background:

1.3.1 FR Notice citation announcing initiation of this review:
79 FR 53171, September 8, 2014.

1.3.2 Listing history:

Original Listing
FR notice: 35 FR 8495
Date listed: June 2, 1970
Entity listed: Sperm Whale (*Physeter macrocephalus*)
Classification: Endangered

1.3.3 Associated rulemakings:

None

1.3.4 Review history:

S.L. Perry, D.P. DeMaster, and G.K. Silber. 1999. The Great Whales: History and Status of Six species Listed as Endangered Under the U.S. Endangered Species Act of 1973. Marine Fisheries Review, 61:1, pp. 44-51. Department of Commerce.

H.W. Braham. 1991. Endangered whales: Status update. Unpubl. Doc. 56p., on file at Natl. Mar. Mammal Lab. NMFS, NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115.

H.W. Braham. 1984. The status of endangered whales: An overview. Marine Fisheries Review, 46:4, pp. 2-6.

M.E. Gosho, D.W. Rice, and J.M. Breiwick 1984. The sperm whale, *Physeter macrocephalus*. Marine Fisheries Review, 46:4, pp. 54-64.

NMFS. 2009. Sperm Whale (*Physeter macrocephalus*) 5-Year Review: Summary and Evaluation.

1.3.5 Species' recovery priority number at start of 5-year review:

"5", reflecting a moderate magnitude of threat, high recovery potential, and the presence of conflict.

1.3.6 Recovery plan or outline

Name of plan or outline: Final Recovery Plan for the Sperm Whale
Date issued: December 2010

2.0 REVIEW ANALYSIS

2.1 Application of the 1996 distinct population segment (DPS) policy

2.1.1 Is the species under review a vertebrate?

Yes

2.1.2 Is the species under review listed as a DPS?

No

2.1.4 Is there relevant new information for this species regarding the application of the DPS policy?

__X__ Yes

> On December 9, 2011, we received a petition from WildEarth Guardians to list the sperm whale population in the Gulf of Mexico as an endangered or threatened Distinct Population Segment (DPS) under the ESA. We found the petitioned action may be warranted (78 FR 19176, March 29, 2013). We conducted a status review, and based on the best scientific and commercial information, including data on genetics, size, behavior, and regulatory mechanisms, we found the available information does not indicate the sperm whales in the Gulf of Mexico are discrete from other populations of the sperm whale. We found that the Gulf of Mexico population of the sperm whale does not meet the DPS Policy criteria for qualifying as a DPS; thus, we found the petitioned action was not warranted (78 FR 68032, November 13, 2013).

Globally, 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. Populations are often divided and discussed on an ocean basin level. There is a need for an improved understanding of the genetic differences among and between populations. Although there is new information since the last review, existing knowledge of population structure for this broadly distributed species remains poor. New information that is available is currently insufficient to identify units that are both discrete and significant to the survival of the species.

2.2 Recovery Criteria

2.2.1 Does the species have a final, approved recovery plan containing objective, measurable criteria?

Yes

2.2.2 Adequacy of recovery criteria.

2.2.2.1 Do the recovery criteria reflect the best available and most up-to date information on the biology of the species and its habitat?

Yes

2.2.2.2 Are all of the 5 listing factors that are relevant to the species addressed in the recovery criteria (and is there no new information to consider regarding existing or new threats)?

Yes

2.2.3 List the recovery criteria as they appear in the recovery plan, and discuss how each criterion has or has not been met, citing information

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.

Status: Efforts to attain this criterion are ongoing, but data are insufficient for many stocks to determine population abundance and trends and to conduct the risk analysis. The most recent stock assessment reports provide a best estimate of abundance of 2,288, with a minimum population estimate of 1,815 sperm whales in the western North Atlantic stock. Data are insufficient to determine a population trend for the U.S. North Atlantic sperm whale stock. For the northern Gulf of Mexico, the best estimate of abundance for sperm whales is 763, with a minimum population estimate of 560 sperm whales. Data are insufficient to determine a population trend for the northern Gulf of Mexico sperm whale stock. For the Pacific Ocean, the population is estimated between 26,300-32,100 for the North Pacific and 14,800-34,600 for the eastern tropical Pacific. The California/Oregon/Washington stock best estimate of abundance is 2,106 whales, with a minimum population estimate of 1,332. The Hawaii stock best abundance estimate is 3,354, with a minimum population estimate of 2,539. There is currently no reliable estimate about the minimum population estimate for the Northeast Pacific stock. For the Indian Ocean, there are no currently reliable estimates. Approximately 400 whales are estimated to occur in the Mediterranean Sea. There is currently no accepted recent abundance estimate for sperm whales worldwide. The most recent estimate is from 2002, which indicated a global population of between 300,000-450,000 sperm whales. See Section 2.3.1.2 for further details.

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)[1]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.

A1. Effects of reduced prey abundance due to climate change continue to be investigated and action is being taken to address the issue, as necessary.

Status: The impact climate change is having on sperm whale prey continues to be studied. The range of sperm whales is vast; consequently, the sperm whale may be more resilient to climate change than a species with a narrower range. Continued research is needed to provide quantitative data on possible changes that could occur as a result of climate change, and what impacts, if any, would occur to sperm whales and their prey. See Section 2.3.2.1 for further detail.

A2. Effects of anthropogenic noise continue to be investigated and actions taken to minimize potential effects, as necessary.

Status: Efforts to attain this criterion are ongoing. Anthropogenic noise is believed to be increasing in the marine environment as a result of oil and gas exploration, shipping, construction, and naval exercises. Possible negative impacts to sperm whales include changes in foraging behavior. NMFS developed draft guidance for assessing the effects of anthropogenic sound on marine mammal species, including the sperm whale (78 FR 78822; December 27, 2013). The guidance provides updated received levels, or thresholds above which individual marine mammals are predicted to experience changes in their hearing sensitivity (either temporary or permanent) for all underwater anthropogenic sound sources. This guidance is intended to be used by NOAA analysts, managers, and other relevant user groups and stakeholders, including other federal agencies, when seeking to determine whether and how their activities are expected to result in particular types of impacts to marine mammals via acoustic exposure. NMFS is reviewing updated information on acoustic impacts since the 2013 release of the draft guidance and will incorporate the new information prior to finalizing the guidance. NMFS also developed a cetacean and sound mapping tool to predict wide-ranging, long-term underwater noise contributions from multiple human activities. Information can be found at: http://cetsound.noaa.gov/. See Section 2.3.2 for additional information on actions taken to minimize effects of anthropogenic noise.

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[1] Factor C—disease or predation and Factor E—other natural or manmade factors affecting its continued existence—were not considered a threat to the sperm whale and recovery criteria were not developed for these factors (NMFS 2010a).

A3. Competition with fisheries for resources is being addressed through fishery management plans and other measures.

Status: Efforts to attain this criterion are ongoing. Currently, there are no management plans factoring in predation by sperm whales when setting catch limits for fisheries. See Section 2.3.2.1 for further detail.

A4. Effects of oil spills and contaminants are determined to not affect the potential for continued growth or maintenance of sperm whale populations.

Status: Efforts to attain this criterion are ongoing. The 2010 Deepwater Horizon oil spill released millions of gallons of oil into the Gulf of Mexico. The impacts of the oil on sperm whales in the Gulf of Mexico are unknown. In addition, chemical dispersants were applied to the surface and at depth to mitigate the impacts of the oil leak. It was determined that the dispersants used had the potential to be cytotoxic and genotoxic to sperm whale skin cells. Depending on concentrations whales were exposed to, it is plausible that the dispersants could have severe impacts on reproduction in females and to the health of the whales exposed. After the spill, the observed mortality was assumed to underrepresent the number of whales actually impacted because not all dead whales are detected (e.g., strand on shore). Not only is the mortality underestimated, but the long-term impacts of the exposure to oil on the population are unknown. See Section 2.3.2.1 for further detail.

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

B1. Management measures are in place to ensure that any direct harvest (commercial, subsistence, and scientific) is at a sustainable level.

Status: Efforts to attain this criterion are ongoing. In 1982, the International Whaling Commission (IWC) adopted a temporary moratorium on the commercial whaling of all whale species, having taken effect in 1986. Iceland and Norway formally reserved their position on the moratorium, although these nations expressed no interest in taking sperm whales. Canada withdrew its membership in the IWC, but has continued to ban whaling for the large baleen whales (with the exception of the bowhead whale, *Balaena mysticetus*) in its territorial waters under domestic regulations. A resumption of sperm whaling in Canada is unlikely in the near future. There is no evidence that whaling will resume in the Portuguese islands of the Azores and Madeira. However, Japan continues to hunt sperm whales reportedly for the purposes of scientific research under Article VIII of the International Convention for the Regulation of Whaling. The number taken is unknown, but is likely relatively small. See Section 2.3.2.2 for further detail.

Factor D: The inadequacy of existing regulatory mechanisms.

D1. Ship collisions continue to be investigated and actions taken to minimize potential effects, as necessary.

Status: Efforts to attain this criterion are ongoing. Within specified areas of the U.S. waters in the Atlantic Ocean, NMFS established ship speed restrictions, mandatory ship reporting systems, recommended routes, related routing measures, and an extensive sighting advisory system. While these measures were designed to protect right whales specifically, they are expected to also reduce, to some extent, the risk of ship strikes to other marine mammals, including sperm whales (NMFS 2008a). In 2013, shipping lanes off Los Angeles/Long Beach and San Francisco, California, were modified to reduce the probability of colliding with large whales. While these measures were designed to protect mainly humpbacks, blue and fin whales, they are expected to also reduce the risk of ship strikes to other marine mammals, including sperm whales.

Ship collisions continue to be recorded when reported or observed and necropsies on dead whales are performed when possible to confirm cause of death. Federal agencies continue to consult under the ESA with NMFS on federally funded or permitted actions and take measures to reduce the likelihood of ship strikes. Observers are being placed on ships to monitor whale presence and avoid collisions. See Section 2.3.2.1 for additional information.

Delisting Objectives and Criteria

Because we have not met the downlisting objectives and criteria (discussed above and see Section 3.1 Recommended Classification) for the sperm whale, an analysis of the delisting objectives and criteria was not required. The criteria for delisting the sperm whale are listed in the 2010 final recovery plan for the sperm whale, which is available at: http://www.nmfs.noaa.gov/pr/recovery/plans.htm.

2.3 Updated Information and Current Species Status

2.3.1 Biology and Habitat

2.3.1.1 New information on the species' biology and life history:

Demographic Features (age structure, sex ratio, family size, birth rate, age at mortality, mortality rate, etc.)

Sperm whales aggregate in groups of various sizes often involving adult females (some related and some not related to each other) travelling with their sub-adult offspring. These social units may unite with other groups and multiple groups may comprise a clan (reviewed by Whitehead et al. 2012). Males eventually leave these groups, after which they live in "bachelor schools." The cohesion among males within a bachelor school declines as the animal ages, although bonding is evident by the fact that males mass strand (Bond 1999), and immature males in the Mediterranean Sea were found to form long-term relationships (Pace et al. 2014). During their prime breeding period and old age, male sperm whales are essentially solitary (Christal and Whitehead 1997). Full maturation in males usually occurs 20 years of age or older. Females usually begin ovulating at 7-13 years of age, with some females in the southeast Pacific Ocean ovulating as early as 6.5 years of age (Clarke et al. 2011). Since females within a group often come into estrus synchronously, males need not remain within proximity to females for an entire season to maximize breeding opportunities (Best and Butterworth 1980). In the northern hemisphere, peak breeding season for sperm whales occurs between March/April and June, and in the southern hemisphere, peak breeding season occurs between October and December (Best et al. 1984). In both cases, some mating activity takes place earlier or later. Inter-birth interval is generally 4-6 years for prime-aged females and, apparently, much longer for females over 40 years of age; although, females rarely become pregnant after the age of 40 (Best et al. 1984; Whitehead 2003). The average calving interval in South Africa ranges from 5.2 (west coast) to 6.0-6.5 years (east coast) (Best et al. 1984). Clarke at al. (2011) suggested that a 4-year reproductive cycle existed for the southeast Pacific Ocean sperm whale population. 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. Nursing females may change vocal repertoires (see Hearing and Vocalization discussion below) and may separate from the basic social unit as these individuals care for young offspring (Gero et al. 2013). Despite the apparent isolation of nursing females and offspring, alloparental care has been well documented in sperm whales, with many individuals from the entire clan participating in caring for newborns and calves. Females may also participate in allonursing--feeding calves that are not their own (Gero et al. 2009).

