Revised 6/1/2018

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 40°N 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 150°W at the equator, is 160°W between 40-50°N, and ends up at 180°W north of 50°N; 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 1962-70, 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). Recent 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 150°W) 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. 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.

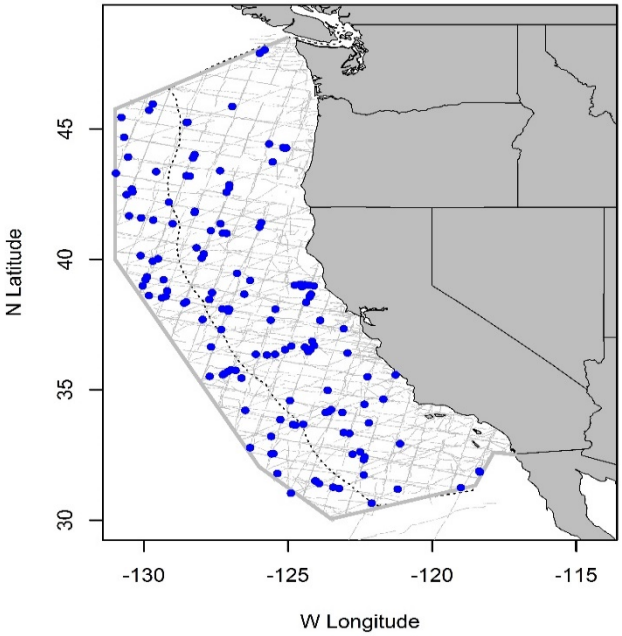

Figure 1. Sperm whale sighting locations from shipboard surveys off California, Oregon, and Washington, 1991-2014. Dashed line represents the U.S. EEZ, thin lines indicate completed transect effort of all surveys combined.

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 ten-fold difference that cannot be attributed to human-caused or natural population declines and likely reflect sampling variance or 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), using the same methods and in a previous abundance trend analysis (Moore and Barlow 2014). Abundance trend models incorporate information from the entire 1991-2014 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 ranged between 2,000 and 3,000 animals for the 1991-2014 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 survey (2014), or 1,997 (CV= 0.57) animals. 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 level of uncertainty, with a growth rate parameter from a Markov model having 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 estimate a regression model had 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).

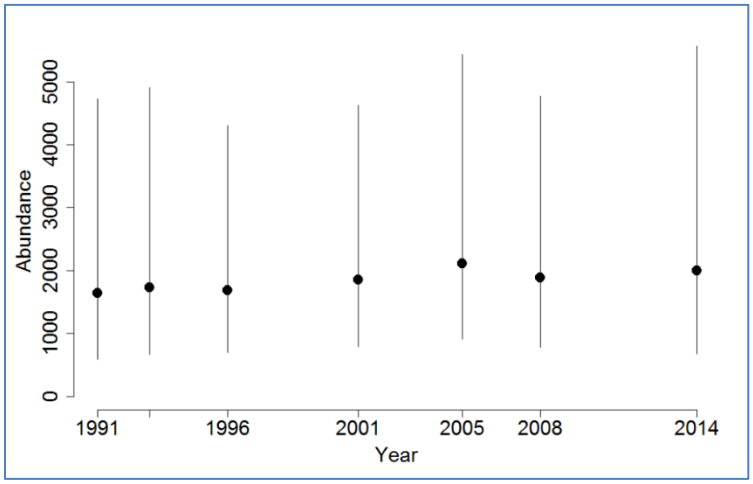

Figure 2. Trend-based estimates of sperm whale abundance in the California Current, 1991-2014 (Moore and Barlow 2017). Abundance estimates (posterior medians [●] and 95% CRIs) from the trend model.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

A reliable estimate of the maximum net productivity rate is not currently available 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) times one half the default maximum net growth rate for cetaceans (½ of 4%) times 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

Serious Injury Guidelines

NMFS uses guidance from previous serious injury workshops, expert opinion, and analysis of historic injury cases to distinguish serious from non-serious injury (Angliss and DeMaster 1998, Andersen *et al.* 2008, NOAA 2012). NMFS defines serious injury as an "injury that is more likely than not to result in mortality."

