

Sperm Whale
(Physeter macrocephalus)

**5-Year Review:
Summary and Evaluation**

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

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TABLE OF CONTENTS

1.0 GENERAL INFORMATION	1
1.1. Reviewers	1
1.2. Methodology	1
1.3. Background	1
1.3.1. FR Notice citation announcing initiation of this review	1
1.3.2. Listing history	1
1.3.3. Associated rulemakings	1
1.3.4. Review history	2
1.3.5. Species recovery priority number at start of 5-year review	2
1.3.6. Recovery plan or outline	2
2.0 REVIEW ANALYSIS	3
2.1. Application of the 1996 Distinct Population Segment (DPS) policy	3
2.1.1. Is the species under review a vertebrate?	3
2.1.2. Is the species under review listed as a DPS?	3
2.1.4. Is there relevant new information for this species regarding the application of the DPS policy?	3
2.2. Recovery Criteria	5
2.2.1. Does the species have a final, approved recovery plan containing objective, measurable criteria?	5
2.3. Updated Information and Current Species Status	5
2.3.1. Biology and Habitat	5
2.3.1.1. New information on the species' biology and life history	5
2.3.1.2. Abundance, demographics, and population trends	7
2.3.1.3. Genetics	8
2.3.1.4. Taxonomic classification or changes in nomenclature	10
2.3.1.5. Spatial distribution	10
2.3.1.6. Habitat or ecosystem conditions	11
2.3.1.7. Other	12
2.3.2. Five-Factor Analysis	12
2.3.2.1. Present or threatened destruction, modification or curtailment of its habitat or range	12
2.3.2.2. Overutilization for commercial, recreational, scientific, or educational purposes	20
2.3.2.3. Disease or predation	20
2.3.2.4. Inadequacy of existing regulatory mechanisms	21
2.3.2.5. Other natural or manmade factors affecting its continued existence	21
2.4. Synthesis	22
3.0 RESULTS	23
3.1. Recommended Classification	23
3.2. New Recovery Priority Number	23
3.3. Listing and Reclassification Priority Number	23
4.0 RECOMMENDATIONS FOR FUTURE ACTIONS	24
5.0 REFERENCES	25

5-YEAR REVIEW

Sperm Whale (*Physeter macrocephalus*)

1.0 GENERAL INFORMATION

1.1 Reviewers

Lead Regional or Headquarters Office: Susan Pultz, Office of Protected Resources (OPR), 301-713-1401 x116

1.2 Methodology used to complete the review:

The first draft of the 5-year review was completed in the Office of Protected Resources (OPR), relying heavily on the 2006 draft recovery plan for the sperm whale. Reviews were completed by Susan Pultz (OPR), Monica DeAngelis (Southwest Regional Office), Kyle Baker (Southeast Regional Office), Jay Barlow and Sarah Mesnick (Southwest Fisheries Science Center), Keith Mullin (Southeast Fisheries Science Center), Debra Palka (Northeast Fisheries Science Center), Mark Minton (Northeast Regional Office), Erin Oleson (Pacific Islands Fisheries Science Center) and Robyn Angliss, Sally Mizroch and Dale Rice (National Marine Mammal Laboratory).

1.3 Background:

1.3.1 FR Notice citation announcing initiation of this review:

72 FR 2649; January 22, 2007

1.3.2 Listing history

Original Listing

The sperm whale was listed under the precursor to the Endangered Species Act (ESA), the Endangered Species Conservation Act of 1969, and remained listed after the passage of the ESA in 1973.

FR notice: 35 FR 8495

Date listed: June 2, 1970

Entity listed: Sperm Whale (*Physeter catodon=macrocephalus*)

Classification: Endangered

1.3.3 Associated rulemakings: N/A

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.

1.3.5 Species' Recovery Priority Number at start of 5-year review:

“7”, reflecting moderate magnitude of threat, low to moderate recovery potential, and the presence of conflict.

1.3.6 Recovery Plan or Outline

Name of plan or outline: Draft Recovery Plan for the Sperm Whale (*Physeter macrocephalus*)

Date issued: June 2006

Dates of previous revisions, if applicable: N/A

The Endangered Species Act requires that NMFS develop and implement recovery plans for the conservation and survival of threaten and endangered species under its jurisdiction, unless it is determined that such plans would not promote the conservation of the species. A recovery plan was drafted in 1998 and another in 2006 (71 FR 38385). The latter plan has undergone peer and public review and is in the process of being revised and finalized. Because changes are expected between the draft and final recovery plans, the draft recovery criteria are not used in this review.

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
 No

2.1.2 Is the species under review listed as a DPS?

Yes
 No

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

Yes
 No

Sperm whales have a global distribution, being found in the North Atlantic, North Pacific and Southern Oceans. Currently, 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 nearly continuously 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.

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

The low mtDNA diversity in sperm whales requires that studies using this marker have large sample sizes. Mesnick *et al.* (2005) compiled over 2,473 tissue samples and 1,038 mtDNA sequences from a global consortium of investigators. While sufficient sampling exists to get a rough idea of scale, sample gaps remain large, particularly in the North Atlantic, Western Pacific and southern hemisphere. This compilation found 28 haplotypes worldwide, defined by 24

variable sites. The three most common haplotypes ("a", "b" and "c") comprised 82% of the total, with haplotype "a." comprising 39% of the total. Several hypotheses for the lack of diversity have been proposed, such as an historic bottleneck effect on population size (Lyrholm *et al.* 1996), dissimilar environmental conditions experienced by separate matrilineal groups causing disparity of fecundities (Tiedemann and Milinkovitch 1999) and cultural "hitchhiking" in matrilineal species (Whitehead 1998). Currently, efforts are underway to define North Pacific stock structure based on 300 samples collected throughout the northeastern, southeastern and central North Pacific using mtDNA and nuclear markers which, for the first time, will include the use of single nucleotide polymorphisms (SNPs) to improve the power to detect structure (Mesnick *et al.* 1999a; S. L. Mesnick, pers. comm.. 2008).