Hearing and Vocalizations

Sperm whales may possess better low frequency hearing than some of the other odontocete species, although not as low as many baleen whale species (Ketten 1992). Underwater audiograms indicate that most odontocetes hear best at frequencies above 10 kHz. Generally, most of the acoustic energy in sperm whale clicks is at frequencies below 4 kHz, although diffuse energy up to and above 20 kHz has been reported (Thode et al. 2002), with source levels up to 236 dB re 1 μPa-m for a presumed adult male (Mohl et al. 2003). Ridgway and Carder (2001) measured low-frequency-high-amplitude clicks with peak frequencies at 500 Hz to 3 kHz from a sperm whale neonate. The clicks of neonate sperm whales are very different than those produced by adults in that they are of low directionality, long duration, and low frequency, with estimated source levels between 140 and 162 dB re 1 μPa-m (Madsen et al. 2003).

Sperm whales produce four types of clicks—codas, usual clicks, creaks, and slow clicks. Distinctive, short, patterned series of clicks, called codas, are associated with social behavior and interactions within social groups (Weilgart and Whitehead 1993). Codas are shared among individuals of a social unit and are considered to be primarily for intra-group communication to reinforce social bonds (Weilgart and Whitehead 1997; Rendell and Whitehead 2004; Shulz et al. 2008). Certain acoustic features of codas may be unique to individual sperm whales within the social unit, allowing for distinction among members (Antunes et al. 2011). In the Mediterranean Sea, mature males who have left their social units will use codas upon encountering other males, a behavior not reported for sperm whales in the Pacific and Atlantic Oceans (Frantiz and Alexiadou 2008). Usual clicks and creaks (also called buzzes) are heard most often when sperm whales engage in foraging/diving behavior (Miller et al. 2004; Zimmer et al. 2005). These clicks may be associated with echolocation used in feeding, contact calls for communication, and orientation during dives. Rapid-click creaks are associated with rapid maneuvers during foraging believed to be an echolocation signal adapted for prey capture (Miller et al. 2004). Sperm whales may switch between coda clicks used for communication to echolocation clicks used for foraging through anatomical adaptations in the right nasal passage where they can change the volume and distribution of air and control the sound energy emission (Huggenberger et al. 2014). Slow clicks are believed to be only produced by males (Mullins et al. 1998). Slow clicks (>2-s duration) are detectable at a greater distance (up to 37 km) than quicker "usual" clicks, detectable at 18.5 km (Barlow and Taylor 2005). Slow clicks have lower source levels than usual clicks suggesting they are unlikely to be used for echolocating or debilitating prey (Oliveira et al. 2013). Indeed, solitary males foraging in the Arctic Ocean only occasionally used slow clicks and never during rapid maneuvers associated with prey capture, or during a deep (> 370 m) dive. Slow clicks were mainly recorded during an ascent or at the surface, indicating slow clicks are likely used to communicate with other whales rather than foraging (Oliveira et al. 2013).

In the South Pacific Ocean, sperm whales from multiple social units temporarily form large aggregations (or clans), sometimes exceeding thousands of females, with individuals exhibiting similar foraging strategies and codas. Social units from different clans often overlap in distribution and share mitochondrial deoxyribonucleic acid (mtDNA) haplotypes, which suggests that distinct coda dialects are culturally transmitted (Rendell et al. 2012; reviewed by Whitehead et al. 2012). The formation of these large clans in the Pacific Ocean is possibly to cope with predation pressure by killer whales (*Orcinus orca*) (reviewed by Whitehead et al. 2012). However, other factors may drive the formation of these large clans including differences in oceanographic conditions, effects of whaling, and social learning (reviewed by Whitehead et al. 2012). In contrast to the Pacific Ocean sperm whales, in the North Atlantic Ocean, sperm whales tend to aggregate in small social units and exhibit calving rates much higher than in other ocean basins, likely due, in part, to the lack of predation pressure by killer whales (reviewed by Whitehead et al. 2012). The duration which groups stayed together also varies by ocean basin: Gulf of Mexico sperm whales aggregate in groups for longer periods than do sperm whales in the Pacific Ocean (Richter et al. 2008; Ortega-Ortiz et al. 2012). The duration and composition of these groups in the Gulf of Mexico was not associated with kinship and may be more closely correlated with resource availability (Ortega-Ortiz et al. (2012).

In the North Pacific Ocean, codas of sperm whales in two locations off Japan (Kumano coast and Ogasawara Islands) separated by over 1,000 km differed by number of clicks per coda, duration of coda, suggesting a geographic segregation of clans (Amano et al. 2014). Oceanic conditions varied greatly between the two locations. Off the Kumano Coast, the Kuroshio Current flows northeastward and a similarly strong current is lacking off Ogasawara Islands. The differences in local conditions likely control prey type and distribution, which may require different foraging strategies for sperm whales in these areas (Amano et al. 2014).

Schulz et al. (2011) investigated individual vocal production within a sperm whale social unit and found that vocalization repertoires between individual whales were statistically indistinguishable from each other. However, calf and mother pairs exhibited vocalizations that differed from other group members, suggesting that adults with calves rely on these calls to locate each other or to establish/maintain social bonds. Parents and their offspring could signal identity, age-class, or reproductive status using distinctive codas. Adult females were able to switch from the social unit coda to a distinctive repertoire to locate and suckle their calf during lactation. The adult females also had higher rates of coda production and higher rates of coda overlap, indicating the importance of codas among adult females, possibly to establish or maintain social bonds. More study is needed to understand this female vocal repertoire as it relates more generally to the species (Schulz et al. 2011).

Natural Mortality
Causes of natural mortality include predation, competition, and disease; however, there are many documented cases of strandings for which the cause of the stranding 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). Although an observation off California showed a prolonged and sustained attack by killer whales on a pod of sperm whales (mainly adult females) resulting in the severe wounding and death of some of the individuals (Pitman et al. 2001), the paucity of documented attacks by killer whales indicates that predation risk to sperm whales is low.

Entire schools of sperm whales occasionally strand, but the causes of this phenomenon are uncertain (Rice 1989). Although the causes of strandings of cetaceans in general are not well known, there is some evidence that sperm whale strandings may be linked to changes in wind patterns which result in colder and presumably nutrient-rich waters being driven closer to the surface, driving their prey to shallower waters (Evans et al. 2005). Lunar cycles, possibly as a result of the effects that light levels have on the vertical migration of their prey species (Wright 2005), and solar cycles, possibly by creating variations in the Earth's magnetic field (Vanselow and Ricklefs 2005; Vanselow et al. 2009), may also play a role. However, the precise mechanisms are unclear.

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). 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, which is essentially decompression sickness, or what is called the "bends" in humans.

2.3.1.2 Abundance, population trends (e.g. increasing, decreasing, stable):

Whitehead (2002) estimated sperm whale abundance to be approximately 300,000-450,000 worldwide. These estimates are based on extrapolating surveyed areas to unsurveyed areas and thus, are not necessarily accurate; however, without a systematic survey design, these are probably the best available and most current estimates of global sperm whale abundance. No other attempts have been made to estimate worldwide sperm whale abundance although there are stock assessments and surveys done for smaller ranges.

Historical data on the killing of sperm whales are important in understanding the current global population status. From 1900 to 1999, sperm whales were the second most hunted whale species, with 761,523 hunted globally by industrial whaling operations. From 1969 to 1975, sperm whale kills exceeded 10,000 whales each year (Rocha et al. 2014). Unfortunately, whaling data from the Soviet Union have been underreported, and illegal whaling continued in both hemispheres from the 1950s through the 1970s (Rocha et al. 2014). From 1948 to 1979, the total global catch (all species) for the Soviet Union was 534,204 whales, of which 178,811 were not reported (Rocha et al. 2014). During that same period, sperm whale Soviet catch data in the North Pacific, showed 157,680 sperm whales were hunted of which 25,175 were unreported

(Ivaschchenko et al. 2014). Areas with high catch levels included the Gulf of Alaska, central Pacific, and southern Kurils/northern Japan. Extensive illegal catches of female sperm whales in higher latitudes likely continues to impact the populations in the North Pacific (Mizroch and Rice 2013; Ivaschchenko et al. 2014). The impact of historical hunting on females is of note. Mizroch and Rice (2013) noted that few matrilineal groups are currently found in Alaskan waters and Ivashchenko et al. (2014) noted that large aggregations of sperm whales are seldom seen during current surveys. Because of the extensive illegal catch of female sperm whales (Berzin 2008; Ivashchenko et al. 2014), Mizroch and Rice (2013) suggested that the effects of the removal of so many females may be disproportionately negative because of the importance of females in sperm whale social interactions (Whitehead et al. 1997; Best et al. 1984).

Atlantic Ocean

There are no reliable estimates of total sperm whale abundance in the entire western North Atlantic Ocean. Based on the sum of several aerial and shipboard surveys conducted within the U.S. Exclusive Economic Zone (EEZ) from June-August 2011, abundance for the North Atlantic U.S. population was estimated to be 2,288 (CV=0.28), but is likely an underestimate as it was not corrected for whales that were not visible on the surface (NMFS 2014a). The minimum population estimate for the western North Atlantic population is 1,815 (NMFS 2014a). Data are insufficient to determine a population trend for the U.S. North Atlantic sperm whale stock. Other estimates that encompass populations that may not enter U.S. waters have been conducted for the North Atlantic Ocean. In 2001, based on combined line-transect and cue-count shipboard survey, which corrected for whales below the surface assuming 20% surface time and two deep dives per hour, Gunnlaugsson et al. (2009) estimated 11,185 (CV=0.34) sperm whales in the North Atlantic. Between 2003 and 2011, nine organizations collected abundance estimates of the sperm whale for the North Atlantic Marine Demarcation and the waters of the Bay of Biscay. The best estimate for sperm whale abundance during that time is 865 whales (95% CI: 767-1,041; Vázquez et al. 2013).

For U.S. stocks in Puerto Rico and the U.S. Virgin Islands, sightings of sperm whales are too few to derive abundance estimates and population trends (NMFS 2010b). In the eastern Caribbean, Whitehead and Gero (in review) used empirical data on mortality and fecundity of individuals in the population to estimate trends. The population growth rate was estimated to be *r*=+3.4%/yr (95% c.i. 1.0% to 5.7%/yr) from 1984 through 2012, suggesting an increase in adults (except mature males) from about 118 in 1990 to 245 in 2012. However, this observed rate of increase is tempered by the projected negative population growth rate of *rs*=-2.7%/yr (95% c.i. -5.4% to -0.4%/yr), suggesting mortality is not compensated by fecundity for the eastern Caribbean population. Whitehead and Gero (in review) hypothesize that the observed rate of increase in the area may be due to immigration of social units from other areas because foraging conditions are more favorable in the eastern Caribbean Sea. High mortality in the Caribbean population may act as a population sink. That is, as individuals migrate to the area, they will not deplete food resources because these immigrants die at a higher rate, and favorable resource conditions remain intact for future immigrants. Thus, a positive observed rate of increase may not be an indication of a healthy population. Analyzing individual members of a population and estimating current and future trends are important in understanding discrete and metapopulation trends (Whitehead and Gero in review).