Fishery Information

The fishery most likely to directly take sperm whales from this stock is the California thresher shark/swordfish drift gillnet fishery (Julian and Beeson 1998, Carretta *et al.* 2017a, 2017b). Observed serious injury and mortality has been rarely documented in the gillnet fishery (10 animals from 6 events observed during 8,711 fishing sets between 1990 and 2015, Carretta *et al.* 2017b). 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, Carretta *et al.* 2017b). 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 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 26-year period 1990-2015, where annual estimates incorporate data from all years (Carretta *et al.* 2017b). Additionally, estimates were derived for the most recent 5-year period of 2011-2015, 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 (2006-2015) for additional context. Estimated entanglements for the period 2011-2015 in the California drift gillnet fishery are 2.6 (CV=1.2) sperm whales, however, not all of these represent deaths or serious injuries (Carretta *et al.* 2017b). 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 2011-2015 is therefore 1.8 (CV=1.3) whales (Carretta *et al.* 2017b), or 0.4 whales annually (Table 1). The 5-year annual mean (0.4 whales, CV=1.3) is similar to the 10-year annual mean of 0.55 (CV=0.78) 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.* 2017b, 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 (rounded value of 2 observations plus an estimated 0.03 whales from unobserved sets) (Carretta *et al.* 2017b). The ratio estimate of bycatch for the same year is 16.7 whales and is considered positively-biased (Carretta *et al.* 2017b).

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). 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). The mean annual serious injury and mortality of sperm whales due to unidentified fisheries for 2007-2015 is 3 animals / 9 years, or 0.3 whales annually. Total annual fishery-related serious injury and mortality of sperm whales is the sum of California drift gillnet fishery (0.4/yr), plus unidentified fisheries (≥0.3 / yr), or 0.7 whales annually (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 2011-2015 data and annual estimates for the most recent 10-year period are provided for additional context. The

Fishery Name	Year(s)	Data Type	Percent Observer Coverage	Observed mortality (and serious injury in parentheses)	Estimated mortality and serious injury (CV in parentheses)	Mean annual mortality and serious injury (CV in parentheses)
CA thresher shark/swordfish drift gillnet fishery	2006	observer	19%	0	0.6 (3.4)	0.55 (0.78)
	2007		16%	0	0.9 (2.4)	
	2008		14%	0	0.1 (4.2)	
	2009		13%	0	0.1 (3.6)	
	2010		12%	1 (1)	2 (n/a)	
	2011		20%	0	0.4 (3.7)	
	2012		19%	0	0.2 (2.8)	
	2013		37%	0	0.2 (2.3)	
	2014		24%	0	0.9 (1.9)	
	2015		20%	0	0.1 (6.8)	
	2011-2015	**observer**	**24%**	**0**	**1.8 (1.3)**	**0.4 (1.3)**
Unknown fishery	2007-2015	stranding	n/a	3	≥ 3	≥ 0.33 (n/a)
Total annual takes						≥ 0.7 (1.3)

Sperm whales from the North Pacific stock are known to depredate on 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 2011-2015, one ship strike death of a sperm whale was documented in 2012 (Carretta *et al.* 2017a) and the mean annual average mortality and serious injury is ≥ 0.2 whales. 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).

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 which is no longer accepted as valid. 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 on taking sperm whales in the North Pacific since 1988, but large-scale pelagic whaling stopped in 1980. Sperm whales are formally listed as "endangered" under the Endangered Species Act (ESA), and consequently the California to Washington stock is automatically considered as a "depleted" and "strategic" stock under the MMPA. The status of sperm whales with respect to carrying capacity and optimum sustainable population (OSP) is unknown. Including annual fishery ($\geq$ 0.7) and ship-strike ($\geq$ 0.2) mortality and serious injury, the annual rate of documented mortality and serious injury ($\geq$ 0.9 per year) is less than the calculated PBR (2.5) for this stock, but this is likely underestimated due to incomplete detection of carcasses. Total human-caused mortality is greater than 10% of the calculated PBR and, therefore, cannot be considered to be 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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