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SPERM WHALE (*Physeter macrocephalus*): California/Oregon/Washington Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

Sperm whales are 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; Rice 1989; Gosho *et al.* 1984; Miyashita *et al.* 1995). The International Whaling Commission (IWC) historically divided the North Pacific into two management regions (Donovan 1991) defined by a zig-zag line which starts at 150ºW at the equator, is 160ºW between 40-50ºN, and ends up at 180ºW north of 50ºN; however, the IWC has not reviewed this stock boundary recently (Donovan 1991). Sperm whales are found year-round in California waters (Dohl *et al.* 1983; Barlow 1995; Forney *et al.* 1995), but they reach peak abundance from April through mid-June and from the end of August through mid-November (Rice 1974). Sperm whales are seen off Washington and Oregon in every season except winter (Green *et al.* 1992). Of 176 sperm whales that were marked with Discovery tags off southern California in winter between 1962 and 1970, only three were recovered by whalers: one off northern California in June, one off Washington in June, and another far off British Columbia in April (Rice 1974). 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 declines westward towards the middle of the tropical Pacific (near the IWC stock boundary at 150ºW) and declines northward towards the tip of Baja California. Sperm whale population structure in the eastern tropical Pacific is unknown, but the only photographic matches of known individuals from this area have been between the Galapagos Islands and coastal waters of South America (Dufault and Whitehead 1995) and between the Galapagos Islands and the southern Gulf of California (Jaquet *et al.* 2003), suggesting that eastern tropical Pacific animals constitute a distinct stock. No apparent distributional hiatus was found between the U.S. Exclusive Economic Zone (EEZ) off California and Hawaii during a survey designed specifically to investigate stock structure and abundance of sperm whales in the northeastern temperate Pacific (Barlow and Taylor 2005). Sperm whales in the California Current have been identified as demographically independent from animals in Hawaii and the Eastern Tropical Pacific, based on genetic analyses of single-nucleotide polymorphisms (SNPs), microsatellites, and mtDNA (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 areas: 1) California, Oregon and Washington waters (this report), 2) waters around Hawaii, and 3) Alaska waters.

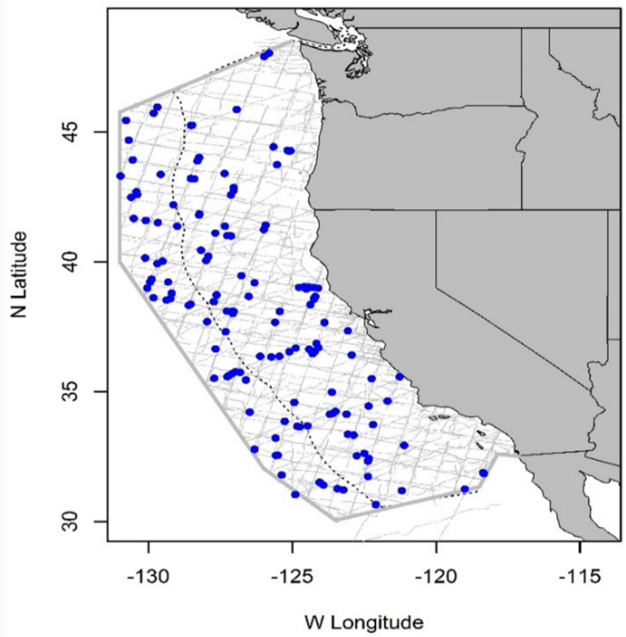

Figure 1. Sperm whale sighting locations from shipboard surveys off California, Oregon, and Washington, 1991-2014. Dashed line represents the U.S. EEZ, thin lines indicate completed transect effort of all surveys combined.

POPULATION SIZE

Previous estimates of sperm whale abundance from 2005 (3,140, CV=0.40, Forney 2007) and 2008 (300, CV=0.51, Barlow 2010) show a 10-fold difference that cannot be attributed to human-caused or natural population declines and likely reflect sampling variance and inter-annual variability in movement of animals into and out of the study area. New estimates of sperm whale abundance in California, Oregon, and Washington waters out to 300 nmi are available from a trend-model analysis of line-transect data collected from seven surveys conducted from 1991 to 2014 (Moore and Barlow 2017). Abundance trend models incorporate information from the entire 1991 to 2014 time series to obtain each annual abundance estimate, yielding estimates with less inter-annual variability. The trend model also uses improved estimates of group size and trackline detection probability (Moore and Barlow 2014, Barlow 2015). Sperm whale abundance estimates based on the trend-model range between 2,000 and 3,000 animals for the 1991 to 2014 time series (Moore and Barlow 2014). The best estimate of sperm whale abundance in the California Current is the trend-based estimate corresponding to the most recent 2014 survey, or 1,997 (CV= 0.57) whales. This estimate is corrected for diving animals not seen during surveys.