Reeves et al. (2011) estimated that 1,179 sperm whales were caught during whaling in the Gulf of Mexico from the 1780s–1870s. Evidence suggests that most of these whales were juveniles and females. For the Northern Gulf of Mexico stock, abundance was estimated at 763 (CV=0.38) whales based on a summer 2009 oceanic survey in the Northern Gulf of Mexico from the 200-m isobath to the seaward extent of the U.S. EEZ. The minimal population estimate is 560 sperm whales (NMFS 2012a). The current data are insufficient to determine population trends.

Mediterranean Sea

In the Mediterranean Sea, the sperm whale population is estimated to be less than 2,500 mature individuals (Notarbartolo di Sciara et al. 2012). Based on photo-identification from 1990-2008, the average abundance estimate was approximately 400 mature individuals (Rendell et al. 2014). Current abundance estimates are thought to be well below historical abundance, although specific data are lacking (Reeves and Notarbartolo di Sciara 2006).

Pacific Ocean

For the North Pacific Ocean, prior to whaling, abundance was reported to be 1,260,000, which was reduced to 930,000 sperm whales by the late 1970s (Rice 1989). In 1997, based on a combined visual and acoustic line-transect survey, sperm whales were estimated in the northeastern temperate North Pacific to be 26,300 (CV=0.81) based on visual sightings, and 32,100 (CV=0.36) based on acoustic detections and visual group size (Barlow and Taylor 2005). The sperm whale population along the U.S. west coast was estimated to be 971 (CV = 0.31) whales based surveys conducted in 2005 and 2008 (Carretta et al. 2013). Data collected on sperm whales observed in the California Current off the U.S. coast during surveys conducted from 1991 to 2008 provide a best estimate of abundance of 2,106 whales (CV=0.58), with a minimum of 1,332 (Moore and Barlow 2014). The number of small groups has increased in the area likely due to an increase in adult males occurring as lone individuals or in pairs in the region (Moore and Barlow 2014). For the North Pacific populations that enter U.S. waters, population trends are unknown (NMFS 2013).

In the eastern tropical Pacific Ocean, sperm whale abundance was estimated to be 22,700 (95% C.I.=14,800-34,600; Wade and Gerrodette 1993 as cited in NMFS 2014b). Surveys conducted in the Hawaiian Islands EEZ in 2002, resulted in an abundance estimate of 6,919 (CV=0.81) (Barlow 2006), and in 2010 an estimate of 3,354 (CV = 0.34) sperm whales, which included a correction factor for diving animals (Bradford et al. 2013 as cited in NMFS 2014b). The latter is currently the best available abundance estimate for the U.S. Hawaiian stock. The minimum population size estimate is 2,539 and no population trend has been determined for this stock (NMFS 2014b). Additionally, there is no trend available for the U.S. California, Oregon, and Washington stock of sperm whales. The best population estimate for the stock is 971 (CV=0.31) whales, which represents the geometric mean of surveys conducted in 2005 (3,140; CV=0.40) and 2008 (300; CV=0.51) and the minimum population size estimate is 751 (NMFS 2012b). Estimates of the sperm whale population off the west coast of Baja California are 1,640 (CV=0.33) (Barlow and Taylor 2001 as cited in NMFS 2012b). The mean number male sperm whales seen daily in Kaikoura, New Zealand, was 4 (± 0.13) between 2010 to 2012, which is much lower than daily estimates of 13.8 (± 1.3) from 1990 to 2001 (Sagnol et al. 2014).

Indian Ocean

In the Indian Ocean, the current estimate of 299,400 (no CV) sperm whales from the Equator to latitude 70°S, dating from 1977, is statistically unreliable (IWC 1988). The historical abundance estimates for the entire Southern Hemisphere for the year 1946 is 547,600 (no CV) sperm whales (Gosho et al. 1984). Both estimates are statistically unreliable due to their use of historical whaling catch and catch per unit effort data from whaling operations. Sperm whale catches from the early 19th century through the early 20th century were calculated on barrels of oil produced per whale rather than the actual number of whales caught. Hence, extrapolation from these types of data has led to only rough estimates of the number of whales killed per year (Gosho et al. 1984).

Off Western Australia (Albany), an aerial survey was done in 2009 that replicated surveys used by spotter planes for the purposes of hunting sperm whales from 1968 to 1978. The number of male sperm whales observed in 2009 was 2.43 (95% C.I. = 0.96, 6.08). This increased to 3.38 (95% C.I. = 1.30, 7.60) whales when sightings off transect were included. The 2009 sightings were lower than the mean of any of the years between 1968 and 1978, which ranged from 6.30 (±1.18) in 1976 to 12.45 (±1.83) in 1968 (Carroll et al. 2014). Albeit, the 2009 confidence intervals overlap with the standard error estimates from the earlier data, which makes it difficult to interpret whether a true population decline occurred or simply fewer males are seen in an area where they were once abundant (Carroll et al. 2014).

2.3.1.3 Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding, etc.):

Since the last 5-year review, technology continues to advance the ability to distinguish slight variations in the genetic characteristics of sperm whale populations, which allows for scientists to draw more accurate conclusions about population structure. Single-nucleotide polymorphisms are reproducible across technologies and laboratories, ideal for long-term studies of globally distributed species such as sperm whales, and able to detect population structure even when differentiation within the population is low (Mesnick et al. 2011).

Genetic research has focused on social structure as it may play a key role in structuring populations. Sperm whale population structure is largely driven by female site fidelity and male-mediated gene flow. Females and juveniles form stable social "units" that generally stay within home ranges of approximately 2,200 km in any direction (Whitehead et al. 2008), and the breeding males rove among female groups (Christal and Whitehead 2001; Whitehead 2003). Males are thought to move over vast distances within and between ocean basins, as evidenced by the lack of heterogeneity in nuclear microsatellite markers (Lyrholm et al. 1999). There is no known genetic evidence of a strictly or largely matrilineal unit or group of sperm whales. Rather, genetic studies suggest that groups of female and immature sperm whales generally contain more than one matriline, as indicated by the presence of multiple mtDNA haplotypes. Both "groups" and "units" contain clusters of closely related animals, but some individuals have no close relations (Richard et al. 1996; Bond 1999; Lyrholm et al. 1999; Mesnick 2001; Mesnick et al. 2003; Engelhaupt 2004). Although multiple mtDNA haplotypes are found in groups and units, sperm whales exhibit relatively low mtDNA diversity compared to other globally distributed and large cetacean populations (Alexander et al. 2012). The low diversity may be a result of a population bottleneck during the glaciation period of the Pleistocene or by neutral mtDNA alleles that are transmitted culturally through the matrilineal line (Alexander et al. 2012).

Engelhaupt et al. (2009) studied population structure comparing mtDNA and nuclear markers from sperm whales in the Gulf of Mexico, Mediterranean Sea, North Sea, and western North Atlantic Ocean. Based on nuclear deoxyribonucleic acid (nDNA), the Mediterranean Sea population was significantly differentiated, but at a low level, from the Gulf of Mexico, North Sea, and western North Atlantic Ocean. Based on mtDNA markers, the Mediterranean Sea population showed no haplotype diversity within the basin, but significant differentiation occurred between all sampled regions (Gulf of Mexico, Mediterranean Sea, North Sea, and western North Atlantic Ocean). The possibility of a genetically isolated Mediterranean population is further supported by studies examining movement based on photo-identification. Female sperm whales were shown to exhibit high site fidelity within the Mediterranean Sea, and it is hypothesized that there is little to no movement of female sperm whales between the east and west basins of the Mediterranean through the Strait of Sicily or the Strait of Messina (Frantzis et al. 2011). Male sperm whales were shown to move throughout the whole western Mediterranean basin but did not move between the Atlantic Ocean and Mediterranean Sea (Carpinelli et al. 2014). Within the Gulf of Mexico, significant matrilineal differentiation occurred even for populations within close geographic proximity (Engelhaupt et al. 2009). Differentiation also occurred between populations within close proximity in the western North Atlantic; yet no differentiation was found between populations at the opposite ends of the ocean basin. Females are likely philopatric to the Gulf of Mexico and Mediterranean basins (Engelhaupt et al. 2009).

Microsatellite loci were also used to study the population structure of sperm whales along the Azores archipelago in the North Atlantic (Pinela et al. 2009). Results indicated individuals who visit the Azores represent a single population, which is part of the larger North Atlantic population. The study also determined social structure similar to that of the Caribbean and Galapagos; primary units and secondary social groups are mostly composed of familial members. Additionally, there were high levels of genetic variability indicating a lack of inbreeding within the population (Pinela et al. 2009). Increasing the sample size and including long-term photo identification would allow for a more detailed picture of the population structure of sperm whales in the North Atlantic.

Mesnick et al. (2011) compared genetic diversity among three North Pacific populations (California Current, Hawaii, eastern tropical Pacific) to investigate population structure in the region. They also compared males from sub-Arctic foraging grounds (Gulf of Alaska and Aleutians) to the populations in the California Current, Hawaii, and eastern tropical Pacific in an attempt to assign the males to one of the three regions. Low but significant differentiation was found for both mtDNA and nDNA in animals from the California Current and those from waters to the south and west to Hawaii, indicating population structure occurs in the eastern Pacific Ocean. The differentiation in nDNA indicates some males may return to their natal origin to breed. Further, males from the Alaskan foraging grounds were found to not originate solely from any one of the lower latitude regions, suggesting males from different populations return, post-breeding, to common feeding grounds off Alaska (Mesnick et al. 2011). Stable isotope analysis of sperm whales from the California Current indicated the whales were feeding throughout the California Current, which may support that a resident population occurs in the area (Ruiz-Colley et al. 2014).

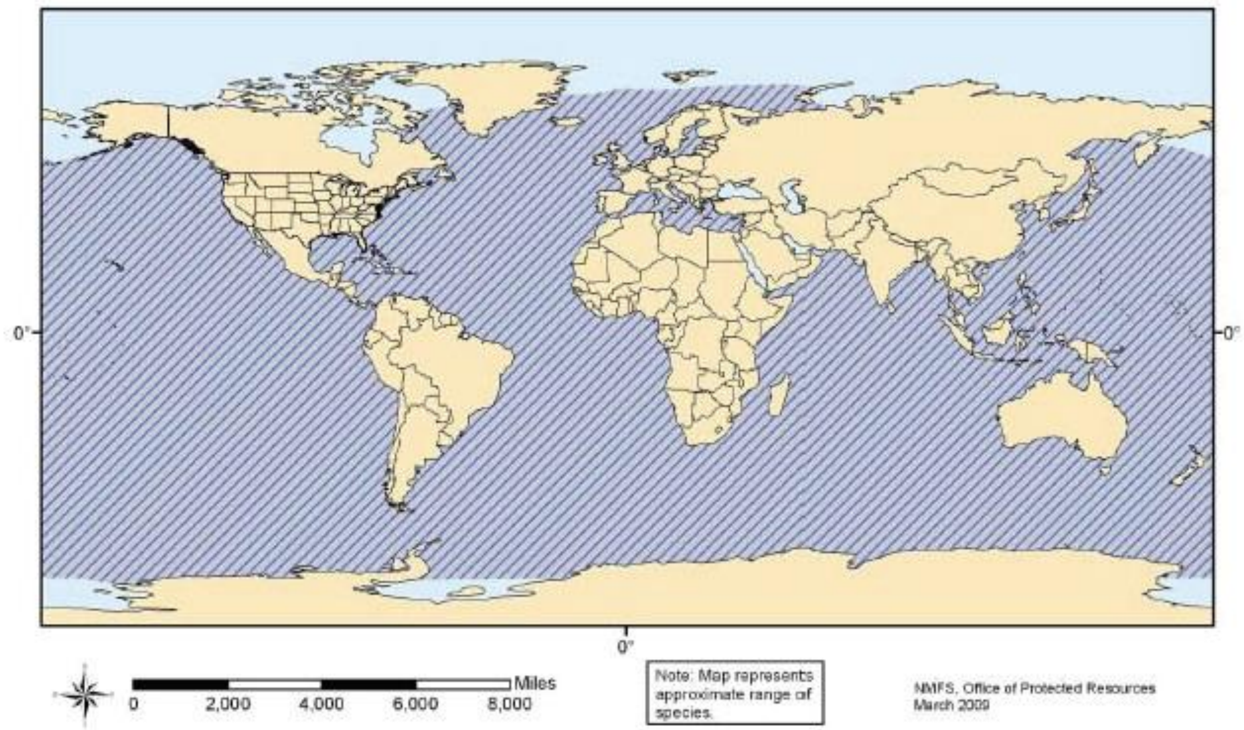
2.3.1.4 Taxonomic classification or changes in nomenclature:

While there is scientific consensus that only one species of sperm whale exists, debate has been ongoing as to which of the two Linnaean species epithets for the sperm whale, *catodon* or *macrocephalus*, is the correct name and should be used. The sperm whale was categorized first by Linnaeus in 1758, recognizing four species in the genus *Physeter*. Husson and Holthuis (1974) showed that the correct name should be *P. macrocephalus*, the second name in the genus Physeter published by Linnaeus concurrently with *P. catodon*. Grounds for this proposal were that the names were synonyms published simultaneously and therefore the International Code of Zoological Nomenclature (ICZN) principle of "First Reviser" should apply, in this instance leading to the choice of *P. macrocephalus* over *P. catodon*, a view re-stated by Holthuis (1987) and Rice (1989). This has been adopted by most subsequent authors. However Schevill (1986, 1987) argued against this and upheld the name *catodon*, stating that *macrocephalus* lacked accuracy when it was described, therefore rendering the principle of "First Reviser" inapplicable. However Linnaeus described *macrocephalus* as attaining a length of 60 feet, and having spermaceti in the head, a description that can apply to no other species of whale. Currently, most authors have accepted *P. macrocephalus* as the correct name.

