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SPERM WHALE (*Physeter macrocephalus*): Hawaii Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

Sperm whales are widely distributed across the entire North Pacific and into the southern Bering Sea in summer but the majority are thought to be south of 40ºN in winter (Rice 1974, 1989; Gosho *et al.* 1984; Miyashita *et al.* 1995). For management, the International Whaling Commission (IWC) had divided the North Pacific into two management regions (Donovan 1991) defined by a zig-zag line which starts at 150ºW at the equator to 160ºW between 40-50ºN, and ending at 180ºW north of 50ºN; however, the IWC has not reviewed this stock boundary in many years (Donovan 1991). Summer/fall surveys in the eastern tropical Pacific (Wade and Gerrodette 1993) show that although sperm whales are widely distributed in the tropics, their relative abundance tapers off markedly westward towards the middle of the tropical Pacific (near the IWC stock boundary at 150ºW) and tapers off northward towards the tip of Baja California. The Hawaiian Islands marked the center of a major nineteenth century whaling ground for sperm whales (Gilmore 1959; Townsend 1935). Sperm whales have been sighted throughout the Hawaiian EEZ, including nearshore waters of the main and Northwestern Hawaiian Islands (NWHI) (Rice 1960; Baird 2016, Lee 1993; Mobley *et al.* 2000, Shallenberger 1981). In addition, the sounds of sperm whales have been recorded throughout the year within the main and NWHI (Thompson and Friedl 1982, Merkens *et al*. 2019). Summer/fall shipboard surveys of waters within the U.S. Exclusive Economic Zone (EEZ) of the Hawaiian Islands resulted in 43 sperm whale sightings in 2002, 46 in 2010, and 24 in 2017 throughout the study area (Figure 1; Barlow 2006, Bradford *et al*. 2017, Yano *et al*. 2018).

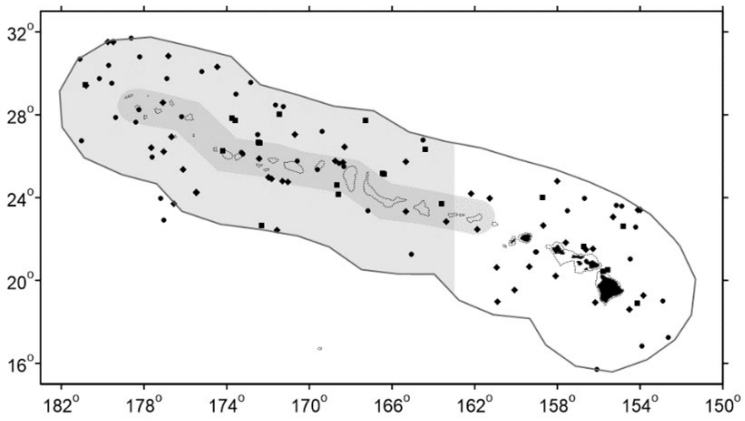

Figure 1. Sperm whale sighting locations during the 2002 (diamond), 2010 (circle), and 2017 (square) shipboard surveys of U.S. EEZ waters surrounding the Hawaiian Islands (Barlow 2006, Bradford *et al*. 2017, Yano *et al*. 2018). Outer line represents approximate boundary of survey area and U.S. EEZ. Dark gray shading indicates the original Papahanaumokuakea Marine National Monument, with the lighter gray shading denoting the full 2016 Expansion area. Dotted line represents the 1000 m isobaths.

The stock identity of sperm whales in the North Pacific has been inferred from historical catch records (Bannister and Mitchell 1980) and from trends in CPUE and tag-recapture data (Ohsumi and Masaki 1977). A 1997 survey designed specifically to investigate stock structure and abundance of sperm whales in the northeastern temperate Pacific revealed no apparent hiatus in distribution between the U.S. EEZ off California and areas farther west, out to Hawaii (Barlow and Taylor 2005). Genetic analyses revealed significant differences in mitochondrial and nuclear DNA and in single-nucleotide polymorphisms between sperm whales sampled off the coast of California, Oregon and Washington and those sampled near Hawaii and in the eastern tropical Pacific (ETP) (Mesnick *et al*. 2011). These results suggest demographic independence between matrilineal groups found California, Oregon, and Washington, and those found elsewhere in the central and eastern tropical Pacific. Further, assignment tests identified male sperm whales sampled in the sub-Arctic with each of the three regions, suggesting mixing of males from potentially several populations during summer (Mesnick *et al*. 2011).

For the Marine Mammal Protection Act (MMPA) stock assessment reports, sperm whales within the Pacific U.S. EEZ are divided into three discrete, non-contiguous stocks: 1) waters around Hawaii (this report), 2) California, Oregon and Washington waters, and 3) Alaskan waters. The Hawaii stock includes animals found both within the Hawaiian Islands EEZ and in adjacent high seas waters; however, because data on abundance, distribution, and human-caused impacts are largely lacking for high seas waters, the status of the Hawaii stock is evaluated based on data from U.S. EEZ waters of the Hawaiian Islands (NMFS 2005).

