Revised 3/14/2022

HUMPBACK WHALE (*Megaptera novaeangliae*): California/Oregon/Washington Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

NMFS conducted a global Status Review of humpback whales and revised the ESA listing of the species, based on identification of distinct population segments (DPSs) (Bettridge *et al*. 2015, NOAA 2016a). NMFS is evaluating the stock structure of humpback whales under the MMPA, but no revisions to the current stock definition are presented at this time.

North Pacific humpback whales (*M. novaeangliae kuzira*) comprise a distinct subspecies based on mtDNA and DNA relationships and distribution compared to North Atlantic humpback whales (*M. n. novaeangliae*) and those in the Southern Hemisphere (*M. n. australis*) (Jackson *et al*. 2014). Humpback whales occur throughout the North Pacific, with multiple populations recognized based on low-latitude winter breeding areas (Baker *et al*. 1998, Calambokidis *et al*. 2001, Calambokidis *et al*. 2008, Barlow *et al*. 2011, Fleming and Jackson 2011). North Pacific breeding areas fall broadly into three regions: 1) western Pacific (Japan and Philippines); 2) central Pacific (Hawaiian Islands); and 3) eastern Pacific (Central America and Mexico) (Calambokidis *et al*. 2008). Exchange of animals between breeding areas occurs rarely, based on photo-identification evidence (Calambokidis *et al*. 2001, Calambokidis *et al*. 2008). Photo-identification evidence also shows strong site fidelity to feeding areas, but animals from multiple feeding areas converge on common winter breeding areas and whales from multiple breeding areas may share feeding areas (Calambokidis *et al*. 2008, Wade 2017, 2021). Baker *et al*. (2008) reported significant differences in mtDNA haplotype frequencies among different North Pacific breeding and feeding areas, reflecting strong matrilineal site fidelity to respective migratory destinations. The most significant differences in haplotype frequencies were found between California/Oregon and Russian and Southeastern Alaska feeding areas (Baker *et al*. 2013). Among breeding areas, the greatest level of differentiation was found between Okinawa and Central America (Baker *et al*. 2013). Genetic differences between feeding and breeding grounds were also found, even for areas where regular exchange of animals between feeding and breeding grounds is confirmed by photo-identification (Baker *et al*. 2013).

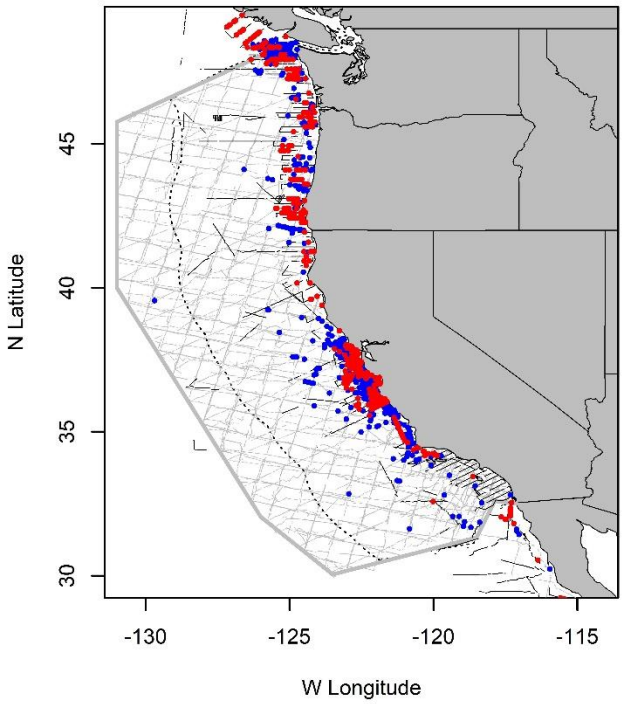

Figure 1. Humpback whale sightings based on shipboard surveys off California, Oregon, and Washington, 1991-2018. Dashed line represents U.S. EEZ, thin lines indicate completed transect effort (gray = 1991-2014, black = 2018). Sightings from the 2018 survey are shown in red.