Minimum Population Estimate

The minimum population estimate for sperm whales is taken as the lower 20th percentile of the posterior distribution of the 2014 abundance estimate, or 1,270 whales (Moore and Barlow 2017).

Current Population Trend

Moore and Barlow (2014) reported that sperm whale abundance appeared stable from 1991 to 2008 (Figure 2) and additional data from a 2014 survey does not change that conclusion (Moore and Barlow 2017). Estimated growth rates of the population include a high uncertainty levels: the growth rate parameter from a Markov model has a posterior median and mean of +0.01 (SD = 0.06) with a broad 95% credible interval (CRI) ranging from -0.11 to +0.13 and a 60% chance of being positive. Another growth rate estimated from a regression model has a posterior mean of +0.01 with 95% CRI ranging from −0.06 to +0.07 (62% chance that growth has been positive), indicating that for the 1991-2014 study period, conclusions about whether the population has increased or decreased are uncertain (Moore and Barlow 2017).

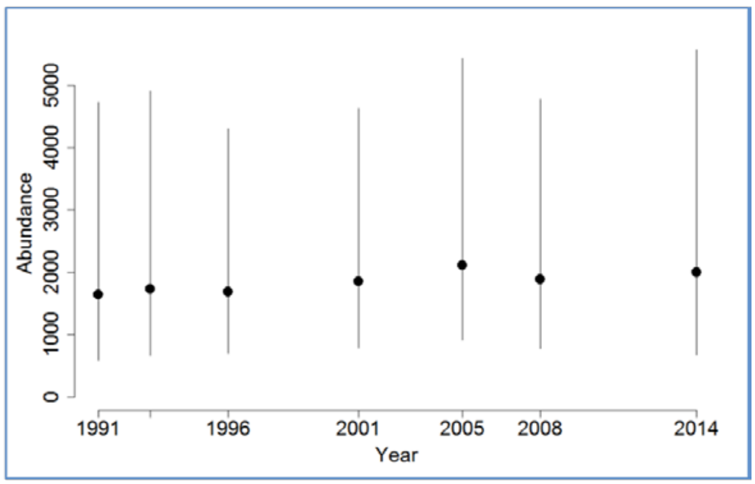

Figure 2. Trend-based estimates of sperm whale abundance in the California Current, 1991-2014 (Moore and Barlow 2017). Abundance estimates (posterior medians [●] and 95% CRIs) from the trend model.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

A reliable estimate of the maximum net productivity rate is not unavailable for the CA/OR/WA stock of sperm whales. Hence, until additional data become available, it is recommended that the cetacean maximum net productivity rate (R_{max}) of 4% be employed for this stock at this time (Wade and Angliss 1997).

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for this stock is calculated as the minimum population size (1,270) <u>times</u> one half the default maximum net growth rate for cetaceans (½ of 4%) <u>times</u> a recovery factor of 0.1 (for an endangered stock with N_{min} <1,500; Taylor *et al.* 2003), resulting in a PBR of 2.5 animals per year.

HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

Fishery Information

The fishery most likely to injure or kill sperm whales from this stock is the California thresher shark/swordfish drift gillnet fishery (Julian and Beeson 1998, Carretta *et al.* 2019a, 2019b). Observed serious injury and mortality is rarely observed in the fishery (10 animals from 6 events observed during 8,956 fishing sets between 1990 and 2017, Carretta *et al.* 2019b). Previous ratio estimates of drift gillnet bycatch for this stock suffered from inter-annual volatility and estimation bias because estimates were based on intra-annual data where observed entanglements were rare and observer coverage was low (Julian and Beeson 1998, Carretta *et al.* 2004, Carretta and Moore, 2014,). The prescribed strategy of pooling 5 years of annual bycatch estimates in stock assessments (Wade and Angliss 1997) is insufficient to overcome these biases when events are rare and when estimates are based on within-year data (Carretta and Moore 2014). However, model-based bycatch estimates that incorporate all available data for annual estimates allow for the robust pooling of data over 5-year time periods. New model-based estimates of sperm whale bycatch based on random forest regression trees were generated for the 28-year period 1990-2017, where annual estimates incorporate data from all years (Carretta *et al.* 2019b). Additionally, estimates were derived for the most recent 5-year period of 2013 to 2017, and because the last observation of sperm whale entanglement occurred >5 years ago, Table 1 also includes bycatch estimates for the most recent 10-year period (2008-2017) for additional context. Estimated entanglements for the period 2013-2017 in the California drift gillnet fishery are 2.9 (CV=1.3) sperm whales, however, not all of these represent deaths or serious injuries (Carretta *et al.* 2019b). Based on a review of sperm whale entanglements in the fishery, 7 of the 10 entanglements resulted in serious injury (n=2) or death (n=5), with the remaining 3 cases resulting in non-serious injuries because animals were released from nets uninjured and were expected to live. The estimated number of sperm whales seriously-injured or killed from 2013-2017 is therefore 2.0 (CV=1.4) whales (Carretta *et al.* 2019b), or 0.4 whales annually (Table 1). The 5-year annual mean (0.4 whales, CV=1.4) is similar to the 10-year annual mean of 0.56 whales (Table 1). Two notable differences between intra-annual ratio estimates and model-based estimates of bycatch are: 1) annual model-based estimates can be positive, even when no entanglements were observed and 2) estimates can take on fractional values (<1 whale) (Carretta *et al.* 2019b, Table 1). As some estimates of serious injury and mortality are < 0.5 of a whale, resulting coefficients of variation (CVs) can be quite large due to the extremely small mean estimates. Of particular note is that the regression tree bycatch estimate for 2010 is 2.0 sperm whales entangled (Carretta *et al.* 2019b). The ratio estimate of bycatch for the same year is 16.7 whales and is considered positively-biased (Carretta *et al.* 2019b). The estimate of serious injury and death in the fishery in 2017 is also 2.0 whales, even though there were no entanglements observed that year. The 2017 estimate (equal to the 2010 estimate) is among the highest in the previous 10 years because observed fishing depths and locations in 2017 are similar to fishing conditions associated with observed sperm whale entanglements and predictions of unobserved bycatch are based on these fishing set characteristics (Carretta *et al.* 2019b).

Estimates of sperm whale bycatch in the limited-entry sablefish hook and line fishery are also available for 2012 to 2016, based on a single observed interaction in 2007 (Jannot *et al.* 2018). Estimates are based on a Bayesian model for years without observed bycatch and are approximately 0.25 whales annually (Jannot *et al*. 2018, Table 1).

Strandings of sperm whales are rare and it is expected that documented anthropogenic deaths and injuries due to entanglements within unknown fisheries or ingestion of marine debris represent a small fraction of the true number of cases, due to the low probability that the carcass of a highly-pelagic species washes ashore (Williams *et al.* 2011, Carretta *et al.* 2016a). Published summaries of human-caused mortality and serious injury of sperm whales from unidentified fisheries and marine debris on the U.S. west coast include records inclusive from 2007 to 2015 (Jacobsen *et al.* 2010, Carretta *et al.* 2013, 2014, 2015, 2016b, 2017a, 2019a). Three separate sperm whale strandings in 2008 (all dead animals) showed evidence of fishery interactions (Jacobsen *et al.* 2010). Two whales died from gastric impaction as a result of ingesting multiple types of floating polyethylene netting (Jacobsen *et al.* 2010). The variability in size and age of the ingested net material suggests that it was ingested as surface debris and was not the result of fishery depredation (Jacobsen *et al.* 2010). Net types recovered from the whales' stomachs included portions of gillnet, bait nets, and fish/shrimp trawl nets. A third whale in 2008 showed evidence of entanglement scars (Carretta *et al.* 2013). In the most recent 5-year period (2013 to 2017), there were no observations of sperm whale serious injuries or mortalities in commercial fisheries for this stock of sperm whales (Carretta *et al.* 2019a, 2019b). Total annual commercial fishery-related serious injury and mortality of sperm whales is therefore the sum of

California drift gillnet fishery serious injury and mortality from 2013-2017 (0.4 whales) and limited-entry sablefish hook and line estimates (0.24 whales) or 0.64 whales per year. (Table 1).