Additional information on population structure can be found in data sets derived from historical, demographic, behavioral, morphological and acoustic sources (Baker and Palumbi 1997; Whitehead and Mesnick 2003a, b). As discussed by Taylor and Dizon (1996), until analyses with sufficient power are applied, the precautionary assumption should be that structuring exists, and reasonable provisional management units should be recognized on the basis of catch history, sighting distribution, and other data. Preliminary investigations of calving seasonality suggest, for example, that the sperm whales in the Gulf of California, Mexico, breed at different times than those in the California Current system (B.L. Taylor, pers. comm. 2006). To address the potential bias due to relatedness within groups, novel analytical approaches are needed (B.L. Taylor, pers. comm. 2008).

Whitehead *et al.* (1998) used acoustic dialects, fluke markings and genetics (mtDNA haplotypes) to test for geography-based population structure of sperm whales in the South Pacific. This study found such structure to be weak in comparison to other non-geographically defined structures, but it is suggested that, if applied more intensively and on a larger geographic scale, this method could help elucidate the possible existence of a process of population differentiation in sperm whales.

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

2.2 Recovery Criteria

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

Yes
 No

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:

New information regarding the biology and life history of sperm whales largely confirms and expands existing knowledge.

Reproduction

Information on the reproduction of sperm whales, obtained mainly from whaling specimens and observations made aboard catcher boats, has been reviewed by several authors (see citations in below discussion). Sperm whales are organized in groups in which adult females (some related and some not related to each other) travel with their sub-adult offspring. Males eventually leave these groups, after which they live in "bachelor schools." The cohesion among males within a bachelor school declines as the animals age, although bonding is evident by the fact that males mass strand (Bond 1999). During their prime breeding period and old age, male sperm whales are essentially solitary (Christal and Whitehead 1997). Maturation in males usually begins in this same age interval, but most individuals do not become fully mature until their twenties. Females usually begin ovulating at 7-13 years of age. Since females within a group often come into estrus synchronously, the male need not remain with them for an entire season to achieve maximal breeding success (Best and Butterworth 1980). In the northern hemisphere, the peak breeding season for sperm whales occurs between March/April and June, and in the southern hemisphere, the peak breeding season occurs between October and December (Best *et al.* 1984). In both cases, some mating activity takes place earlier or later. 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 *et al.* (1980) proposed a 3 year reproductive cycle for the southeast Pacific. Gestation lasts well over a year, with credible estimates of the normal duration ranging from 15 months to more than a year and a half. Lactation lasts at least two years, and the inter-birth interval is 4-6 years for prime-aged females and, apparently, much longer for females over 40 years of age. Female sperm whales rarely become pregnant after the age of 40 (Best *et al.* 1984; Whitehead 2003).

Hearing and Vocalizations

The sperm whale may possess better low frequency hearing than some of the other odontocetes, although not as low as many baleen whales (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 past 20kHz has been reported (Thode *et al.* 2002), with source levels up to 236 dB re 1 μ Pa-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 μ Pa-m (Madsen *et al.* 2003).

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 (Weilgart and Whitehead 1997; Rendell and Whitehead 2004). Clicks are heard most often when sperm whales engage in foraging/diving behavior (Whitehead and Weilgart 1991; Miller *et al.* 2004; Zimmer *et al.* 2005). These may be echolocation clicks used in feeding, contact calls for communication, and orientation during dives. Slow clicks (>2-s period) are detectable at a greater distance (up to 37 km) than quicker “usual” clicks, detectable at 18.5 km (Barlow and Taylor 2005). Rapid-click buzzes called ‘creaks’ are believed to be an echolocation signal adapted for foraging (Miller *et al.* 2004).

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 (*Orcinus orca*) 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. The relatively greater abundance of killer whales in the eastern North Pacific than the western North Atlantic could indicate that sperm whales are at greater risk of predation in the Pacific, although this is speculative. Sperm whales are also “harassed” by pilot whales (*Globicephala* spp.) and false killer whales (*Pseudorca crassidens*), as indicated by observations by Weller *et al.* (1996) and Palacios and Mate (1996), although the witnessed attacks did not result in death.

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 (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), 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). Recently, Moore and Early (2005) identified a type of cumulative bone necrosis in sperm whales that might be caused by the formation of nitrogen bubbles following deep dives and subsequent ascents, 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), demographic features (e.g., age structure, sex ratio, family size, birth rate, age at mortality, mortality rate, etc.), or demographic trends:

Whitehead (2002) estimated current 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 attempt has been made to estimate the total abundance of sperm whales in the North Atlantic Ocean. Instead, researchers have provided estimates of small populations of sperm whales within a relatively narrow portion of their range. Currently, the best estimate for the eastern coast of the U.S. (western North Atlantic) is 4,804 (CV=0.38) based upon two vessel surveys and an aerial survey conducted during the summer of 2004; northern U.S. Atlantic is 2,697 (CV=0.57) and southern U.S. Atlantic 2,197 (CV=0.47) (Waring *et al.* 2007). This joint estimate is considered best because together these two surveys have the most complete coverage of the species' habitat. The estimate pertains to waters from Florida to the Gulf of Maine within the U.S. Exclusive Economic Zone (EEZ) and Canadian portions of the Gulf of Maine, but does not include the Scotian shelf and Gulf of St. Lawrence. Thus, it does not apply to the entire range of sperm whales in the western North Atlantic, which extends across the Scotian Shelf and into the Labrador Sea and Davis Strait (Reeves and Whitehead 1997). The density of sperm whales along the U.S. east coast (17.04 per 1000 km²) is the highest reported in a recent survey of sperm whale densities worldwide (Whitehead 2002). In the oceanic (>200 m deep) northern Gulf of Mexico, vessel surveys conducted during 1996-2001 resulted in a combined estimate of 1,349 (CV=0.23, Mullin and Fulling 2004). The survey estimates for the Gulf of Mexico are negatively biased (an underestimate of actual abundance), as they do not account for the dive-time of sperm whales. Furthermore, the bias associated with a given estimate can be highly variable, depending on the survey platform.

In the eastern North Pacific, a shipboard line-transect survey for sperm whales, using combined visual and acoustic methods, was conducted in a 7.8 million km² area between the west coast of the continental United States and Hawaii in March-June 1997 (Barlow and Taylor 2005). The acoustic and sighting data were analyzed separately, yielding estimates of 32,100 (CV=0.36) and 26,300 (CV=0.81), respectively; the two estimates were not significantly different (Barlow and Taylor 2005). It is not known whether any or all of these animals routinely enter the U.S. EEZ. Barlow (2006) estimated sperm whale abundance in the U.S. EEZ waters surrounding Hawaii as 6,900 (CV=0.81). There are no available estimates for numbers of sperm whales in Alaska waters and no recent estimates of abundance for the entire North Pacific.