Examining molecular phylogenies, Milinkovitch et al. (1993, 1994, 1995) and Milinkovitch (1995) argued that sperm whales are actually more closely related to baleen whales than to other toothed whales, leading to the conclusion that odontocetes 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).

2.3.1.5 Spatial distribution, trends in spatial distribution (e.g. increasingly fragmented, increased numbers of corridors, etc.), or historic range (e.g. corrections to the historical range, change in distribution of the species' within its historic range, etc.):

Sperm whale distribution is global (Figure 1) and 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."



Note: Map represents approximate range of species.

NMFS, Office of Protected Resources
March 2009

Figure 1. Global range of the sperm whale.

Mostly adult males move into high latitudes, while all age classes and both sexes range throughout tropical and temperate seas. Male sperm whales are widely dispersed along the Antarctic ice edge from December to March (austral summer) (Gosho et al. 1984). Sperm whale calls have been detected year-round in the Gulf of Alaska (Mellinger et al. 2004). Females and immature whales have been found in the central Aleutian Islands in the winter; however, in the past 10 years no groups of females or immatures have been observed in this location in the summer (Fearnbach et al. 2012). Commercial whaling data show extensive movements of both males and females from U.S. and Canadian coastal waters into the Aleutian Islands and Gulf of Alaska, and for males into and within the Bering Sea and along the Bering Sea shelf edge (Kasuya and Miyashita 1988, Mizroch and Rice 2013). Only male sperm whales are seen off Kaikoura in New Zealand at lat. 42°S (Jaquet et al. 2000; Sagnol 2014). Commercial whaling data also show that females may be more tolerant of colder temperatures than previously thought. Mizroch and Rice (2013) analyzed commercial whaling catch data and multiple observations of individually marked whales from the North Pacific Ocean from 1949 though 1972, which indicated females were found in areas where sea surface temperatures were colder than 15°C. From 1951 through 1967, 700 females were landed at the Coal Harbour whaling station (about 48ºN to 51ºN), most of which were caught in April and May when sea surface temperatures had ranged between 8°C and 10°C (Mizroch and Rice 2013). In the Atlantic Ocean, mixed groups of females and immature whales have a southern limit in the South Atlantic of latitude 50-54°S (Gosho *et al.* 1984; Tynan 1998). Female movements are likely in response to changes in prey distribution and abundance (Whitehead 2003; Mizroch and Rice 2013).

Intensive whaling may have fragmented the world population of sperm whales. While present-day concentration areas generally match those of the 18th and 19th centuries, at least one large area of the South Pacific (the "Offshore" and "On the Line" whaling grounds between the 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).

2.3.1.6 Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem):

Mature female and immature sperm whales of both sexes are found in more temperate and tropical waters from the equator to around 45°N throughout the year. These groups of adult females and immature sperm whales are rarely found at latitudes higher than 50°N and 50°S (Rice 1989; Reeves and Whitehead 1997). Sexually mature males join these groups throughout the winter. During summer, mature male and some female sperm whales are thought to move north into the Aleutian Islands and Gulf of Alaska, and males also into the Bering Sea. Based mostly on sighting surveys or land station whaling data, sperm whales 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; Gannier 2000; Gregr and Trites 2001; Waring et al. 2001). Sperm whales show a strong preference for deep waters (Rice 1989), especially in areas with high sea floor relief. A vessel survey south of the eastern Aleutian Islands 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). In the southern Pacific Ocean, Kaikoura Canyon, New Zealand, is an important foraging site for male sperm whales (Sagnol 2014).

In waters along the U.S. east coast, the overall distribution is centered along the shelf break and over the continental slope in depths of 50-1,000 fathoms (~90-1,830 m) (Waring et al. 2005). Very high sperm whale densities occur in inner slope waters north of Cape Hatteras, North Carolina seaward of the 1,000 m isobath during summer months (Mullin and Fulling 2003; Southeast Fisheries Science Center unpublished data; Waring et al. 2005). Sperm whales are also known to move onto the continental shelf in waters less than 100 m deep on the southern Scotian Shelf and south of New England, particularly between late spring and autumn (Whitehead et al. 1992a,b; Waring et al. 1997; Tran et al. 2014). The seamount chain off New England is an important spring foraging area for sperm whales. The Gulf Stream meanders and eddies around the seamounts providing rich productivity, including high abundance of cephalopods, which is a primary food source for the sperm whale (Wong and Whitehead 2014).

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 1,000 m isobath (Mullin et al. 1991; Davis et al. 1998; 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). There has been extensive work on the movements and habitat use of sperm whales in the northern Gulf of Mexico by the

Sperm Whale Seismic Study. These studies included habitat cruises, physical oceanographic analysis, and long term satellite tag deployments. A number of sperm whales were satellite-tagged and several tags were in operation for over 12 months. Results indicated movements generally along the shelf break (700-1,000 m depth) throughout the Gulf of Mexico, with some individuals using water depths greater than the shelf break. Of 52 tagged animals, one male left the Gulf of Mexico but subsequently returned. These studies provided detailed information on the habitat preferences and population structure of Gulf of Mexico sperm whales (Jochens and Biggs 2004; Jochens et al. 2008).

In the Mediterranean Sea, sperm whales have been observed over deep canyons, including the Cuma in the Tyrrhenian Sea (Mussi et al. 2014), Pelagos Sanctuary off the coast of France and Italy (Fiori et al. 2014), and the Hellenic Trench (Frantzis et al. 2014). The Cuma submarine canyon topography allows for upwelling of waters rich in primary productivity and supports a high concentration of sperm whales in the area (Mussi et al. 2014). Within the Pelagos Sanctuary in summer the ‘Liguria-Provencal-Catalan’ sea current creates thermal fronts along the continental shelf. High primary production occurs along these fronts over submarine canyons and seamounts, which represents key feeding areas for sperm whales (Fiori et al. 2014). The Hellenic Trench, which runs parallel to the western, southern and south-eastern coasts and islands of Greece is a core habitat area for the sperm whale (Frantzis et al. 2014). Sperm whales were observed all along the 1,000 m contour of the Hellenic Trench, and their presence dropped rapidly in shallow waters and deeper waters further offshore of the Hellenic Trench. Although most surveys were conducted in during the summer, sperm whales were present year round along the Hellenic Trench (Frantzis et al. 2014).

2.3.1.7 Other:

No additional information is available.

2.3.2 Five-Factor Analysis (threats, conservation measures, and regulatory mechanisms)

The following is an analysis of the five factors cited in section 4(a)(1) of the ESA that can cause a species to be endangered or threatened (see below). In considering whether a species reclassification or delisting is warranted, we look at each factor singularly and in aggregate and whether these factors contribute to the extinction risk of the species. Subsequent 5-year reviews completed in accordance with section 4(c)(2) of the ESA must also make determinations about the listing status based, in part, on these same factors.

2.3.2.1 Present or threatened destruction, modification or curtailment of its habitat or range:

Climate Change
The effects of climate and oceanographic change on sperm whales are uncertain, but they have the potential to greatly affect habitat and food availability. Evidence suggests that the productivity in the North Pacific Ocean (Quinn and Neibauer 1995; Mackas et al. 1998; Gregg et al. 2003; Doney et al. 2012) and other oceans is affected by changes in the environment. Increases in global temperatures are expected to have profound impacts on arctic and sub-arctic

ecosystems and these impacts are projected to accelerate during this century. Increases in sea surface temperatures from the Pacific equatorial waters affect sperm whale feeding success and, in turn, calf production rates are negatively affected (Smith and Whitehead 1993; Whitehead 1997). In the California Current System off the U.S. Pacific west coast, nitrogen and carbon isotope values in sperm whales changed from 1993 to 2005, which may indicate a recently progressive shift in primary producer dynamics, likely associated with changes in sea surface temperatures, average state of surface nutrients and/or primary production (Ruiz-Cooley et al. 2014). This could mean that global warming will reduce the productivity of at least some sperm whale populations (Whitehead 1997). Squid, being the primary prey of sperm whales, may be negatively impacted by rising ocean temperatures, especially in the Antarctic. Krill quantities are predicted to decrease and, as the primary prey of squid, this may have implications for squid populations. However, squid are opportunistic feeders, and they may be able to adapt to changes in krill abundance by feeding on a variety of organisms (Rodhouse 2013). Sperm whale strandings have been associated with higher temperatures, possibly due to prey moving further inshore, which may become more frequent as sea temperatures rise (Pierce et al. 2007). Any changes in these factors could lower habitat quality with possible long-term impacts to sperm whales or render currently used habitat areas unsuitable. Habitat is expected to be altered. As sea ice melts, areas will open to shipping lanes and increase the risk of vessel interactions with sperm whales (Alter et al. 2010). Further study is necessary to evaluate and understand the effects of changes to oceanographic conditions due to climate change on sperm whales and marine mammals in general. However, it is worth noting that the feeding range of sperm whales is likely the greatest of any species on earth, and, consequently, it’s likely that sperm whales will be more resilient to climate change than species with a narrow range of habitat preferences (MacLeod 2009).

Anthropogenic Noise

Humans have introduced sound intentionally and unintentionally into the marine environment for many purposes including oil exploration, 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 source level and on various other factors. Marine mammal 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 disrupt marine mammal communication, navigational ability, and social behavior. Marine mammals use sound, both passively (i.e., listening) and actively (i.e., sound generation), to communicate, navigate, locate prey, and sense their environment. Both anthropogenic and natural sounds may cause interference with these functions.