The California/Oregon/Washington Stock as defined includes humpback whales from two feeding groups: California-Oregon and Southern British Columbia – Washington (SBC/WA) (Calambokidis *et al*. 1996, Calambokidis *et al*. 2008, Barlow *et al*. 2011). The California-Oregon feeding group includes whales from the Mexico and Central America DPSs and it is estimated that most Central America DPS whales use California-Oregon waters for feeding (NOAA 2016a, Wade *et al.* 2016, Wade 2017). Based on a Pacific-wide photo-ID effort from 2004-2006, Wade (2021) reported that of 180 unique whale identifications from the SBC/WA stratum, 28 were matched to Mexico wintering areas, 19 to Hawai‘i, and 3 to Central America. Wade (2021) also estimated movement probabilities from the SBC/WA stratum to each wintering area. The highest movement probabilities were between SBC/WA and Hawai’i (0.688),

followed by SBC/WA and Mexico (0.254), and SBC/WA and Central America (0.059). Seven areas important for humpback whale feeding are identified off the U.S. West Coast by Calambokidis *et al*. (2015), including five in California, one in Oregon, and one in Washington. Humpback whales have increasingly reoccupied areas in Puget Sound (the 'Salish Sea'), a region where they were historically abundant prior to whaling (Calambokidis *et al*. 2017).

Three other humpback whale stocks are recognized in the Pacific region stock assessment reports: (1) Central North Pacific Stock (with feeding areas from Southeast Alaska to the Alaska Peninsula), (2) Western North Pacific Stock (with feeding areas from the Aleutian Islands, the Bering Sea, and Russia), and (3) American Samoa Stock in the South Pacific (with largely undocumented feeding areas as far south as the Antarctic Peninsula).

POPULATION SIZE

Calambokidis and Barlow (2020) estimated humpback whale abundance for the U.S. West Coast based on survey data through 2018, using mark-recapture methods consistent with past estimates (Calambokidis and Barlow 2004, 2013, 2017). Data from a 2018 line-transect and photo-ID survey represents the most comprehensive effort with respect to spatial coverage of humpback habitat and photo-ID sample sizes to date on the U.S. West Coast (Calambokidis and Barlow 2020, Henry *et al*. 2020). The best estimate of current abundance is based the most-recent 4 years (2015-2018) of mark-recapture data and a Chao model that accounts for heterogeneity of capture probabilities, resulting in an estimate of 4,973 (CV=0.048) whales (Calambokidis and Barlow 2020). This estimate is calculated using identifications from California and Oregon waters, but the authors note that it likely includes the smaller number of whales from Washington state waters since there is interchange with that area. Becker *et al*. (2020) also estimated humpback whale abundance in California, Oregon, and Washington waters based on habitat models and 1991-2018 line-transect data. Their most-recent estimate for 2018 is 4,784 whales (CV=0.31). However, the mark-recapture estimate is considered the best estimate because 1) it has better precision and 2) the line-transect estimate reflects only whale densities within the study area during summer and autumn when surveys were conducted.

Minimum Population Estimate

The minimum population estimate for humpback whales in the California/Oregon/Washington stock is taken as the lower 20th percentile of the mark-recapture estimate, or 4,776 whales (Calambokidis and Barlow 2020).

Current Population Trend

Calambokidis and Barlow (2020) report that humpback whale abundance appears to have increased within the California Current at approximately 8.2% annually since the late 1980s (Figure 2). This is consistent with observed increases for the entire North Pacific from ~1,200 whales in 1966 to 18,000 - 20,000 whales during 2004 to 2006 (Calambokidis *et al*. 2008). Calambokidis and Barlow (2020) note that the apparent increase in abundance from 2014 to 2018 is too great to represent real population growth and may reflect negatively-biased estimates during 2009 to 2014 due to less representative sampling compared with 2018.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

The proportion of calves in the California/Oregon/Washington stock from 1986 to 1994 appeared much lower than previously measured for humpback whales in other areas (Calambokidis and Steiger 1994), but between 1995 and 1997 a greater proportion of calves were identified, and the 1997 reproductive rates for this population were closer to those reported for other humpback whale populations (Calambokidis *et al*. 1998). Despite the apparently low proportion of calves, two independent lines of evidence indicate that this stock was growing in the 1980s and early 1990s (Barlow 1994; Calambokidis *et al*. 2003). Calambokidis and Barlow (2020) note that the growth of this population since the 1980s to a current estimate of 4,784 whales implies a rate of increase of 8.2% per year (Calambokidis *et al*. 1999), which is taken as the maximum net productivity rate for this stock. The current net productivity rate is unknown.