The density of sperm whales (individuals per 1,000 km²) has been estimated for five large study areas in the North Pacific: 1.36 in the eastern tropical Pacific (Wade and Gerrodette 1993, as corrected by Whitehead 2002); 1.16 in the western North Pacific (Kato and Miyashita 1998, as corrected by Whitehead 2002); 1.7 off the U.S. West Coast (Barlow and Forney 2007); 3.4 to 4.2 in the eastern temperate Pacific (Barlow and Taylor 2005); and 2.82 in the Hawaiian EEZ (Barlow 2006). Collectively, these surveys cover the majority of sperm whale habitat in the North Pacific. Using Whitehead's (2002) global average of sperm whale density (1.40 per 1,000 km²), the North Pacific would have approximately 112,000 sperm whales. Given that the densities in 3 of 5 study areas are higher than Whitehead's average, this could be considered a conservative estimate.

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 sperm whales (no CV) (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). In addition, newly revealed Soviet whaling catch data from Southern Hemisphere factory ships indicate considerable underreporting of sperm whale catches (Zemsky *et al.* 1995; Zemsky *et al.* 1996). According to these "new" catch data, approximately 14,700 harvested sperm whales went unreported in the original Soviet catch data between 1947 and 1987. As more of these Soviet data are made available, catch-based population estimates will need to be revised.

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

Sperm whales have a complex social structure with the observed "group" of females and juveniles being the more stable social "units" and the breeding males roving among female groups (Christal and Whitehead 2001; Whitehead 2003). At present, there is no known genetic evidence of a strictly or largely matrilineal unit or group of sperm whales. Rather, genetic results suggest that groups of female and immature sperm whales generally contain more than one matriline, as indicated by the presence of multiple mtDNA haplotypes. Both "groups" and "units" contain clusters of closely related animals, but some individuals have no close relations. These results are consistent across 50+ groups sampled at sea and in strandings in four different ocean basins (Richard *et al.* 1996; Christal 1998; Bond 1999; Lyrholm *et al.* 1999; Mesnick 2001; Mesnick *et al.* 2003; Engelhaupt 2004).

Genetic studies based on maternally inherited (mtDNA) markers show significant genetic differentiation between the southern hemisphere and the North Pacific and North Atlantic (Lyrholm *et al.* 1996, 1998), and no significant heterogeneity in bi-parentally inherited (microsatellite) markers was found (Lyrholm *et al.* 1999). These contrasting patterns suggest that interoceanic movement has been more prevalent among males than females (Lyrholm *et al.* 1999), consistent with observation of females having smaller geographic ranges.

The recent finding that vocal clan is a more important factor in genetic structure than geography in the eastern South Pacific draws into question the practice of basing populations solely on geographic strata (Rendell *et al.* 2005; Mesnick *et al.* 2008). A similar well-documented situation occurs among the highly social and vocal killer whales in the Pacific Northwest where vocal clans are sympatric but genetically distinct (Krahn *et al.* 2007). Rendell *et al.* (2005) and Mesnick *et al.* (2008) examined mtDNA variation among vocal clans of sperm whales from social groups sampled from three broad areas of the Pacific (Chile/Peru, Galapagos/Ecuador, and the Southwest Pacific) to address the question of cultural philopatry. Using genetic samples from 194 individuals from 30 social groups belonging to one of three vocal clans, both hierarchical Analysis of Molecular Variance (AMOVA) and partial Mantel tests showed acoustic dialect to have greater genetic structure than geography and coda dialects could be especially significant as they directly describe an apparently important type of non-geographical population structure.

However, recent genetic studies have shown significant genetic subdivision between distinct geographic basins and the rest of the North Atlantic. Two PhD. dissertations examined structure within the North Atlantic using genetic markers. Drout (2003) found mtDNA variation between samples collected in the Mediterranean and North Atlantic Ocean. Engelhaupt (2004) examined genetic variation among samples collected in the Gulf of Mexico, Mediterranean, North Sea, and North Atlantic Ocean using both mtDNA and nuclear genetic markers. Both studies found that all Mediterranean samples were represented by a single mtDNA haplotype and Engelhaupt (2004) found two unique haplotypes in the Gulf of Mexico. Both studies found significant genetic subdivision between the Gulf of Mexico, the Mediterranean, and the North Atlantic.

Mesnick *et al.* (1999a) addressed the question of population structure among sperm whales in the North Pacific using a data set of over 500 samples collected from 84 social groups and a custom-written program to control for the biases of relatedness among individuals sampled within groups (B.L. Taylor, pers. comm. 2008). The authors analyzed variation in mtDNA and nuclear (microsatellite) loci and found significant north to south subdivision between samples collected in the California Current and samples collected to the south (between the Gulf of California and waters off central and northern South America and the Galapagos) and little east-west structure throughout the rest of the North Pacific. Estimates of population structure using all individuals (including relatives), or using only one individual per group, showed positive (more structure) and negative (less structure) biases, respectively, illustrating the need for factoring social structure into population level studies. Results are consistent from groups from areas without a significant whaling history (*e.g.*, the western North Atlantic; Engelhaupt 2004) which are valuable data in addressing whether the non-matrilineal structure is an artifact of removal by commercial whaling.

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 names 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*. Until 1911 the species was generally known as *P. macrocephalus*, however in that year Thomas (1911) concluded that *P. catodon* was the correct name. Later Husson & 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.