POPULATION SIZE

Encounter data from shipboard line-transect surveys of the entire Hawaiian Islands EEZ was recently reevaluated for each survey year, resulting in the following abundance estimates of sperm whales in the Hawaii EEZ (Becker *et al*. 2021; Table 1).

Table 1. Model-based line-transect abundance estimates for sperm whales derived from surveys of the entire Hawaii EEZ in 2002, 2010, and 2017 (Becker *et al*. 2021).

Year	Model-based abundance	CV	95% Confidence Limits
2017	5,707	0.23	2,961-10,998
2010	5,497	0.22	2,863-10,555
2002	5,387	0.22	2,668-10,878

Sighting data from 2002 to 2017 within the Hawaii EEZ were used to derive habitat-based models of animal density for the overall period. The models were then used to predict density and abundance for each survey year based on the environmental conditions within that year (see Forney *et al*. 2015, Becker *et al*. 2016). The modeling framework incorporated Beaufort-specific trackline detection probabilities for sperm whales from Barlow *et al*. (2015). Bradford *et al*. (2021) produced design-based abundance estimates for sperm whales for each survey year that can be used as a point of comparison to the model-based estimates. While on average, the estimates are similar between the two approaches, the annual design-based estimates show much greater uncertainty for some years than do the model-based estimates (Figure 2). The model-based approach reduces variability through explicit examination of habitat relationships across the full dataset, while the design-based approach evaluates encounter data for each year separately and thus is more susceptible to the effects of encounter rate variation. Model based-estimates are based on the implicit assumption that changes in abundance are attributed to environmental variability alone. There are insufficient data to explicitly incorporate a trend term into the model due to the insufficient sample size to test for temporal effects. Despite not fully accounting for inter-annual variation in total abundance, the model-based estimates are considered the best available estimate for each survey year. Previously published design-based estimates for the Hawaii EEZ from 2002 and 2010 surveys (e.g. Barlow 2006, Bradford *et al*. 2017) used a subset of the dataset used by Becker *et al*. (2021) and Bradford *et al*. (2021) to derive line-transect parameters, such that these estimates have been superseded by the estimates presented here. The best estimate of abundance is from the 2017 survey, or 5,707 (CV=0.23).

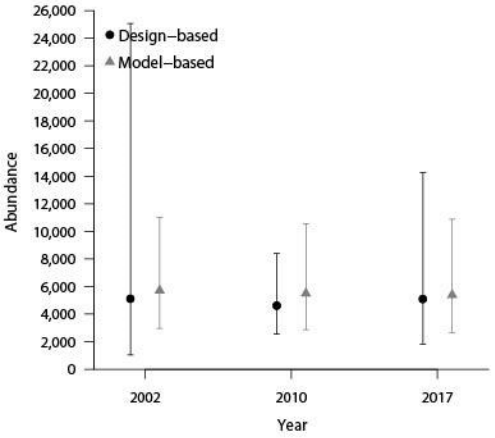

Figure 2. Comparison of design-based (circles, Bradford *et al*. 2021) and model-based (triangles, Becker *et al*. 2021) estimates of abundance for sperm whales for each survey year (2002, 2010, 2017).

A large 1982 abundance estimate for the entire eastern North Pacific (Gosho *et al*. 1984) was based on a CPUE method which is no longer accepted as valid by the International Whaling Commission. A spring 1997 combined visual and acoustic line-transect survey conducted in the eastern temperate North Pacific resulted in estimates of 26,300 (CV=0.81) sperm whales based on visual sightings, and 32,100 (CV=0.36) based on acoustic detections and visual group size estimates (Barlow and Taylor 2005). Sperm whales appear to be a good candidate for acoustic surveys due to the increased range of detection; however, visual estimates of group size are still required (Barlow and Taylor 2005). In the eastern tropical Pacific, the abundance of sperm whales has been estimated as 22,700 (95% CI = 14,800 - 34,600; Wade and Gerrodette 1993). However, it is not known whether any or all of these animals routinely enter the U.S. EEZ of the Hawaiian Islands.

Minimum Population Estimate

The minimum population size is calculated as the lower 20th percentile of the log-normal distribution (Barlow *et al*. 1995) around the 2017 abundance estimate or 4,486 sperm whales within the Hawaiian Islands EEZ.

Current Population Trend

The model-based abundance estimates for sperm whales provided by Becker *et al.* (2021) do not explicitly allow for examination of population trend other than that driven by environmental factors. Model-based examination of sperm whale population trends including sighting data beyond the Hawaii EEZ will be required to more fully examine trend for this stock. .