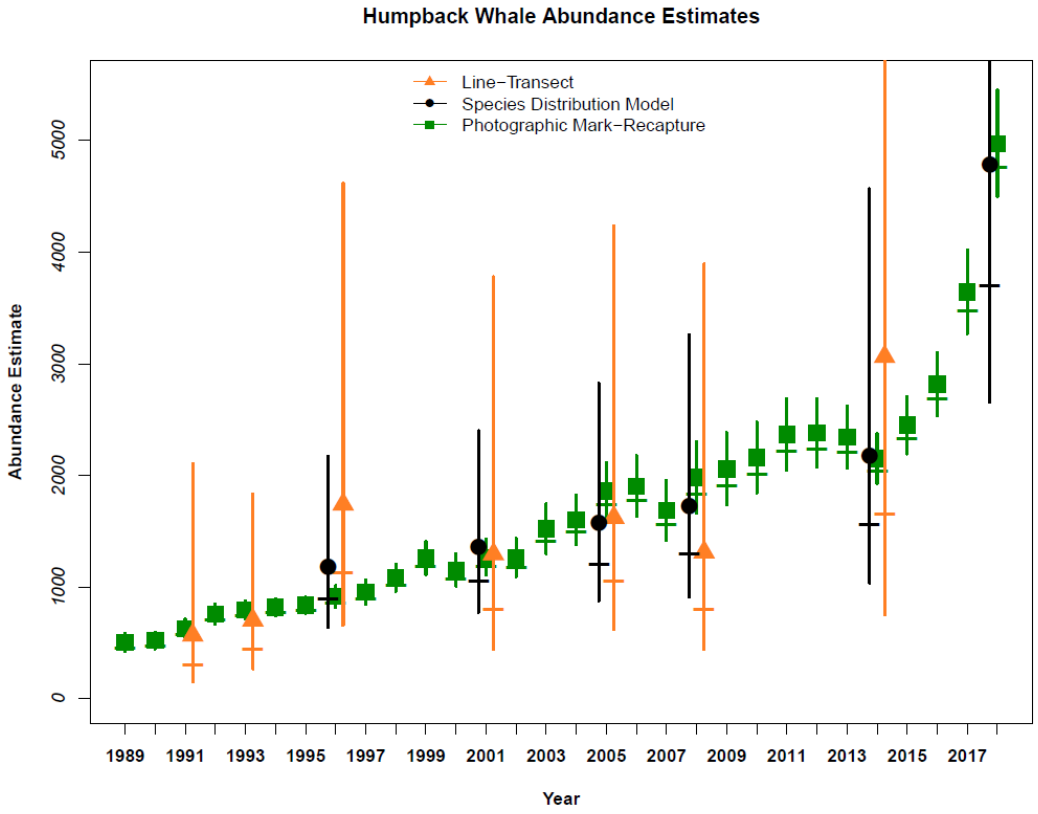

Figure 2. Estimated abundance of humpback whales off California, Oregon, and Washington, based on line-transect surveys (Barlow 2016), habitat-based species distribution models (Becker *et al.* 2020) and photographic mark-recapture surveys (Calambokidis and Barlow 2020). Mark-recapture estimates are based on a Chao model that uses rolling 4-year periods and accounts for heterogeneity of capture probability. Horizontal hatch marks represent minimum population size estimates based on 20th percentiles of mean estimates. Line-transect surveys in 1991 and 1993 did not include the waters of Oregon and Washington. The y-axis has been truncated to provide the best display in variability in mean estimates between methods. Upper 95% confidence limits for line-transect surveys in 2014 and species distribution models in 2018 not visible in this plot were approximately 12,000 and 8,600 whales respectively.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for this stock is calculated as the minimum population size (4,776) times one half the estimated population growth rate for this stock of humpback whales (½ of 8.2%) times a recovery factor of 0.3 (for an endangered species with $N_{min} > 1,500$ and $CV(N_{min}) < 0.50$, Taylor *et al*. 2003), resulting in a PBR of 58.7. Because this stock spends approximately half its time outside the U.S. Exclusive Economic Zone (EEZ), the PBR in U.S. waters is 29.4 whales per year.

HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

A total of 173 human-related interactions involving humpback whales are summarized during 2015 to 2019 by Carretta *et al.* (2021). These records include serious injuries, non-serious injuries, and mortalities involving pot/trap fisheries (n= 81), unidentified fishery interactions (68), gillnet fisheries (11), vessel strikes (11), hook and line fisheries (1) and marine debris (1). The number of serious injuries and mortalities in each category are summarized below. In addition to interactions with humpback whales, 16 entanglements involving 'unidentified whales' occurred from 2015 to 2019, some of which were certainly humpback whales. These 16 unidentified whale injuries are prorated to species using the method in Carretta (2018) and result in an additional ≥ 2.0 humpback whale serious injuries annually (Table 1).

Fishery Information

Pot and Trap Fisheries