The higher-level taxonomy, Archaeoceti, was subsequently reviewed extensively by Milinkovitch *et al.* (1993, 1994, 1995) and Milinkovitch (1995). Examining molecular phylogenies, they 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.):

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

Mostly adult males move into high latitudes, while all age classes and both sexes range throughout tropical and temperate seas. Discovery Mark data from the days of commercial whaling (260 recoveries with location data) show extensive movements of both males and

females from U.S. and Canadian coastal waters into the Aleutian Islands and Gulf of Alaska, and for males into and within the Bering Sea (Omura and Ohsumi 1964; Ivashin and Rovnin 1967; Ohsumi and Masaki 1975; Wada 1980; Kasuya and Miyashita 1988, Mizroch, pers. comm.) although, of nearly 60,000 sperm whales killed in the North Pacific above 50° N, approximately 57,000 were males (Mizroch and Rice 2006 appendix). Sperm whale calls have been detected year-round in the Gulf of Alaska (Mellinger *et al.* 2004). Male sperm whales are widely dispersed along the Antarctic ice edge from December to March (austral summer) (Gosho *et al.* 1984). 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). Only male sperm whales are seen off Kaikoura in New Zealand at lat. 42°S (Jaquet *et al.* 2000). A combination of factors, including wide dispersal by males, ontogenetic changes in association patterns, and female pod fidelity and cohesion, complicates the evaluation of population structure.

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 the 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, it is thought that they are often concentrated around oceanic islands in areas of upwelling, and along the outer continental shelf, continental slope, and mid-ocean waters (Hain *et al.* 1985; Kenney and Winn 1987; Waring *et al.* 1993; Gannier 2000; Gregr and Trites 2001; Waring *et al.* 2001). However, based on pelagic whaling data, sperm whales were found in large numbers in a broad band around 40°N in the northeastern North Pacific and a broad band around 30°N in the northwestern North Pacific (Mizroch and Rice 2006, Fig. 9). Sperm whales show a strong preference for deep waters (Rice 1989), especially in areas with high sea floor relief. The following gives some examples of habitat preferences along the U.S. coast.

Along the U.S. east coast, the overall distribution is centered along the shelf break and over the continental slope 50-1,000 fathoms (~90-1,830 m) deep (CETAP 1982; Waring *et al.* 2005). Very high 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 and b; Waring *et al.* 1997; Scott and Sadove 1997).

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, 1994; Jefferson and Schiro 1997; Davis *et al.* 1998; Weller *et al.* 2000; Wursig *et al.* 2000; Mullin and Fulling 2004). They appear to prefer steep rather than shallow depth gradients (Davis *et al.* 1998). The spatial distribution of sperm whales within the Gulf is strongly correlated with mesoscale physical features such as Loop Current eddies that locally increase primary production and prey availability (Biggs *et al.* 2005). There has recently been extensive work on the movements and habitat use of sperm whales in the northern Gulf of Mexico by the Sperm Whale Seismic Study (SWSS). These studies included habitat cruises, physical oceanographic analysis, and long term satellite tag deployments. Several satellite tags operated for over 12 months and indicate movements generally along the shelf break (700-1,000 m depth) throughout the Gulf, with some animals using deeper oceanic waters. Of 52 tagged animals, one male left the Gulf of Mexico but subsequently returned. The SWSS research provided detailed information on the habitat preferences and population structure of Gulf of Mexico sperm whales (Jochens and Biggs 2004; Jochens *et al.* 2008).

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

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.

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

Fishery Interaction

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). The pelagic drift gillnet fishery closed in 1997 and the use of drift gillnets prohibited in 1999, but sperm whales are still threatened by fishing gear. An

estimated average of ≥ 0.2 sperm whales are killed or seriously injured annually in the driftnet fishery for thresher sharks and swordfish and unknown fisheries off Oregon and California (Carretta *et al.* 2007). No estimates of mortality are available for the Mexican drift gillnet fisheries.

Since the last status review, several studies have been conducted to examine the phenomenon known as “depredation” in which sperm whales remove fish from longline gear. Investigations have been conducted to document rates of depredation, to understand how sperm whales manage to find vessels and remove fish from the gear, and to quantify the amount of prey removed and record the frequency of resulting mortality or serious injury due to entanglement. For instance, in 2006, the “Symposium on Fisheries Depredation by Killer and Sperm Whales: Behavioural Insights, Behavioural Solutions,” was held in British Columbia.

In the North Pacific, long-line depredation is a localized phenomenon, occurring mainly in the central and eastern Gulf of Alaska, occasionally in the western Gulf of Alaska and Aleutian Islands, and absent in the Bering Sea (Sigler *et al.* 2008). In this region, depredation occurs in the sablefish (black cod, *Anoplopoma fimbria*) and Pacific halibut (*Hippoglossus stenolepis*) fishery (Sigler *et al.* 2008). In the Gulf of Alaska, depredation was first documented in 1978, and from 1989-2003, 38 surveyed stations recorded sperm whale predation on long-line catch (Angliss and Outlaw 2005). However, from 1998 to 2004, neither sperm whale presence nor depredation rate increased significantly (Sigler *et al.* 2008). From 2001-2005, no whale mortalities or serious injuries were observed in federally-regulated Alaska fisheries (Angliss and Outlaw 2007). However, in 2006, there were three observed serious injuries in the Gulf of Alaska sablefish longline fishery, which extrapolates to 10 estimated serious injuries for that fishery for that year (R.P. Angliss, pers. comm. 2008)..

Depredation, primarily of Patagonian toothfish (*Dissostichus eleginoides*), has been recorded in the southern hemisphere including (from west to east) Chile, Patagonia and the Falklands, South Georgia, Prince Edward, Crozet, and Kerguelen Islands; depredation is also likely to occur near Heard and McDonald Islands (CCAMLR 1994, Ashford *et al.* 1996, Capdeville 1997, Crespo *et al.* 1997, Nolan and Liddle 2000, González and Olivarría, Roche *et al.* 2006, Kock *et al.* 2006). In several places in the southern oceans, such as the Falkland Islands (Nolan and Liddle 2002) and in Chile (Hucke-Gaete *et al.*, 2004), aggressive competition between sperm and killer whales for a spot at the hauling station of longliners has been reported. Entanglements in longline fishing gear have been observed in South Georgia (Purves *et al.* 2004) and Chile (Ashford *et al.* 1996). Although the magnitude of these interactions is infrequently documented, there are reports of sperm whales that have been shot by guns or harpoons and the use of explosives to keep animals away from fishing gear (Gonzalez 2001).