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

No data on current or maximum net productivity rate are available.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for the Hawaii stock of sperm whales is calculated as the minimum population size (4,486) within the U.S. EEZ of the Hawaiian Islands times one half the default maximum net growth rate for cetaceans (½ of 4%) times a recovery factor of 0.2 (for an endangered species with $N_{min} > 1,500$ and $CV_N <= 0.50$, with low vulnerability to extinction; (Taylor *et al*. 2003), resulting in a PBR of 18 sperm whales per year.

HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

Fishery Information

Information on fishery-related mortality of cetaceans in Hawaiian waters is limited, but the gear types used in Hawaiian fisheries are responsible for marine mammal mortality and serious injury in other fisheries throughout U.S. waters. No estimates of human-caused mortality or serious injury are currently available for nearshore hook and line fisheries because these fisheries are not observed or monitored for protected species bycatch.

There are currently two distinct longline fisheries based in Hawaii: a deep-set longline (DSLL) fishery that targets primarily tunas, and a shallow-set longline fishery (SSLL) that targets swordfish. Both fisheries operate within U.S. waters and on the high seas. Between 2014 and 2018, no sperm whales were observed hooked or entangled in the SSLL fishery (100% observer coverage) or in the DSLL fishery (18-21% observer coverage) (Bradford 2018a, 2018b, 2020, Bradford and Forney 2017). On unidentified cetacean taken in the DSLL fishery was identified as a large whale based on the Observer's description and may have been a sperm whale.

Historical Mortality

Between 1800 and 1909, about 60,842 sperm whales were estimated taken in the North Pacific (Best 1976). The reported take of North Pacific sperm whales by commercial whalers between 1947 and 1987 totaled 258,000 (C. Allison, pers. comm.). Factory ships operated as far south as 20ºN (Ohsumi 1980). Ohsumi (1980) lists an additional 28,198 sperm whales taken mainly in coastal whaling operations from 1910 to 1946. Based on the massive under-reporting of Soviet catches, Brownell *et al*. (1998) estimated that about 89,000 whales were additionally taken by the Soviet pelagic whaling fleet between 1949 and 1979. Japanese coastal operations apparently also under-reported catches by an unknown amount (Kasuya 1998). Thus a total of at least 436,000 sperm whales were taken between 1800 and the end of commercial whaling for this species in 1987. Of this total, an estimated 33,842 were taken by Soviet and Japanese pelagic whaling operations in the eastern North Pacific from the longitude of Hawaii to the U.S. West coast, between 1961 and 1976 (Allen 1980, IWC statistical Areas II and III), and 965 were reported taken in land-based U.S. West coast whaling operations between 1947 and 1971 (Ohsumi 1980). In addition, 13 sperm whales were taken by shore whaling stations in California between 1919 and 1926 (Clapham *et al*. 1997). There has been a prohibition on taking sperm whales in the North Pacific since 1988, but large-scale pelagic whaling stopped earlier, in 1980. Some of the whales taken during the whaling era were certainly from a population or populations that occur within Hawaiian waters.

STATUS OF STOCK

The only estimate of the status of North Pacific sperm whales in relation to carrying capacity (Gosho *et al*. 1984) is based on a CPUE method no longer accepted as valid. The status of sperm whales in Hawaiian waters relative to OSP is unknown, and there are insufficient data to evaluate trends in abundance. Sperm whales are formally listed as "endangered" under the Endangered Species Act (ESA), and consequently the Hawaiian stock is automatically considered as a "depleted" and "strategic" stock under the MMPA. Given the absence of recent recorded fishery-related mortality or serious injuries in U.S. EEZ waters, total fishery mortality and serious injury for sperm whales can be considered insignificant and approaching zero. The increasing level of anthropogenic noise in the world's oceans has been suggested to be a habitat concern for whales (Richardson *et al*. 1995), particularly for deep-diving

whales like sperm whales that feed in the oceans' "sound channel". One sperm whale stranded in the main Hawaiian Islands tested positive for both *Brucella* and *Morbillivirus* (Jacob *et al*. 2016). *Brucella* is a bacterial infection that if common in the population may limit recruitment by compromising male and female reproductive systems, and can also cause neurological disorders that may result in death (Van Bressem *et al*. 2009). *Morbillivus* is known to trigger lethal disease in cetaceans (Van Bressem *et al*. 2009); however, investigation of the pathology of the stranded sperm whale suggests that *Brucella* was more likely the cause of death in this sperm whale. The presence of *Morbillivirus* in 10 species (Jacob *et al*. 2016) and *Brucella* in 3 species (Cherbov 2010) raises concerns about the history and prevalence of these diseases in Hawaii and the potential population impacts on Hawaiian cetaceans. It is not known if *Brucella or Morbillivirus* are common in the Hawaii stock.

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