Pot and trap fishery entanglements are the most frequently-documented source of serious injury and mortality of humpback whales in U.S. west coast waters and reported entanglements increased considerably in 2014 (Carretta *et al*. 2013, 2019a). From 2015 to 2019, 81 observed interactions with pot and trap fisheries were observed (Carretta *et al.* 2021). Four pot/trap fishery records involved recreational fisheries and one record involved Washington tribal crab pot gear, which are excluded from commercial fishery totals in Table 1, but are summarized in the 'Other Mortality' section of this report. Serious injuries and mortalities in the remaining 76 commercial fishery cases involving pot/trap gear total 51.75 whales for 2015 to 2019 (Table 1, Carretta *et al*. 2021). Table 1 totals represent minimum observed cases from opportunistic at-sea sightings or stranding records, except for bycatch estimates based on systematic observer program data. It is recognized that entanglement totals do not represent all cases due to incomplete detection of incidents and no method is currently available to correct for undetected entanglements.

Gillnet and Unidentified Fisheries

Gillnet (n=11) and unidentified fisheries (n=68) accounted for 79 humpback whale interactions from 2015 to 2019 (Carretta *et al.* 2021). Based on the proportion of humpback whale entanglements where the type of fishing gear is positively-identified, it is likely that most cases involving "unidentified fisheries" represent pot and/or trap gear (Carretta *et al*. 2021). Of 11 gillnet-related interactions, three were attributed to tribal fisheries (see Other Mortality section). Commercial fishery serious injuries and mortalities due to gillnet (3.5) plus unidentified fishery interactions (51.25) total 54.75 whales for 2015 to 2019 (Table 1).

Three humpback whale entanglements (all released alive) were observed in the CA swordfish drift gillnet fishery from 9,158 fishing sets monitored between 1990 and 2019 (Carretta 2021). Some at-sea sightings of free-swimming humpback whales entangled in gillnets may originate from this fishery. The most recent estimate of humpback whale serious injury and mortality in this fishery for 2015 to 2019 is 0.1 whales (CV= 4.6) (Carretta 2021). The average annual estimated serious injury and mortality in the CA swordfish drift gillnet fishery is 0.02 whales.

Table 1. Observed and estimated incidental mortality and serious injury of humpback whales (California/Oregon/Washington stock) in commercial fisheries that are likely to take this species (Carretta 2021, Carretta *et al.* 2021, Jannot *et al*. 2018). Mean annual takes are based on 2015 to 2019 data unless noted otherwise. Serious injuries may include prorated serious injuries with values less than one (NOAA 2012), thus the sum of serious injury and mortality may not be a whole number.