In the North Atlantic, depredation has been recorded in waters around Norway, the southern coast of Greenland and the Davis Strait between Newfoundland and Greenland in fisheries targeting Greenland halibut (*Reinhardtius hippoglossoides*), Atlantic halibut (*Hippoglossus hippoglossus*), Atlantic cod (*Gadus morhua*) and Greenland cod (*Gadus ogac*) (Dyb 2006; Nils Oien and Paul Winger, pers. comm. to Sarah Mesnick). Sperm whales have been found following deep-water trawlers during hauling operations targeting Greenland halibut, and one case of entanglement in the trawl was reported (Karpouzli and Leaper 2004). Between 2001 and

2005, no sperm whales were known to be killed due to fishery interactions in the U.S. Atlantic Gulf of Mexico (Waring *et al.* 2007).

Such results indicate that current fishing practices pose a low threat to the recovery of sperm whale populations. However, levels of mortality and injury due to entanglement in lost or discarded gear and number of cases of entanglement in fisheries that was not reported are unknown.

Vessel Interaction

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 low and level of threat from vessel interactions is also considered low. Sperm whales spend long periods (typically up to 10 minutes; Jacquet *et al.* 1998) "rafting" at the surface between deep dives. When in close proximity to vessels, this makes them vulnerable to ship strikes. There were instances in which sperm whales approached vessels too closely and were cut by the propellers. Reports of ships colliding with sperm whales are said to be "frequent" in the Canary Islands, where ship traffic is heavy and the local density of sperm whales relatively high (André *et al.* 1997). For example, in 1992, a high-speed ferry collided with a sperm whale, and one of the ferry passengers died as a result (André *et al.* 1997). In the North Atlantic, a merchant ship reported a strike in Block Canyon in May 2000 (Waring *et al.* 2007), and from 2001-2003, one stranded sperm whale was reported struck by a naval vessel and another by a merchant vessel near Rhode Island (Waring *et al.* 2005). More recently in the Pacific, two sperm whales were struck by a ship in 2005, but it is not known if these ship strikes resulted in a mortality or injury (California Marine Mammal Stranding Network Database 2006).

New studies have compiled available information from around the world documenting collisions between ships and large whales (baleen whales and sperm whales) (Laist *et al.* 2001; Jensen and Silber 2003). They found that sperm whales were struck 17 known times out of a total record of 292 strikes of all large whales, 13 of which resulted in mortality. Vessel types include mainly Navy vessels, container/cargo ships, whale-watching vessels, cruise ships, ferries, Coast Guard vessels, and tankers (Jensen and Silber 2003). The most severe injuries are caused by larger vessels (80 m or longer) and vessels traveling at a speed of 14 knots or faster (Laist *et al.* 2001). Within specified areas of U.S. waters in the Atlantic, the speed restriction, routing and other measures of the proposed Right Whale Ship Strike Reduction rulemaking is designed to reduce the risk of ship strikes to other marine mammals, such as sperm whales (NMFS 2008).

These estimates of serious injury or mortality should be considered minimum estimates because many ship strikes go either undetected or unreported for various reasons, and the offshore distribution of sperm whales could conceivably make ship strikes less likely to be detected than for some other species. For instance, carcasses that do not drift ashore may go unreported, and those that do strand may show no obvious signs of having been struck by a ship. In addition, some ships may not be aware of collisions, while others choose not to report them "out of apathy or fear of enforcement consequences" (Jensen and Silber 2003). However, given the current number of reported cases of injury and mortality, it does not appear that ship strikes are a significant threat to sperm whales (Whitehead 2003a).

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. Sperm whales are not often seen from whale-watching vessels on the east 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.

Contaminants and Pollutants

The threat of contaminants and pollutants to sperm whales 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. It is not known if high levels of heavy metals, PCBs, and organochlorines found in prey species accumulate with age and are transferred through nursing, as demonstrated in other marine mammals, such as killer whales.

A dramatic increase in the rate of sperm whale strandings in western Europe since the early 1980s has raised concern that anthropogenic effects, including pollution, may be a contributing factor (Goold *et al.* 2002). The results of a study that analyzed the tissues of some stranded whales for a wide range of contaminants showed no clear link between contamination and stranding (Jacques and Lambertsen 1997). However, levels of mercury, cadmium, and certain organochlorines in these whales' tissues were high enough to cause concern about toxicity and other possibly indirect and less obvious effects (Bouquegneau *et al.* 1997; Law *et al.* 1997). Fossi *et al.* (2003) stated that high concentrations in the Mediterranean could have an effect on reproductive rates of this species, warranting further study.

Aguilar (1983) found that levels of organochlorine contaminants in sperm whales killed off northwestern Spain were intermediate between the levels found in fin whales (*Balaenoptera physalus*) and small odontocetes from the same region, most likely due to their diet of squid and benthic fish. Also, the levels of organochlorine compounds found in females were consistently higher than those in males, which is contrary to the typical findings in other marine mammals. Given that male and female sperm whales are geographically separated during much of the year, it is possible that males feed in less polluted waters or perhaps on less contaminated prey than females.

Japanese scientists, Umezu *et al.* (1984), have investigated the hypothesis that sperm whales provide a medium for transporting radioactive cobalt (and other artificial radionuclides) from the deep seabed to surface waters. They showed that ⁶⁰Co bio-accumulates in sperm whales as they

consume mesopelagic cephalopods, and this ^{60}Co is then dispersed as the sperm whales defecate at the surface, therefore generating an upward movement of ^{60}Co from the deep sea. Although it has been suggested that a high content of ^{60}Co may cause body burden to longer-living sperm whales (Umezu *et al.* 1984), it is generally unknown whether ^{60}Co has any negative effects on the overall health of sperm whales.

Although data is extremely scarce, concentrations of organochlorines in the tropical and equatorial fringe of the northern hemisphere and throughout the southern hemisphere appear to be low or extremely low in marine mammals (Aguilar *et al.* 2002). The lowest concentrations of DDTs and PCBs are found in the polar regions of both hemispheres, while the highest concentrations of organochlorines are found in mammals from the temperate fringe of the northern hemisphere, especially the Mediterranean Sea (Aguilar *et al.* 2002). However, due to the systematic long-term transfer of airborne pollutants from warmer to colder regions, it is expected that the Arctic and, to a lesser extent, the Antarctic will become major sinks for organochlorines in the future, warranting long-term monitoring of polar regions (Aguilar *et al.* 2002).