Effects of various anthropogenic sonar sources on sperm whales have not been studied extensively and remain uncertain, although sperm whales are potentially disturbed by sonar. Since the last 5-year review, studies of the potential impacts of sonar on sperm whales have been conducted. One, study by Sivle et al. (2012) compared diving behavior before and after sonar exposure (LFAS: Low Frequency Active Sonar, MFAS: Mid Frequency Active Sonar and silent exposure). During LFAS exposure (1-2 kHz), sperm whales continued to dive deep, but not to the normal depths and their vocal activity diminished, indicating the whales were not foraging. During MFAS exposure (6-7 kHz), whales retained their normal diving and foraging activity. Another study investigated the severity of behavior changes in sperm whales when exposed to naval sonar and found that sperm whales reacted most during LFAS, supporting previous studies (Miller et al. 2012). Whales exposed to sonar that rapidly change their dive behavior may not be able to manage nitrogen loads during the dive and are physiologically impaired when gas-bubbles form in the blood and tissue (decompression sickness) (Hooker et al. 2009, 2011). Although whales are adapted to diving, they still must manage nitrogen saturation as a trade-off to maximizing forage success, oxygen deprivation, predator avoidance, and other biological constraints such as thermoregulation. When exposed to an unanticipated threat, whether manmade or natural, the animal may forego nitrogen management, which increases the risk of decompression sickness (Hooker et al. 2011). Sperm whales exposed to LFAS and MFAS continued deep dives but the dives were shallower, which increased their risk of decompression sickness although the risk was within the normal range for sperm whales (Kvadsheim et al 2012). However, necropsies conducted on fresh stranded cetaceans found higher than normal concentrations of gas bubbles in the tissue of deep-diving whales, including sperm whales, compared to shallow divers (Bernaldo de Quirós et al. 2012). The possible effects of sonar activity on sperm whales need further research (Hooker et al. 2009, 2011; Kvadsheim et al 2012; Miller et al. 2012; Sivle et al. 2012).

The waters of the northern Gulf of Mexico have been increasingly subject to extensive seismic airgun sounds in the search for hydrocarbon deposits. To determine airgun impacts to sperm whales, visual tracking, passive acoustic monitoring, and movement recording tags were used to quantify behavior prior to, during, and following exposure to airgun arrays at received levels in the range 140–160dB at distances of 7–13km, following a phase-in of sound intensity and full array exposures at 1–13 km (Miller et al. 2009). Sperm whales did not exhibit avoidance behavior at the surface. However, foraging behavior may have been affected. The sperm whales exhibited 19% less vocal (buzz) rate during full exposure relative to post exposure, and one whale closest to the exposed airgun began to forage post-exposure. These data raise concerns that seismic surveys may impact foraging behavior in sperm whales, but more data are required to understand whether the differences were due to exposure or natural variation in sperm whale behavior (Miller et al. 2009).

Sperm whales are likely sensitive to aircraft. Several authors have reported that sperm whales did not react to fixed-wing aircraft or helicopters in some circumstances (Au and Perryman 1982; Green et al. 1992) and reacted in others (Würsig et al. 1998; Richter et al. 2003, 2006; Smultea et al. 2008). For example, Smultea et al. (2008) recorded reactions of sperm whales to the noise from fixed-wing aircraft off Kauai, Hawaii. Of the eight groups of whales under observation, three groups reacted by diving abruptly. One group (n=11), which included a calf, gathered in a defensive formation, minimizing exposure of their flanks and the calf to the perceived danger. The prolonged or consistent exposure to aircraft may have negative implications in areas of breeding, foraging, or in areas that function as a nursery.

Surface shipping is the most widespread source of anthropogenic, low frequency (0 to 1,000 Hz) noise in the oceans (Simmonds and Hutchinson 1996). The National Resource 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 Ocean (Andrew et al. 2002; McDonald et al. 2006, 2008) and at least 3.3 dB per decade between 1950 and 2007, which was attributed to commercial shipping as a result of global economic growth (Frisk 2012). Michel et al. (2001) suggested an association between long-term exposure to low frequency sounds from shipping and an increased incidence of marine mammal mortalities caused by collisions with ships. Prop-driven vessels also generate high frequency noise through cavitation, which accounts for approximately 85% or more of the noise emitted by a large vessel. Preliminary data from the Mediterranean Sea suggest that the sperm whales might be avoiding areas where shipping noise is at high levels (André et al. 2013).

Fishery Interaction

Since the last status review, more studies have been conducted to examine the phenomenon known as "depredation" when sperm whales remove fish from longline gear. Investigations were conducted to document rates of depredation, understand how sperm whales manage to find vessels and remove fish from the gear, quantify the amount of prey removed, and record the frequency of resulting mortality or serious injury due to entanglement. In some locations, the percentage of fish damaged by depredation can be 100%, significantly impacting fisheries quotas (Hernandez-Milian et al. 2008). Depredation behavior may also be transmitted socially between individuals (Schakner et al. 2014). There are many negative outcomes to depredation such as injury or entanglement of the whales, in addition to the negative impacts on the fisheries (Hamer et al. 2012).

In Alaskan and Icelandic waters, sperm whales are known to remove sablefish (*Anoplopoma fimbria*) (Thode et al. 2007, 2014; Straley et al. 2014) and Greenland halibut (*Reinhardtius hippoglossoides*) from longlines (Peterson and Carothers 2013). In the southern hemisphere, sperm whales impact the Patagonian toothfish (*Dissostichus eleginoides*) fisheries off the coast of Chile, South Georgia, Falkland Islands, Prince Edward Islands and Crozet and Kerguelen Islands (Clark and Agnew 2010; Goetz et al. 2010; Tixier et al. 2010). Combined losses from sperm and killer whale (*Orcinus orca*) depredation of Patagonian toothfish in the Crozet EEZ were calculated to be 571 tonnes between 2003 and 2008 (Tixier et al. 2010). From 2003 through 2009, fisheries operating off South Georgia had approximately 18% of their sets depredated by sperm whales (Clark and Agnew 2010). However, sperm whales were depredating fish (25kg-150kg) well below their daily energetic needs (400 -500kg), indicating the depredation was only supplementing their normal foraging activities. Additionally, Clarke and Agnew (2010) found a link between catch-per-unit-effort (CPUE) and sperm whale presence: CPUE was higher in the presence of sperm whales, suggesting that the whales are drawn towards areas of high catch rates. Sperm whale sightings increased during retrieval of the gear and their presence was positively correlated with fish depredation on Spanish vessels targeting Patagonia toothfish in the southwest Atlantic Ocean between 2007 and 2008 (Goetz et al. 2010). The overall depredation rate was low (0.44% of the total catch), but may have been underestimated because sperm whales were suspected of also taking fish without leaving visual evidence (Goetz et al. 2010).

Since the last 5-year review, several studies have looked at gear and/or fishing practices to reduce depredation. A new fishing technique was developed for the Chilean Patagonian toothfish fishery as a way to prevent depredation by sperm and killer whales and to reduce seabird bycatch (Moreno et al. 2008). The system consists of a buoyant net sleeve that is attached to secondary vertical hook lines that allows the sleeve to slide along the line. During haulback of the main line, the sleeve slides down the vertical line and covers the hooks as they are brought to the surface. With the use of sleeves, depredation dropped from a maximum of 5% in 2002 to a maximum of 0.36% in 2006. In addition to decreasing depredation, observers noted that after about a week of unsuccessful attempts to remove fish from the lines, the whales left the fishing grounds (Moreno et al. 2008). Goetz et al. (2010) tested a similar sleeve design in the Patagonian toothfish fishery operating off Argentina and found it effective at reducing sperm whale depredation, but it also reduced overall catches of the fish. Thode et al. (2007) investigated what may attract sperm whales to a fishing vessel, including the hydraulic system, fishing gear strum, echosounders, visual cues (e.g., birds), and propeller noise. The study consisted first of passive observation of reactions by sperm whales and then by hypothesis testing which determined that engaging and disengaging the propeller caused the greatest reaction by the sperm whales. The identification of acoustic cues that attract sperm whales can then be used to develop long-term strategies to reduce depredation, such as the production of "false-cues" or methods to reduce the detection range of the stimuli.

Incidental capture in fishing gear, such as gillnets and bottom-set longline gear, continues to be a threat to sperm whale populations, although the degree of threat is considered low. Sperm whales have been found as bycatch in pelagic drift gillnets targeting swordfish and tuna in U.S. east-coast waters (Waring et al. 1997), and in artisanal gillnets targeting sharks and large pelagic fishes off the Pacific coasts of northwestern South America, Central America, and Mexico (Palacios and Gerrodette 1996). From 2008 to 2012, six sperm whales were reported stranded along the U.S. Pacific Coast due to human-related activities (Carretta et al. 2014). Causes of the strandings were marine debris ingestion (two dead), vessel strike (one dead), gillnet entanglement (unknown source; one dead), California thresher shark/swordfish gillnet fishery (>14 inch mesh) entanglement (one dead and one with serious injury released with gear and was observed on its side and breathing abnormally) (Carretta et al. 2014). Between 1990 and 2012, ten sperm whales were found tangled in fishing nets within the California swordfish and thresher shark gillnet fishery, half of which were discovered deceased (Carretta 2013). No estimates of mortality are available for the Mexican drift gillnet fisheries.

In the Mediterranean Sea, significant sperm whale mortality has resulted from interactions with the high seas swordfish and tuna driftnet fishery since the 1980s when the fishery became a large scale commercial operation (Reeves and Notarbartolo di Sciara 2006; reviewed by Notarbartolo di Sciara 2014). In 2003, five sperm whales (two adult females and three juveniles) were found entangled in a driftnet in the southern Tyrrhenian Sea (Italy; Pace et al. 2008). All whales were freed successfully, however driftnets continue to be a concern in Italy, where they are illegal but continue to be used (Pace et al. 2008). Between 1971 and 2004, 229 sperm whales were found dead or entangled, most of which occurred in driftnets (reviewed by Notarbartolo di Sciara 2014). The historical interaction with driftnets is still impacting the sperm whale population today. Surveys conducted from 2002 to 2012 in the Tyrrhenian Sea, did not observe any large mature males (Pace et al. 2014). In 2002, pelagic driftnets were banned in the Mediterranean Sea, which has resulted in a decrease in entanglements of sperm whales in recent years. However, many countries (e.g. Algeria, Italy, Morocco, and Turkey) continue to fish illegally with pelagic driftnets; thus, entanglement in this gear continues to be a threat to sperm whales (reviewed by Notarbartolo di Sciara 2014).

Data on fisheries entanglements include the Peruvian coast where between 1995 and 2012, three sperm whales were discovered entangled in fishing gear (Garcia-Godos et al. 2013). In the Northwest Atlantic, a total of 9 sperm whales were entangled in fishing gear from 1970-2009 (Van der Hoop et al. 2012).

Fishery-caused reductions in prey resources could also have an influence on sperm whale abundance and pose a threat to the species. Other cetaceans eat the prey species taken by sperm whales. Thus, competitive interactions are possible, but it is unknown what, if any, effect competition for food among these cetacean species is a factor in determining sperm whale population trends and abundance (NMFS 2010a). The effect commercial fisheries may have on sperm whales by removal of large aggregations of the sperm whale's prey species is not well known. The effect may be limited if a large biomass of sperm whale prey remains unharvested and accessible. Furthermore, commercial harvest may result in smaller, multiple aggregations of prey, which could enhance sperm whale foraging success (NMFS 2010a). Data are lacking on species-specific duration and degree of prey disruption due to commercial harvest, and it is not known what impact switching to alternate prey may have on sperm whales (NMFS 2010a).

Oil Spills and Contaminant

The threat of contaminants and pollutants to sperm whales and their habitat is highly uncertain and further study is necessary to assess the impacts of this threat. Little is known about the possible long-term and trans-generational effects of exposure to pollutants. Marine mammals are considered to be good indicators for concentrations of metal and pollutant accumulation in the environment due to their long life span and (in some cases) position near the top of marine food webs (Savery et al. 2014a).

Global baseline data on several metal contaminants were collected from apparently healthy free-ranging sperm whales during cruises aboard the research vessel *Odyssey* conducted between 1999 and 2005 (Wise et al. 2009, 2011a,b; Savery et al 2013a, b, 2014b). Metals analyzed included barium, strontium, titanium, gold, silver, lead, chromium, mercury, selenium, and arsenic (Table 1). The following discussion provides more detail on these metals.