Fishery Name	Year(s)	Data Type	Percent Observer Coverage	Observed Mortality + Serious Injury	Estimated mortality and serious injury (CV)	Mean Annual mortality and serious injury (CV)
WA/OR/CA Sablefish Pot	2012	observer	35%	0	0.12 (n/a)	0.32 (n/a)
	2013		14%	0	0.19 (n/a)	
	2014		31%	1	1.15 (n/a)	
	2015		61%	0	0.08 (n/a)	
	2016		71%	0	0.06 (n/a)	
Open Access Fixed Gear Pot	2012	observer	7%	0	1.12 (n/a)	1.58 (n/a)
	2013		9%	0	0.67 (n/a)	
	2014		8%	0	1.3 (n/a)	
	2015		6%	0	2.03 (n/a)	
	2016		7%	0 + 0.75	2.76 (n/a)	
CA swordfish and thresher shark drift gillnet fishery	2015-2019	observer	21%	0	0.1 (4.6)	0.02 (4.6)
CA halibut/white seabass and other species large mesh (≥3.5") set gillnet fishery	2017	observer	~10%	0	0	0 (n/a)
CA spot prawn pot	2015-2019	Strandings / sightings	n/a	0 + 2.5	n/a	≥ 0.50 (n/a)
CA lobster trap / pot[1]	2015-2019	Strandings / sightings	n/a	0	n/a	0 (n/a)

[1] There was one non-serious injury involving this fishery during 2015-2019.

Unspecified pot or trap fisheries (includes generic 'Dungeness' crab gear not attributed to a specific state fishery)	2015-2019	Strandings / sightings	n/a	1 + 12	n/a	≥ 2.6 (n/a)
CA Dungeness crab pot	2015-2019	Strandings / sightings	n/a	5 + 22.75	n/a	≥ 5.55 (n/a)
OR Dungeness crab pot	2015-2019	Strandings / sightings	n/a	0 + 1.75	n/a	≥ 0.35 (n/a)
WA Dungeness crab pot	2015-2019	Strandings / sightings	n/a	1 + 4.25	n/a	≥ 1.05 (n/a)
CA Coonstripe Shrimp Pot[1]	2015-2019	Strandings / sightings	n/a	0	n/a	0
unidentified fisheries (includes 'unidentified gillnet') involving identified humpback whales	2015-2019	Strandings / sightings	n/a	2 + 52.75	n/a	≥ 10.95 (n/a)
Unidentified fishery interactions involving *unidentified whales* prorated to humpback whale	2015-2019	Strandings / sightings	n/a	0 + 10.0	n/a	≥ 2.0
Total Annual Takes						≥ 24.9 (n/a)

Unidentified whales represent approximately 15% of entanglement cases along the U.S. West Coast, (Carretta 2018). Observed entanglements may lack species identifications (IDs) due to rough seas, distance from whales, or a lack of cetacean identification expertise. In older stock assessments, these unidentified entanglements were not assigned to species, which results in underestimation of entanglement risk, especially for commonly-entangled species. To remedy this negative bias, a cross-validated species identification model was developed from known-species entanglements. The model is based on several variables (location + depth + season + gear type + sea surface temperature) found to be statistically-significant predictors of known-species entanglement cases (Carretta 2018). The species model was used to assign species ID probabilities for 16 unidentified whale entanglement cases from 2015 to 2019 (Carretta 2018). The sum of species assignment probabilities for 2015 to 2019 result in an additional 13.3 humpback whale entanglements. Unidentified whale entanglements typically involve whales seen at-sea with unknown gear configurations that are prorated to represent 0.75 serious injuries per entanglement case. Thus, it is estimated that at least 13.3 x 0.75 = 10 additional humpback serious injuries are represented from the 16 unidentified whale entanglement cases, or 2.0 humpback whales annually.