Anthropogenic Noise

The effects of anthropogenic noise are difficult to ascertain and research on this topic is ongoing. It is unlikely that the amount of noise generated by humans would not have an effect on such highly communicative animals; however, the level of threat that such noise represents is uncertain. Multiple studies examining the impacts of anthropogenic noises have been conducted since the last status review, including a comprehensive review on marine mammal noise exposure (Southall *et al.* 2007). Sperm whales can be adversely affected by anthropogenic noise by permanently or temporarily damaging their hearing, masking the sounds animals would normally produce or hear, or instigating behavioral reactions to the noise that may lead to long-term effects on their survival or reproductive abilities. However, it is difficult to ascertain the level of threat from these sources with currently available information. Anthropogenic sources of noise have increased ambient noise levels in the ocean over the last 50 years, much of which is due to increased number of ships and larger tonnage (Jasny *et al.* 2005; National Resource Council 2003; Southall *et al.* 2005). Commercial fishing vessels, cruise ships, transport boats, recreational boats, and aircraft, all add more sound into the ocean that is unfamiliar and potentially disruptive to marine mammals (National Resource Council 2003).

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 (Andrew *et al.* 2002; McDonald *et al.* 2006, 2008). Michel *et al.* (2001) suggest 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 higher frequency noise through cavitation, which accounts for approximately 85% or more of the noise emitted by a large vessel.

Little is known about odontocete reactions to seismic exploration and available studies provide inconsistent results. There was an early preliminary account of possible long-range avoidance of seismic vessels by sperm whales in the Gulf of Mexico (Mate et al. 1994). However, this has not been substantiated by subsequent more detailed work in that area (Gordon et al. 2006; Jochens et al. 2006; Winsor and Mate 2006). In one Digital Acoustic Recording Tag (DTAG) deployment in the northern Gulf of Mexico on July 28, 2001, researchers documented that the tagged whale moved away from an operating seismic vessel once the seismic pulses were received at the tag at roughly 137 dB re 1 μ Pa (Johnson and Miller 2003). In contrast, Davis *et al.* (2000) noted that sighting frequency in the northern Gulf of Mexico did not differ significantly among the different acoustic levels. Another recent study offshore of northern Norway indicated that sperm whales continued to call when exposed to pulses from a distant seismic vessel of up to 146 dB re 1 μ Pa peak-to-peak (Madsen *et al.* 2002). Similarly, a study conducted off Nova Scotia that analyzed recordings of sperm whale sounds at various distances from an active seismic program did not detect any obvious changes in the distribution or behavior of sperm whales (McCall Howard 1999). Seismic work off Angola (Weir et al. 2001) found no difference in encounter rates of sperm whales or obvious behavioral changes due to air gun activity. Recent data from vessel-based monitoring programs in United Kingdom waters suggest that sperm whales in that area may have exhibited some changes in behavior in the presence of operating seismic vessels, but the compilation and analysis of the data led to the conclusion that seismic surveys did not result in observable effects to sperm whales (Stone 2003). However, there may have been adverse effects that this data did not detect, due to the difficulty of making surface observations for a species that spend relatively less time at the surface (Stone 2003). Jochens *et al.* (2008) found in the Gulf of Mexico no horizontal avoidance of sperm whales from seismic exposure but did record decreases in foraging activity. Although the sample size is small (4 whales in 2 experiments), the results are consistent with those off northern Norway mentioned above.

Military operations sometimes use explosives in the marine environment when conducting training or combat missions. These operations could include activities such as mine countermeasures, demolition of underwater obstacles, ship shock trials, and expenditure of ordnance against a towed target. Animals may exhibit a behavioral response and, depending on the energy level of the explosive and vicinity of animal to the target, possibly suffer some type of physiological impact (*i.e.*, tympanic membrane rupture, slight to extensive lung injury).

Auditory interference, or masking, of acoustic signals can also change the behavior of individual animals, groups of animals, or entire populations by preventing or hindering communication, navigation, foraging, reproduction, and familiarization of their environment. Masking generally occurs when the interfering noise is louder than, and of a similar frequency to, the auditory signal received by animals from conspecifics. Animals can determine the direction from which a sound arrives based on cues, such as difference in arrival times, sound levels, and phases at the two ears. Thus, an animal's directional hearing capabilities have a bearing on its vulnerability to masking (NRC 2003). There are still many uncertainties regarding how masking affects marine mammals. For example, it is not known how loud acoustic signals must be for animals to recognize or respond to another animal's vocalizations (NRC 2003). It is also unknown if animals listen/respond to all the sounds they can hear or select to which sounds they will listen.

Most observations of behavioral responses of marine mammals to anthropogenic sounds have been limited to short-term behavioral responses, which included the cessation of feeding, resting, or social interactions. Behavioral changes may include producing more calls, longer calls, or shifting the frequency of the calls. Carretta *et al.* (2001) and Jasny *et al.* (2005) identified increasing levels of anthropogenic noise as a habitat concern for whales and other marine mammals because of its potential effect in their ability to communicate. Foote *et al.* (2004) conducted a long-term study of three social groups (pods) of killer whales that suggested that killer whales may change their vocal behavior once background noise reaches a threshold level. Holt *et al.* (2009) found that killer whales increase their vocal amplitude in response to background noise levels. A recent preliminary analysis of acoustical data from the northern Gulf of Mexico also indicates that sperm whales are, in some cases, affected by the passing of vessels, with fewer clicks and fewer whales detected afterwards (Ioup *et al.* 2005). It is not known if this reflects a change in sound-producing behavior, or the physical movement of whales away from the source. Interestingly, similar changes in behavior were observed when the data were analyzed for the effects of a passing tropical storm (Newcomb *et al.* 2004). Sperm whales were found to have moved away from affected areas and click rates decreased during the storm and did not increase back to pre-storm levels.

It is difficult to measure behavioral or stress responses in free-ranging whales. There is evidence that many individuals respond to certain sound sources, provided the received level is high enough to evoke a response, while other individuals do not. Relationships between the responses of marine mammals to specific sources are still subjected to scientific investigation, but no clear patterns have emerged.

Sonar

Effects of sonar on sperm whales have not been studied extensively and remain uncertain, although sperm whales are potentially disturbed by sonar. The following information was not included in the last status review.