Barium, strontium, titanium, and gold generally have low toxicity levels in the marine environment, but increasingly are being used in industry products (e.g., sunscreens, household cleaners, catalytic convertors) as a result of nanotechnology (Wise et al. 2011a). The use of nanoparticles in consumer products has increased since 2005. Metals that are manipulated on a quantum scale change properties, which may alter their toxicity levels in the marine environment. Barium, strontium, titanium, and gold contaminant burdens did not increase with size or age of the sperm whale. Overall, Wise et al. (2011a) found that barium, strontium, titanium, and gold levels were generally low in sperm whales; however, sperm whales are exposed to these four metals even in remote areas. This study provides information that pre-dates some recent nanoparticle industries and is a source of global baseline for these metals. Additional studies are needed to understand the toxicity to whales that nanosized metals present and how these metals are transported through the environment to reach remote ocean regions (Wise et al. 2011a).

Silver is another pollutant that is increasingly used in nanotechnology and is of concern in marine waters due to its chemistry, toxicity, and bioavailability (Savery et al. 2013b). Sperm whales are likely exposed to silver through consumption of prey and swallowing sea water. Silver is a potent inhibitor of selenium, which is an essential element that functions as an antioxidant in cells. Thus, in areas with elevated silver levels, sperm whales may become more sensitive to the toxicity of other chemicals or diseases. Although silver levels in sperm whale skin samples were generally low, several regions in the Pacific Ocean, Australia, Mauritius, Seychelles, Sri Lanka and Papua New Guinea had high concentrations of silver. One whale in the waters near Seychelles had the highest (4,179 µg/g ww) silver concentration sampled (Savery et al. 2013b). Although silver bioaccumulation has been found in pilot and beluga whales, Savery et al. (2013b) did not find a difference in silver concentrations in larger and older males. However, the apparent lack of accumulation may be a consequence of not being able to age the whales more accurately or small sample sizes per region. Silver concentrations may be increasing in the Pacific Ocean; however, more research is needed to assess whether the increase in concentrations is localized or wide-spread (Savery et al. 2013b) and to understand levels at which negative reproductive or physiological consequences are experienced.

Lead is prevalent in the environment and more than 90% of its presence is a result of anthropogenic activities, including the mining and smelting of ore (Mao et al. 2009 as cited in Savery et al. 2014b). Lead has a high potential for bioaccumulation and serious health consequences. Sperm whales are likely exposed to lead through consumption of prey, swallowing water, or accidental consumption of sediment during bottom feeding (Savery et al. 2014b). Lead concentrations in sperm whale skin were high in Papua New Guinea, the Bahamas, Australia, and several areas in the Sea of Cortez. A whale in waters adjacent to Papua New Guinea had a lead concentration of 129.6 ug/g ww. Sources of the elevated lead concentrations around Papua New Guinea may be from mining operations (Savery et al. 2014b).

Chromium is released into the marine environment by both natural (primarily continental dust) and anthropogenic sources, including industrial, commercial and residential fuel combustion, emissions from metal industries, and wastewaters from industries such as electroplating operations, leather tanning industries, and textile manufacturing (US Department of Health, 1993 as cited in Wise et al. 2009). Hexavalent chromium (Cr(VI)) is the predominant form of chromium found in marine waters and can have residence times up to18 years (Wise et al. 2009). However, CR(VI) degrades rapidly to trivalent chromium in marine organisms. Thus, studies typically measure total chromium levels in marine organisms. Overall, Wise et al. (2009) found high levels of chromium in sperm whales, but the consequence of such high levels is not known. The toxicity of CR(VI) in whales is also not well understood but has been shown to damage/kill (cytotoxic) or cause genetic mutation (genotoxic) in human cells resulting in cancer (Wise et al. 2011b). It is notable that Wise et al. (2009) found chromium levels in sperm whales to be similar to levels reported for lung tissue from human workers with Cr(VI)-induced lung cancer. Wise et al. (2011b) exposed fibroblasts skin cells from sperm whales to CR(VI) in controlled experiments and found it to be both cytotoxic and genotoxic. These results coupled with high levels of chromium found in free ranging sperm whales support the possibility that chromium exposure results in health risks to sperm whales (Wise et al. 2011b).

Mercury is of high concern due to its toxicity, stability in the atmosphere (enabling global mobility and deposition), and ability to bioaccumulate throughout food webs (Savery et al. 2013a). Mercury is released to the atmosphere from natural and anthropogenic sources (primarily from combustion of fossil fuels) (Pacyna et al. 2006). Of the populations studied, sperm whales from the Mediterranean Sea had the highest concentration of mercury. The Mediterranean Sea is thought to have high mercury levels due to geological, biochemical, and or ecological processes in the area (Savery et al. 2013a). Selenium, an essential element in marine mammal tissue, binds with mercury and may have a protective effect against mercury's toxicity. Selenium concentrations in sperm whales in this area were much higher than mercury suggesting that mercury is being detoxified in the skin tissue by some other element (Savery et al. 2013a).

Arsenic is among the top 10 most hazardous substances in the environment based on toxicity and potential of exposure from air, water, and soil (Savery et al. 2014a). It occurs naturally in the earth's crust and is also introduced through anthropogenic sources such as emissions from smelters or coal-fired power plants. By ocean basin, the highest mean arsenic concentration was found in sperm whales in the Indian Ocean particularly from the Seychelles, Maldives, and Sri Lanka. Overall, the global mean arsenic concentration for females was significantly lower than males possibly due to the female's ability to pass arsenic loads to their offspring during birth and lactation, as well as differences in hormone metabolism. Differences in mean arsenic concentration between sexes may also be a result from males eating larger prey and foraging deeper waters and coming in contact more frequently with the ocean benthos (Savery et al. 2014a). The mean arsenic concentrations in sperm whales from this study were three-fold greater than concentrations found in other toothed whales. However, the arsenic found in sperm whales in this study was thought to be the nontoxic form, arsenobetaine (Savery et al. 2014a).

Table 1. Global baseline data on metal contaminants gathered from sperm whales during a research cruise conducted between 1999 and 2005.

Metal	**Global Mean**	**Global Mean High Region**	**Global Mean Low Region**	**Global Mean by Gender & Significance**	**Age and Size Significance**	**Citation**
Barium	0.93 +/- 0.2 μg g^{-1}; range 0.1 to 27.9 μg g^{-1} (n = 275)	Maldives, Indian Ocean (1.64 +/- 0.81 μg g^{-1})	Canary Islands, Atlantic Ocean (0.20 +/- 0.02 μg g^{-1}).	Significant Female (1.1 +/-0.23 μg g^{-1}) Males (0.6 ± 0.1 μg g^{-1}).	Not significant	Wise et al. 2011a
Strontium	2.2 +/- 0.1 μg g^{-1}; range 0.2 to 11.5ug/g (n = 298).	Galapagos, Pacific Ocean (3.82 +/-1.40 μg g^{-1})	Canary Islands, Atlantic Ocean (1.15 +/- 0.08 μg g^{-1}).	Not significant Female (2.2 +/- 0.1 μg g^{-1}) Males (2.3 +/- 0.2 μg g^{-1})	Not significant	Wise et al. 2011a
Titanium	4.5 +/- 0.25 μg g^{-1}; range 0.1 to 29.8 μg g^{-1} (n = 298).	Australia (6.4 +/- 1.2 μg g^{-1});	Indian Ocean (1.68 +/-0.18 μg g^{-1}).	Significant Females 5.4 +/- 0.34 μg g^{-1} Males 3.0 +/- 0.3 μg g^{-1}	Not significant	Wise et al. 2011a
Gold	0.2 +/- 0.02ug/g; range 0.1 to 2.3 μg g^{-1} (n = 50).	Mauritius, Indian Ocean (0.53 +/- 0.13 μg g^{-1})	Canary Islands, Atlantic Ocean and Indian Ocean, where all of the	Not significant Females 0.2 +/- 0.03 μg g^{-1}	Not significant	Wise et al. 2011a

Metal	Global Mean	Global Mean High Region	Global Mean Low Region	Global Mean by Gender & Significance	Age and Size Significance	Citation
			whales sampled had undetectable gold levels	Males 0.2 +/- 0.02 µg g^{-1}		
Silver	16.9 ± 14.1 µg g^{-1} ww; range 0.1 to 4,179.0 9 µg g^{-1} ww (n = 176).	Seychelles, Indian Ocean 123.3+/- 122.99 µg g^{-1} ww	Mediterranean Sea 1.5 µg g^{-1} ww	Not significant Females (3.5+/- 1.7 9 µg g^{-1}ww; range 0.04 to 297.3 µg g^{-1} ww) Males (42.0 +/- 40.2 9 µg g^{-1} ww; range 0.1 to 4,179 9 µg g^{-1}ww)	Not significant	Savery et al. 2013b
Lead	1.6 ± 0.4 µg g^{-1} ww; range 0.1 to 129.6 9 µg g^{-1}ww (n = 337)	Papua New Guinea, Indian Ocean (6.1 ± 5.6 9 µg g^{-1} ww	Mauritius, Indian Ocean (0.3 ± 0.1 9 µg g^{-1}ww	Not significant Females (1.9 ± 0.6 9 µg g^{-1} ww) Males (1.1 ± 0.1 9 µg g^{-1} ww)	Not significant	Savery et al. 2014b
Chromium	8.8 ± 0.9 µg g^{-1}; range 0.9 to 122.6 9 µg g^{-1} (n = 359)	Islands of Kiribati, Pacific Ocean (44.3 ± 14.49 µg g^{-1})	Sri Lanka, Indian Ocean (mean = 3.3 ± 0.4 9 µg g^{-1}).	Not significant Females (9.3 ± 1.2 9 µg g^{-1}) Males (7.9 ± 1.4 9 µg g^{-1})	Not significant	Wise et al. 2009
Mercury	2.5±0.1 µg g^{-1}; range 0.1 to 16.0 µg g^{-1} (n = 343)	Mediterranean Sea (6.1 µg g^{-1})	Indian Ocean (2.1 µg g^{-1}).	Not significant Females (2.4±0.1 µg g^{-1}) Males (2.5±0.2 µg g^{-1})	Not significant	Savery et al. 2013a
Selenium	33.1±1.1 µg g^{-1}; range 2.5 to 179 µg g^{-1} (n = 343)	Pacific Ocean (42.8 µg g^{-1})	Mediterranean Sea (17.7 µg g^{-1})	Not significant Female (2.4±0.1 µg g^{-1}) Males (2.5±0.2 µg g^{-1})	Not significant	Savery et al. 2013a
Arsenic	1.9 µg g^{-1} ww; range 0.1 to 15.6 9 µg g^{-1} ww (n = 342)	Maldives, Indian Ocean (3.5 ± 0.4 9 µg g^{-1} ww)	Canary Islands, Atlantic Ocean (0.8 ± 0.04 9 µg g^{-1})	Significant Females (1.8 ± 0.1 9 µg g^{-1} ww) Males (2.0 ± 0.2 9 µg g^{-1} ww)	Not significant	Savery et al. 2014a

In the Gulf of Mexico, as a result of the Deepwater Horizon oil spill in 2010, over 8 million liters of chemical dispersants were applied at the surface and at the source of the leak without knowledge of the potential short and long-term toxicological impact these dispersants may have on marine organisms (Wise et al. 2014a). To combat the oil spill, two dispersants were applied, Corexit 9500 and Corexit 9527. Wise et al. (2014a) examined the cytotoxicity and genotoxicity of the dispersants at different concentration levels on sperm whale skin cells. Both compounds were cytotoxic to the sperm whale skin cells with possible effects of fibrosis and impaired organ function. Corexit 9527 was also genotoxic to the sperm whale skin cells. Sperm whales occur in the Gulf of Mexico and depending on their proximity to the application of the dispersants, their exposure could have been less than 1% and up to 100% (Wise et al. 2014a). If genotoxicity occurred during essential stages of reproduction or embryogenesis, mortality or developmental abnormalities in the offspring would increase. Given the damaging potential of the dispersants used in response to Deepwater Horizon, monitoring the populations for further long-term health effects is needed (Wise et al. 2014a).