Table 1. Summary of available information on the incidental mortality and injury of sperm whales (CA/OR/WA stock) for commercial fisheries that might take this species. n/a indicates that data are not available. Mean annual serious injury and mortality for the California swordfish drift gillnet fishery are based on 2013-2017 data and annual estimates for the most recent 10-year period are provided for additional context.

Fishery Name	**Year(s)**	**Data Type**	**Percent Observer Coverage**	**Observed mortality (and serious injury in parentheses)**	**Estimated mortality and serious injury (CV)**	**Mean annual mortality and serious injury (CV)**
CA thresher shark/swordfish drift gillnet fishery	2008 2009 2010 2011 2012 2013 2014 2015 2016 2017	observer	14% 13% 12% 20% 19% 37% 24% 20% 18% 19%	0 0 1 (1) 0 0 0 0 0 0 0	0.2 (1.7) 0.3 (2.5) 2 (n/a) 0.6 (2.7) 0.1 (2.1) 0.1 (1.5) 0.2 (2.7) <0.1 (2.7) 0.1 (2.0) 2 (1.7)	0.56 (0.78)
	2013-2017	**observer**	**23%**	**0**	**2 (1.4)**	**0.4 (1.4)**
WA/OR/CA groundfish, bottomfish longline/set line	2012-2016	observer	25-30%	0	0	0.24 (n/a)
Total annual takes						≥ 0.64 (1.4)

Sperm whales from the North Pacific stock depredate longline sablefish catch in the Gulf of Alaska and sometimes incur serious injuries from becoming entangled in gear (Sigler *et al.* 2008, Allen and Angliss 2011). An unknown number of whales from the CA/OR/WA stock probably venture into waters where Alaska longline fisheries operate, but the amount of temporal and spatial overlap is unknown. Thus, the risk of serious injury to CA/OR/WA stock sperm whales resulting from longline fisheries cannot be quantified.

Ship Strikes

One sperm whale died as the result of a ship strike in Oregon in 2007 (NMFS Northwest Regional Stranding data, unpublished). Another sperm whale was struck by a 58-foot sablefish longline vessel in 2007 while at idle speed (Jannot *et al.* 2011). The observer noted no apparent injuries to the whale. Based on the size and speed of the vessel relative to the size of a sperm whale, this incident was categorized as a non-serious injury (Carretta *et al.* 2013). For the most recent 5-year period of 2013 to 2017, no ship strike deaths or serious injuries were observed. Due to the low probability of a sperm whale carcass washing ashore, estimated ship strike deaths are likely underestimated. Ship strikes are assessed over the most recent 5-year period to reflect the degree of shipping risk to large whales since ship traffic routes changed in response to new ship pollution rules implemented in 2009 (McKenna *et al.* 2012, Redfern *et al.* 2013).

Other removals

Whaling removed at least 436,000 sperm whales from the North Pacific between 1800 and the end of legal commercial whaling for this species in 1987 (Best 1976; Ohsumi 1980; Brownell 1998; Kasuya 1998). 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), and approximately 1,000 were reported taken in land-based U.S. West coast whaling operations between 1919 and 1971 (Ohsumi 1980; Clapham et al. 1997). There has been a prohibition ban on taking sperm whales in the North Pacific since 1988, but large-scale pelagic whaling stopped in 1980.

STATUS OF STOCK

Sperm whales are listed as "endangered" under the U.S. Endangered Species Act (ESA), and consequently this stock is automatically considered as "depleted" and "strategic" under the MMPA. The status of sperm whales with respect to carrying capacity and optimum sustainable population (OSP) is unknown. The observed annual rate of documented mortality and serious injury ($\geq$ 0.64 per year) is less than the calculated PBR (2.5) for this stock, but anthropogenic mortality and serious injury is likely underestimated due to incomplete detection of carcasses and injured whales. Total human-caused mortality is greater than 10% of the calculated PBR and, therefore, is not insignificant and approaching zero mortality and serious injury rate. Increasing levels of anthropogenic sound in the world's oceans has been suggested to be a habitat concern for whales, particularly for deep-diving whales like sperm whales that feed in the ocean's sound channel.

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