The loud, low frequency signals (maximum output 215 dB re 1 μ Pa) used by the Navy are in the frequency range of 100-500 Hz, which is well within the likely range of sperm whale hearing (Dept. of the Navy 2007). Similarly, mid-frequency sonar (*e.g.*, U.S. Navy 53C) can produce equally loud sounds at frequencies of 2,000-8,000 Hz (Dept. of the Navy 2008), which are also likely to be heard by sperm whales. Clicks produced by sperm whales (and presumably heard by them) are in the range of < 100 Hz to as high as 30 kHz, often with most of the energy in the 2 to 4 kHz range (Watkins 1980). There have been no sperm whale strandings attributed to Navy sonar. However, the large scale and diverse nature of military activities in large ocean basins indicates that there is always potential for disturbing, injuring, or killing these and other whales.

There is some evidence of disruptions of clicking and behavior from sonars, pingers, the Heard Island Feasibility Test (Bowles *et al.* 1994), and the Acoustic Thermometry of Ocean Climate at Pioneer Seamount off Half Moon Bay, California (ATOC; Costa *et al.* 1997). Sperm whales have been observed to frequently stop echolocating in the presence of underwater pulses made by echosounders, such as pingers at 13 to 6 KHz (Watkins and Schevill 1975). Goold (1999) reported six sperm whales that were driven through a narrow channel using ship noise,

echosounder, and fishfinder emissions from a flotilla of 10 vessels. Sperm whales stop vocalizing for brief periods when codas are being produced by other individuals, perhaps because they can hear better when not vocalizing themselves (Goold and Jones 1995). Watkins and Tyack (1985) determined that sperm whales reacted to military sonar, apparently from a submarine, by dispersing from social aggregations, moving away from the sound source, remaining relatively silent, and becoming difficult to approach. Intensive statistical analyses of aerial survey data showed some subtle shifts in the distribution of humpback and possibly sperm whales slightly farther from the Pioneer Seamount source when it was activated during ATOC transmission periods than when it was not (Calambokidis *et al.* 1998). However, Au *et al.* (1997) determined that the ATOC signal had a minimal effect on physical and physiological effects of cetaceans.

Because they spend large amounts of time at depth and use low frequency sound, sperm whales are likely to be susceptible to low frequency sound in the ocean (Croll *et al.* 1999). Studies to assess the impact of loud low-frequency active sonar signals by the U.S. Navy were completed under its Surveillance Towed Array Sensor System (SURTASS) LFA sonar program. A three-phase research program completed as the basis for a 2001 Environmental Impact Statement (EIS) on their SURTASS LFA sonar system found that blue, fin, humpback, and gray whales exposed to the sound demonstrated no biologically significant response to the LFA sonar.

The effects of naval sonars on marine wildlife have not been studied as extensively as the effects of airguns used in seismic surveys. In the Caribbean Sea, sperm whales avoided exposure to mid-frequency submarine sonar pulses, in the range 1000 Hz to 10,000 Hz (IWC 2005). Maybaum (1989, 1993) observed changes in behavior of humpbacks during playback tapes of the M-1002 system (using 203 dB re 1 μ Pa-m for study); specifically, a decrease in respiration, submergence, and aerial behavior rates; and an increase in speed of travel and track linearity.

Oil and Gas Exploration and Other Industrial Activities (excluding seismic)

The effects of oil and gas exploration and other industrial activities are unknown, but are believed to represent a relatively low level of threat at the current abundance of sperm whales. Oil spills that occur while sperm whales are present could result in skin contact with the oil, ingestion of oil, respiratory distress from hydrocarbon vapors, contaminated food sources, and displacement from feeding areas (Geraci 1990). Actual impacts would depend on the extent and duration of contact, and the characteristics (age) of the oil. Most likely, the effects of oil would be irritation to the respiratory membranes and absorption of hydrocarbons into the bloodstream (Geraci 1990). Contaminated food sources and displacement from feeding areas also may occur as a result of an oil spill.

No instance of marine mammal entanglement in submarine cables has been documented since the 1950s (STARS 2002). Plow marks, possibly made by sperm whales bottom feeding, suggest sperm whales are foraging in areas where cables are placed, and could potentially become entangled in underwater cables; however, improved route selection and burial technologies have reduced the threat of entanglement by minimizing looping in cables.

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

No new information is available regarding the direct harvest of sperm whales. Although historical whaling activities were responsible for the depletion of sperm whales worldwide, they are now hunted only by Japan and in small numbers, and therefore, the threat of overutilization by direct harvest is currently low. However, if the International Whaling Commission's (IWC's) moratorium on commercial whaling was 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. Japan ceased hunting of sperm whales after the 1987 season, but currently takes a small number of sperm whales each year under an IWC exemption for scientific research.

No new information is available for the impacts of research activities on sperm whale behaviors. Moore and Clarke (2002) studied gray whales' responses to research activities and results ranged from no visible responses to short-term behavioral changes.

Information on impacts of whale-watching is included in the section on vessel interaction in 2.3.2.1.

2.3.2.3 Disease or predation:

Currently available evidence suggests that neither disease nor predation is a major threat to the recovery of sperm whale populations. Disease presumably plays a role in natural mortality of sperm whales, but little is known. While serological studies on North Pacific and North Atlantic sperm whales indicate that these whales are carriers of and infected by calciviruses and papillomavirus (Smith and Latham 1978, Lambertsen et al. 1987), only two naturally occurring diseases that are likely to be lethal have been identified in sperm whales: myocardial infarction associated with coronary atherosclerosis, and gastric ulceration associated with nematode infection (Lambertsen 1997). The potential for parasitism to have a population level effect on sperm whales is largely unknown. Although parasites may have little effect on otherwise healthy animals, effects could become significant if combined with other stresses.

In recent years, the potential impact of predation by killer whales on the dynamics of the North Pacific marine ecosystem over the last several decades has received substantial attention within the scientific community. New hypotheses have been developed on how predation by killer whales has influenced marine mammal populations, including sperm whales (Springer *et al.* 2003 ; Mizroch and Rice 2006). However, while evidence indicates that predation by killer whales has been, and is still, a source of natural mortality for sperm whales (Pitman *et al.* 2001),

the extent of impact on sperm whale populations is expected to be small based on the fact that few observations have occurred.