In addition to dispersants, gentoxic metals such as chromium and nickel were present in the oil spilled during the Deepwater Horizon event (Wise et al. 2014b). Chromium and nickel are known carcinogens in humans and damage DNA and bioaccumulate in organisms, resulting in persistent exposures. Sperm whales in the Gulf of Mexico had significantly higher concentrations of nickel and chromium than the global mean average from the global surveys conducted in 1999 through 2005 (discussed above; Wise et al. 2009). The mean global nickel concentration was 2.4 ppm (n = 298; measured as μg g^{-}1 wet weight and expressed as ppm). Whereas, in this study the average nickel concentration in the Gulf of Mexico sperm whales after the Deepwater Horizon was 15.9 ppm, which is 6.6 times higher than the global average (Wise et al. 2014b). Also, resident females and immature males had higher nickel concentrations than the global mean, yet mature males that migrate beyond the Gulf of Mexico to forage in higher latitudes had similar values to the global mean. Chromium levels were also significantly higher in the Gulf of Mexico study compared to the global mean (12.8 ppm versus 9.3 ppm, respectively). Sampling protocols were similar in the global surveys and this study; thus, it is reasonable not to rule out the oil spill as a reason for the higher concentrations in these gentoxic metals in the Gulf of Mexico sperm whales (Wise et al. 2014b).

After the Deepwater Horizon oil spill in the Gulf of Mexico, there was a low number of observed sperm whale mortalities, leading media to report only a “modest” environmental impact (Williams et al. 2011). However, Williams et al. (2011) estimated that the carcass recovery rate for sperm whales was, on average, only 3.4% of the actual mortalities. Assuming only one sperm whale carcass was found and the cause of death was determined to be oil, it could be hypothesized that the best estimate of total mortality (using the 3.4%) was actually 29 sperm whales (Williams et al. 2011). Ackleh et al. (2012) used passive acoustic recordings collected in the Gulf of Mexico in 2007 and compared them to data collected in 2010 after the oil spill to examine the possible impacts the spill may have on sperm whales. Sperm whale abundance and vocalization was higher by a factor of two at a site 25 miles from the spill compared to a site located 9 miles from the spill. Sperm whales likely moved away from the oil spill due to a shortage of non-contaminated food in the area and/or an increase in vessel traffic and anthropogenic noise in response to the spill (Ackleh et al. 2012). The actual number of sperm whales that may have been impacted by the Deepwater Horizon oil spill is unknown, but it can be assumed that the impact was greater than observed.

In the Mediterranean Sea, high concentrations of contaminants such as polychlorinated biphenyls are found (Marsili et al. 2014). In 2009, seven sperm whales stranded along the Adriatic coast of Southern Italy. Necropsies were completed on three and muscle and blubber were collected from the other four for analysis for pollutants. The whales were found to have high levels of organochlorine xenobiotics (immunosupressors) in their blubber and also high levels of polycyclic aromatic hydrocarbons (the most toxic family of hydrocarbons) in their muscle. Biomarkers as indicators of exposure to contaminants were elevated in the liver and skin, indicating that the whales were under significant toxicological stress (Marsili et al. 2014). Although the cause of death for these stranded sperm whales is unknown, the contaminant loads may have lowered their immune system defenses and made them more susceptible to disease (Marsili et al. 2014).

In the Pacific Ocean, baseline data on biomarkers for persistent organic pollutants were collected (Godard-Codding et al. 2011; Fossi et al. 2014). Persistent organic pollutants resulting from activities such as agriculture can have a significantly negative effect on the integrity of the water quality and health of marine organisms. Biomarkers for the organochlorine compounds, polycyclic aromatic hydrocarbons, and planar halogenated aromatic hydrocarbons were collected from free-ranging sperm whales (Godard-Codding et al. 2011). Expression of the biomarkers was highest in whales from the Galapagos Islands, Ecuador, and lowest in whales from the sampling sites farthest away from continents. Differences in age, sex, and diet did not appear to explain regional differences in biomarker expression (Godard-Codding et al. 2011). In the Gulf of California, Sea of Cortez, expression of biomarkers for organochlorine compounds, polybrominated diphenyl ethers, and polycyclic aromatic hydrocarbons was higher in odontocetes (including the sperm whale) compared to mysticetes (Fossi et al. 2014). Several factors likely influence the exposure risk, including position on the food chain, diet, and migratory versus residential nature (Fossi et al. 2014).

In summary, threats to sperm whale habitat remain a concern. Climate change continues to emerge as a possible threat to habitat and food availability, but the degree of impact on sperm whales is uncertain. As sea temperatures rise, prey availability will be altered and sea ice will melt, opening areas to increased vessel traffic and noise. Given its vast feeding range, sperm whales may be more resilient to climate change; however, further study is necessary to evaluate and understand the effects of changes to oceanographic conditions due to climate change on sperm whales. Anthropogenic noise remains a concern, but additional study is needed to fully understand possible injury and behavior changes in exposed sperm whales. Since the last 5-year review, gear modifications in some fisheries have successfully decreased sperm whale depredation and entanglement. In the Mediterranean Sea, significant sperm whale mortality occurred over several decades in the high seas swordfish and tuna driftnet fishery, which is still impacting the sperm whale population today. Contaminants and pollution remain a concern. The Deepwater Horizon oil spill in the Gulf of Mexico may have resulted in elevated health risk in sperm whales in the area; however, monitoring the populations for further long-term health effects is needed.

2.3.2.2 Overutilization for commercial, recreational, scientific, or educational purposes:

Direct Harvest
Members of the IWC reported harvesting a total of 388 sperm whales under reservation or objection to the moratorium from 1986 through 2013; however, the last reported harvest occurred in the 1987/88 Antarctic season (http://iwc.int/table_permit). Although historical whaling activities were responsible for the depletion of sperm whales worldwide, they are now hunted only by Japan and in small numbers for scientific research, and therefore, the threat of overutilization by direct harvest is currently low. However, if the IWC's moratorium on commercial whaling ended, direct harvest could again become a threat to sperm whales. The IWC's moratorium on commercial whaling for sperm whales throughout the North Atlantic and North Pacific has been in place for two decades. There is currently no legal commercial whaling for sperm whales in the Northern Hemisphere. Norway 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. There is no evidence that whaling will resume in the Portuguese islands of the Azores and Madeira, even though Portugal remains outside any regulatory body. Canada has continued to ban whaling for the large baleen whales (except the bowhead, *Balaena mysticetus*) in its territorial waters under domestic regulations, and a resumption of sperm whaling in Canada is unlikely in the near future.

Scientific Research
Moore and Clarke (2002) studied gray whales' responses to research activities and results ranged from no visible responses to short-term behavioral changes. Research on sperm whales is likely to continue and increase in the future, but currently represents a low threat to sperm whales (NMFS 2010a). Japan caught a total of 56 sperm whales from 1986 through 2013 reportedly for the purposes of scientific research under Article VIII of the International Convention for the Regulation of Whaling (http://iwc.int/table_permit). In 2014, the International Court of Justice found that Japan's whale research activities can be broadly characterized as scientific research, but that the evidence did not establish that the program design and implementation are reasonable in relation to achieving stated research objectives. The Court largely took issue with the lack of non-lethal alternatives and justification for sample targets. The Court concluded that the special permits granted by Japan for the killing, taking and treating of whales was not "for purposes of scientific research" pursuant to Article VIII, paragraph 1, of the Convention (International Court of Justice 2014).

In summary, overutilization for commercial and scientific purposes currently is considered a low threat to the sperm whale. If the IWC's moratorium on commercial whaling ended, direct harvest could again become a threat to sperm whales.

2.3.2.3 Disease or predation:

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). There may be diseases that, while they do not result in direct mortality, have the potential to debilitate the whales enough that death may be the ultimate outcome. A live-stranded whale was discovered in Knokke-Heist, Belgium and upon blood testing, was found to have been infected with *Edwardsiella* tarda, a pathogen known to cause sepsis (Cools et al. 2013). Sepsis can cause high fevers, leading to disorientation and compromising echo-navigational abilities, which suggests that the sepsis caused the whale to strand (Cools et al. 2013)

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 stresses.

The potential impact of predation by killer whales on the dynamics of the North Pacific Ocean marine ecosystem has received substantial attention within the scientific community. 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 (NMFS 2010a).

Sperm whales have been observed to be harassed by Risso's dolphins (*Grampus griseus*) where the dolphin performs a head-on charge, resulting in the sperm whale opening its mouth and dropping the lower jaws. Although Smultea et al. (2014) were unable to determine if there were pieces of food in the water, the authors speculate that the apparent interspecific harassment is meant to cause the sperm whale to regurgitate food, allowing the aggressor to eat the regurgitated food. Sperm whales reacted to the harassment by displaying defensive behavior (i.e., herding calves to the middle of the unit and reducing space between individuals). Attacks by other species on sperm whales usually do not result in death (NMFS 2010a).

In summary, available evidence suggests that neither disease nor predation is a major threat to the recovery of sperm whale populations (NMFS 2010a).

2.3.2.4 Inadequacy of existing regulatory mechanisms:

The IWC continues to protect sperm whales from commercial whaling by member states and regulates direct take on a sustainable basis. In U.S. waters, sperm whales are protected under the ESA and the Marine Mammal Protection Act (MMPA). The sperm whale is currently classified as 'vulnerable' on the International Union for Conservation of Nature (IUCN, also known as World Conservation Union) Red List of Threatened Animals, meaning that it is "facing a high risk of extinction in the wild in the medium-term future" (Taylor et al. 2008). The species is also listed in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) that, aside from exceptional circumstances, prohibits the commercial trade of products of sperm whales across international borders of member countries.

Several international instruments have been established to address the impacts of underwater noise (Erbe 2013). In 2008, the European Union created a legislative framework called the Marine Strategy Framework Directive (MSFD), which includes measures to reduce and monitor underwater noise by 2020. The MSFD encompasses four European marine regions – the Baltic

Sea, the North-east Atlantic Ocean, the Mediterranean Sea and the Black Sea. Member states are required to register any impulsive events that “are likely to entail significant impact on marine animals”, in terms of sound exposure levels and peak pressure and to monitor trends in ambient noise in two 1/3 octave bands centered at 63 and 125 Hz. The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) is a legal instrument established in 1992, and its purpose is to protect the marine environment of the North-East Atlantic. Fifteen Governments are parties to OSPAR: Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom. OSPAR addresses both natural and human related impacts to the sea. Under OSPAR Agreements 2014-08ef and 2014-10, monitoring guidance for underwater noise was developed to meet the requirements for reducing and monitoring underwater noise under the MSFD (Dekeling et al. 2014).

The Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area (ACCOBAMS) makes recommendations for vessel speed reduction, propeller maintenance, noise reduction mechanisms and timing of operations to reduce impacts to marine mammals in the region. Recent work includes mapping areas where sperm whales are at high risk of ship strikes and exposure to seismic and sonar activities (ACCOBAMS 2014).

The sperm whale is listed under the Convention on the Conservation of Migratory Species of Wild Animals, also known as the Bonn Convention or CMS. This Convention is an international treaty that focuses on the conservation of migratory species and their habitats. As of May 2014, there are 120 parties to the Convention. In 2008, the Convention adopted Resolution 9.19 on ocean noise impacts, which urges the Parties to assess underwater noise, adopt mitigation measures, develop monitoring guidelines of ambient noise, study noise sources, compile a reference database of noise signatures, characterize sound propagation, study bioacoustic impacts, and investigate the benefits of noise protection areas (Erbe 2013).

In summary, the effectiveness of the IWC moratorium, MMPA, and CITES appear to minimize threats to sperm whales alongside the protections of the ESA. Several international instruments focus on more general threats (e.g., noise) to the environment, and their direct effect on sperm whales is unknown.