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” (Baillie and Groombridge 1996). The species is also listed in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) which, aside from exceptional circumstances, prohibits the commercial trade of products of sperm whales across international borders of member countries.

2.3.2.5 Other natural or manmade factors affecting its continued existence:

Marine Debris

Instances of stomach obstruction caused by marine debris have been documented in sperm whales, but severity of threat is considered low due to the small number of known cases. Harmful marine debris consists of plastic garbage washed or blown from land into the sea, fishing gear lost or abandoned by recreational and commercial fishers, and solid non-biodegradable floating materials (such as plastics) disposed of by ships at sea. Examples of plastic materials are bags, bottles, strapping bands, sheeting, synthetic ropes, synthetic fishing nets, floats, fiberglass, piping, insulation, paints and adhesives. Marine species confuse plastic bags, rubber, balloons and confectionery wrappers with prey and ingest them. The debris usually causes a physical blockage in the digestive system, leading to serious internal injuries.

The bottom-feeding habit of sperm whales, which might involve a suction mechanism (as suggested by observations of apparently healthy sperm whales with deformed or broken jaws), indicates that they ingest marine debris (Lambertsen 1997). The consequences can be debilitating and even fatal. In 1989, a necropsy on a stranded sperm whale carcass indicated that its death was caused by a stomach obstruction following accidental ingestion of 100 square feet plastic bags and sheets in the Lavezzi Islands of the Tyrrhenian Sea (Viale *et al.* 1992). In addition, one of 32 sperm whales examined for pathology in Iceland had a lethal disease thought to have been caused by the complete obstruction of the gut with plastic marine debris (Lambertsen 1990). The stomach contents of two sperm whales that stranded separately in California in (California Marine Mammal Stranding Database 2008) included extensive amounts of netting from discarded fishing nets; however, the cause of death was not determined. Although mortality caused by ingestion of marine debris has been documented in sperm whales, there are only a few known cases and it is, therefore, not believed to be a major threat to the species.

Climate Change

Although the effects of climate and oceanographic change on sperm whales are uncertain, they have the potential to greatly affect habitat and food availability. Site selection for whale migration, feeding, and breeding for sperm whales may be influenced by factors such as ocean currents and water temperature. Evidence suggests that the productivity in the North Pacific (Quinn and Neibauer 1995; Mackas *et al.* 1998) and other oceans is affected by changes in the environment. Increases in global temperatures are expected to have profound impacts on arctic and sub-arctic ecosystems and these impacts are projected to accelerate during this century. There is some evidence from Pacific equatorial waters that sperm whale feeding success and, in turn, calf production rates are negatively affected by increases in sea surface temperature (Smith and Whitehead 1993; Whitehead 1997). This could mean that global warming will reduce the productivity of at least some sperm whale populations (Whitehead 1997). Any changes in these factors could render currently used habitat areas unsuitable. 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 remembering 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.

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 is insufficient data on population structure and abundance of inhabited ocean basins to determine population trends accurately. The current best estimates are fragmented and confined to regions 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, and 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. Thus, the extent of depletion and degree of recovery of populations are uncertain.

Although the historical threat of direct harvest to the worldwide population is no longer a primary threat, sperm whales continue to face several other threats. These current potential threats include entanglement in fishing gear, reduced prey due to overfishing, interference of communication from 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 impacts of these threats on the recovery of sperm whale populations. Furthermore, some threats may, in fact, be intensifying, such as contaminant levels and climate change.

Due to the lack of sufficient and reliable information on the severity of multiple potential threats to the recovery of sperm whale populations, as well as population structure, species abundance and population trends, reclassification should not take place at this point. Thus, the status of the sperm whale should remain as “endangered.”

3.0 RESULTS

3.1 Recommended Classification:

- Downlist to Threatened
- Uplist to Endangered
- Delist
- No change is needed

3.2 New Recovery Priority Number: 11

Brief Rationale: The recommended new recovery priority number is 11, due to a low magnitude of threat, low to moderate recovery potential and the presence of conflict. The magnitude of threat has changed from moderate to low because the main historical threat (directed take) is being addressed and the severity of many current threats to sperm whales (such as anthropogenic noise, exposure to contaminants and climate change) is uncertain. According to NMFS' guidelines for assigning priorities, the magnitude of threat is low when "the impacts of threats to the species' habitat are not fully known" (55 FR 24297). Similarly, recovery potential remains low to moderate because "the limiting factors or threats to the species are poorly understood [and] the needed management actions are not known" (55 FR 24297). Finally, there is a continued presence of conflict, as the protection of sperm whale populations may result in interference with economic activities and military operations.

3.3 Listing and Reclassification Priority Number: NA

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

To assess the sperm whale's recovery status properly and the effectiveness of the IWC moratorium, 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. New techniques such as satellite tagging and international cooperation with foreign scientists in non-U.S. waters 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, and define DPSs if we decide to do so. While many studies showed low genetic diversity and little geographic structure, there is evidence that suggests the possibility of resident populations and development of genetic differentiation due to differences in migratory patterns between males and females. Currently used methods should be continued, but in 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.

Lastly, the U.S. should continue to cooperate with the International Whaling Commission to maintain international regulation of the whaling of sperm whales.

NMFS will finalize and implement the sperm whale recovery plan soon, which will provide criteria for reclassification and an implementation schedule for the completion of recovery tasks. The plan aims to promote recovery of sperm whale populations to levels that warrant downlisting from endangered to threatened status and, ultimately, delisting.

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NATIONAL MARINE FISHERIES SERVICE
5-YEAR REVIEW
Physeter macrocephalus

Current Classification:

Recommendation resulting from the 5-Year Review

- Downlist to Threatened
- Uplist to Endangered
- Delist
- No change is needed

Review Conducted By: Office of Protected Resources, Silver Spring, MD

REGIONAL OFFICE APPROVAL:

Lead Regional Administrator, NOAA Fisheries

Approve: N/A Date: _____

The Lead Region must ensure that other Regions within the range of the species have been provided adequate opportunity to review and comment prior to the review's completion. Written concurrence from other regions is required.

Cooperating Regional Administrator, NOAA Fisheries

Concur Do Not Concur

Signature N/A Date _____

HEADQUARTERS APPROVAL:

Assistant Administrator, NOAA Fisheries

Concur Do Not Concur

Signature *[Signature]* Date 11/14/09