2.3.2.5 Other natural or manmade factors affecting its continued existence:

Vessel Interaction[2]

Sperm whales spend long periods (typically up to 10 minutes; Jaquet et al. 1998) “rafting” at the surface between deep dives. When in close proximity to vessels, this makes them vulnerable to ship strikes. Since the last status review, more cases of sperm whale injuries and fatalities due to ship strikes have been documented; however, the number of incidences recorded is still low and level of threat from vessel interactions is also considered low. Ritter (2012) investigated worldwide collisions or near misses between sailing vessels and cetaceans between 1966 and 2010. Of the 168 incidents that were reported, 75% were reported for the period from 2002-

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[2] The sperm whale recovery plan (NMFS 2010a) has ship strikes under Factor D: the inadequacy of existing regulatory mechanisms. However, for the purposes of this review, we analyze it in the broader context of vessel interactions and activities that may not be related to regulatory mechanisms.

2010, suggesting that vessel interactions with cetaceans is increasing. Sperm whales were identified a total of 18 times, of which half collided with a sailing vessel and half were identified as a near miss. This study identified a growing concern of interactions between sailing vessels and sperm whales; much of the focus has been on vessels such as tankers, cargo ships, ferries and whale watching vessels. While most cases of injury to a whale relate to speed (>14 knots) and size (>80m) of vessels, sailing vessels, while smaller, can have serious impacts on whales due to the high speeds that can be reached (>20 knots) (Laist et al. 2011). Off the Northwest Atlantic, from 1970-2009, there were six documented vessel (unspecified class and size) strike mortalities on sperm whales, of 176 total mortalities observed (Van der Hoop et al. 2012). The Canary Islands are considered a hotspot for collisions between marine mammals and ships due to the high ferry traffic. Between 1991 and 2007, 556 cetacean carcasses were found stranded on the coastline or floating dead at sea along the seven Canary Islands (Carrillo and Ritter, 2010; Ritter 2010). Fifty-nine of those animals showed obvious signs of collision with a ship, 24 being sperm whales. Eleven of the sperm whales were determined to be calves. An average of 6.4 cetacean collisions occurred from 1999-2007. However, many animals may sink or float away or collisions may go unreported, therefore the collision rate may be underestimated (Ritter 2010). Maritime vessel traffic (e.g., high-speed ferries, cargo ships) in the Mediterranean Sea, poses a threat to sperm whales. Between 1998 and 2009, 12 acoustic and visual surveys were completed along the Hellenic Trench (eastern Mediterranean) and found that 61% of whales stranded along the coast showed an indication of collision with vessels (Frantzis et al. 2013). Of 111 sperm whales that stranded in Italy (1986–1999) and Greece (1982–2001), approximately 7 were directly observed to die after colliding with a ship and 39 of the stranded sperm whales in Greece and 22 in Italy bore wounds or scars attributed to a vessel strike (reviewed by Notarbartolo di Sciara 2014).

Effectiveness of preventative measures for collisions between whales and ships continues to be assessed. On-board ship observers and additional radio channels have been proposed as methods to assist with preventing ship strikes. Research has also been done to enhance the Automated Identification Systems (AIS) technology by adding additional channels so vessels could automatically acknowledge receipt of a whale sighting notification (McGillivary et al. 2009).

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. Results also suggested that, with frequent exposure, whales become increasingly tolerant of the vessels' presence. New Zealand implemented whale watching conservation procedures (limited number of tours, limited number of vessel exposures, and restricted approach distance from whale), which appear to minimize the impacts of tour vessels on sperm whales (Markowitz et al. 2011 as cited in Sagnol et al. 2014). Sperm whales are not often seen from whale-watching vessels off the coast of the United States and Canada (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), and the potential for disturbance to sperm whales by such vessels is probably low.

Marine Debris

Since the last status review, there have been more documented cases of mortality due to marine debris (ingestion and entanglement). The threat of marine debris to sperm whales is considered to low due to the small number of documented cases. Marine debris includes recreational or commercial fishing gear that is abandoned or lost, plastic garbage transported from land to sea and solid, non-biodegradable materials disposed of by ships at sea, such as plastics. Insulation, piping, fiberglass, bags, bottles, strapping bands, paints, adhesives, floats, synthetic ropes, sheeting, and synthetic fishing nets are all examples of plastic materials that could be detrimental to marine species. Plastics, such as bags, rubber, balloons and wrappers, can easily be confused for prey and injected by marine species. The debris can cause serious internal injuries due to a physical blockage or puncture in the digestive system.

Ingestion of marine debris by sperm whales is likely incidental ingestion from feeding near the bottom; mistaken ingestion due to resemblance to prey species is highly unlikely due to their echolocation capabilities (Walker and Coe, 1990). Marine debris has been found in the gastrointestinal track of stranded sperm whales. For example, the cause of death for a sperm whale discovered on a beach near Castell de Ferro, Spain, was a gastric rupture caused by a mass of compacted plastics (de Stephanis et al. 2013). In 2008, two sperm whales were found stranded separately along the northern California coast. The cause of death for one whale was a gastric rupture due to impacted debris (24,200g total). The other whale was found to be in poor nutritional condition, and cause of death was established as starvation due to gastric impact (73,630g of total debris; Jacobsen et al. 2010). Lost fishing gear can also entangle sperm whales. Off the Caribbean side of the West Indies, an adult female was spotted with a mixture of nets and ropes attached to her jaw. At the other end was a dead calf with the same nets and rope wrapped around its tail, further illustrating the impact that marine debris may have (Rinaldi and Rinaldi 2013). Although, the threat of entanglement of sperm whales in fishing gear is relatively low, minimizing and avoiding the mortality and injury to sperm whales as a result of entanglement needs to continue. Not only can marine debris have physical impacts on the whales, like entanglement or ingestion, but the chemicals within the plastics, like PCBs, polycyclic aromatic hydrocarbons and petroleum hydrocarbons may also be absorbed and interfere with bodily functions of animals that ingest them (Simmonds 2012).

Renewable Energy

Sperm whales are at risk of entanglement in the moorings and associated power cables used to anchor offshore renewable energy, including offshore wind, wave and tidal energy (Benjamins et al. 2014). Based on a review of current literature, Benjamins et al. (2014) assessed relative risks to marine megafauna groups on the basis of certain biological risk parameters such as size, detection capability, and diving behavior. They also examined the physical features of the mooring and cable devices such mooring tension characteristics, swept volume and curvature. Although baleen whales were determined to be at the highest risk of entanglement, sperm whales also had a relatively moderate to high risk based largely on their size and foraging habits (Benjamins et al. 2014).

In summary, since the last status review, more cases of sperm whale injuries and fatalities due to ship strikes, including sailing vessels, have been documented; however, the number of incidences recorded is still low and level of threat from vessel interactions is also considered low. Sperm whale mortality due to marine debris (ingestion and entanglement) continues to be documented, but the threat is considered to be low due to the small number of documented cases. Sperm whales are also vulnerable to entanglement in the moorings and associated power cables used in offshore renewable energy platforms, but level of impact is unknown.

2.4 Synthesis:

While it is often assumed that the worldwide population of sperm whales has increased since the implementation of the IWC moratorium against whaling in 1988, there are insufficient data on population structure and abundance of inhabited ocean basins to determine population trends accurately. Regional estimates of abundance are fragmented and incomplete, and the best worldwide estimate of 300,000-450,000 (Whitehead 2002) is imprecise. In addition, historical catch records are sparse or nonexistent in some areas of the world and over long periods of time. Also under-reporting or misreporting 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. Further, the removal of adults during historical hunting may still be impacting some populations. Mizroch and Rice (2013) noted that few matrilineal groups are currently found in Alaskan waters and Ivashchenko et al. (2014) noted that large aggregations of sperm whales are seldom seen during current surveys. Because of the extensive illegal catch of female sperm whales (Berzin 2008; Ivashchenko et al. 2014), Mizroch and Rice (2013) suggested that the effects of the removal of so many females may be disproportionately negative because of the importance of females in sperm whale social interactions (Whitehead et al. 1997; Best et al. 1984). Thus, the extent of depletion and degree of recovery of populations are uncertain.

Although the historical threat of whaling to the worldwide population is no longer a primary threat, sperm whales continue to face several other threats. Current potential threats include vessel strikes, entanglement in fishing gear, anthropogenic noise, exposure to contaminants, climate change, and marine debris. The magnitude of threats such as anthropogenic noise, contaminants and pollutants, and climate and ecosystem change is highly uncertain. More attention and research is required to elucidate the magnitude of impact these threats have on the recovery of sperm whale populations. Furthermore, some threats may, in fact, be intensifying, such as contaminant levels and climate change. Although data are lacking on the severity of multiple potential threats, the available evidence indicates that threats are affecting the recovery of sperm whale populations. Thus, reclassification should not occur, and the status of the sperm whale should remain as “endangered.”

3.0 RESULTS

3.1 Recommended Classification:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
_X__ No change is needed

3.2 New Recovery Priority Number *(indicate if no change)*: Recommend change to 7.

Brief Rationale: The threat of directed harvest is low, but current threats include vessel strikes, entanglement in fishing gear, anthropogenic noise, exposure to contaminants, climate change, and marine debris. The magnitude of threats such as anthropogenic noise, contaminants and pollutants, and climate and ecosystem change is highly uncertain; thus, the magnitude of threat is categorized as low to moderate. Many actions needed to recover the species are outside of U.S. jurisdiction. Thus, the recovery potential is low to moderate.

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

The sperm whale recovery plan (NMFS 2010a) anticipates meeting the minimum data requirements by the year 2025 to meet the downlisting criterion no. 1 (achieve sufficient and viable populations in all ocean basins as evidenced by a risk analysis standard of 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).

To ensure we meet the downlisting criterion no. 1, it is essential to estimate current and, to the extent possible, historic species abundance accurately, which will allow for a determination of population trends in each ocean basin in which they occur. Because of the sperm whale's migratory behavior, extremely wide geographic distribution, and deep and prolonged dives, it is difficult to make estimations of population size. Various methods, including population modeling based on acoustic and visual shipboard surveys, visual aerial surveys, and biopsy data, have been used to estimate abundance. The use of these methods should be continued, but expanded geographically and temporally. International cooperation with foreign scientists in non-U.S. waters and new techniques such as autonomous underwater acoustic recorders may also be necessary to collect data in areas that are not currently surveyed and to produce reliable results for entire populations.

Secondarily, more extensive research is necessary to detect the presence of population structures which would help improve management strategies and accuracy of abundance data. While many studies showed low genetic diversity and little geographic structure, there is evidence that suggests the possibility of resident populations (e.g., Mediterranean Sea) and development of genetic differentiation due to differences in migratory patterns between males and females. Currently used methods should be continued, but using larger sample sizes and novel analytical approaches are needed to address the problems with current methods.

In addition to the above, the following is needed to improve knowledge of threats to sperm whales:

- improved knowledge of the impacts of anthropogenic noise from various sources, including military operations, on sperm whales' behavior and ability to communicate and forage;
- continued compilation of documented entanglement in fishing gear and vessel collisions;
- continued research on the effects of exposure to high levels of organochlorine and other contaminants on sperm whales;
- research to investigate the possible effects of climate change on sperm whales' habitat and food availability; and
- continued scientific information from stranded, entangled, or entrapped sperm whales to improve knowledge of species' biology and causes of natural or human-induced mortality.

The U.S. should also continue to cooperate with the IWC to maintain international regulation of the whaling of sperm whales.

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NATIONAL MARINE FISHERIES SERVICE
5-YEAR REVIEW
Sperm Whale *(Physeter macrocephalus)*

Current Classification: Endangered

Recommendation resulting from the 5-Year Review

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
__X__ No change is needed

Review Conducted By: Therese Conant (National Marine Fisheries Service) and Amanda Eplett (Intern, National Marine Fisheries Service)

REGIONAL OFFICE APPROVAL: The draft document was reviewed by the appropriate Regional Offices and Science Centers.

HEADQUARTERS APPROVAL:
Director, Office of Protected Resources, NOAA Fisheries

Approve: Signature Donna S Wieting Date MAY 29 2015
Donna S. Wieting

Assistant Administrator, NOAA Fisheries

_X_ Concur _____ Do Not Concur

Signature________________________ Date June 3, 2015
Eileen Sobeck
Assistant Administrator for Fisheries