Total commercial fishery serious injury and mortality of humpback whales from 2015 to 2019 is the sum of serious injury and mortality observations and estimates from Table 1, or 124.6 whales. The mean annual serious injury and mortality (observed and estimated) from commercial fisheries from 2015 to 2019 is 124.6 whales / 5 years = 24.9 whales (Table 1).

Despite an increase in the number of reported entanglements in recent years, increasing efforts to disentangle humpback whales has led to an increase in the fraction of injuries reported as non-serious, due to the removal of gear from humpback whales that otherwise appear healthy. In the absence of human intervention, these records would have represented at least 10 additional serious injuries from 2015 to 2019, or an additional 2.0 humpback whales annually (Carretta *et al.* 2021).

Vessel Strikes

Eleven humpback whales were reported struck by vessels between 2015 and 2019, totaling 7 deaths and 1.8 serious injuries (Carretta *et al.* 2021). Observed mean annual serious injury and mortality of humpback whales due to vessel strikes is 1.76 whales per year (7 deaths, plus 1.8 serious injuries = 8.8 / 5 years). Vessel strike mortality was estimated for humpback whales in the U.S. West Coast EEZ (Rockwood *et al*. 2017), using an encounter theory model (Martin *et al.* 2016) that combined species distribution models of whale density (Becker *et al*. 2016), vessel traffic characteristics (size + speed + spatial use), and whale movement patterns obtained from satellite-tagged animals to estimate whale/vessel interactions that would result in mortality. The estimated number of annual vessel strike deaths was 22 humpback whales, though this includes only July – November when whales are most likely to be present in the U.S. West Coast EEZ and the season that overlaps with cetacean habitat models generated from line-transect surveys (Becker *et al*. 2016, Rockwood *et al*. 2017). This estimate was based on an assumption of a moderate level of vessel avoidance (55%) by humpback whales, as measured by the behavior of satellite-tagged whales in the presence of vessels (McKenna *et al*. 2015). The estimated mortality of 22 humpback whales annually due to vessel strikes represents approximately 0.4% of the estimated population size of the stock (22 deaths / 4,973 whales). The results of Rockwood *et al*. (2017) also include a no-avoidance encounter model that results in a worst-case estimate of 48 annual humpback whale vessel strike deaths, representing 0.9% of the estimated population size. The authors note that 82%

of humpback whale vessel strike mortalities occur within 10% of the study area, implying that vessel avoidance mitigation measures may be effective if applied over relatively small regions. The number of vessel strikes attributable to each DPS (Central America, Hawaii, Mexico) is unknown. Using the moderate level of avoidance model from Rockwood *et al.* (2017), estimated vessel strike deaths of humpback whales are 22 per year. A comparison of average annual vessel strikes observed during 2015 to 2019 (1.76/yr) and estimated vessel strikes (22/yr) indicates that the detection rate of humpback whale vessel strikes is ≤10%. Rockwood *et al*. (2021) provided updated estimates of annual vessel strike mortality for southern California only (4.6) that are higher than estimates for the same region (3.4) reported in Rockwood *et al.* (2017). Additionally, they estimated winter / spring vessel strike mortality for southern California (5.7 /yr) for the first time, which is higher than estimates for summer / autumn, despite the higher abundance of humpback whales in this region in summer and autumn.

Vessel strikes within the U.S. West Coast EEZ impact all large whale populations (Redfern *et al*. 2013; 2019; Moore *et al*. 2018). Diverse vessel types, speeds, and destination ports all contribute to variability in vessel traffic and these factors may be influenced by economic and regulatory changes. For example, Moore *et al*. (2018) found that primary routes travelled by vessels changed when emission control areas (ECAs) were established off the U.S. West Coast. They also found that large vessels typically reduced their speed by 3-6 kts in ECAs between 2008 and 2015. The speed reductions are thought to be a strategy to reduce operating costs associated with more expensive, cleaner burning fuels required within the ECAs. In contrast, Moore *et al*. (2018) noted that some vessels increased speed when transiting longer routes to avoid the ECAs. Further research is ongoing to understand how variability in vessel traffic affects vessel strike risk and mitigation strategies, though Redfern *et al*. (2019) note that a combination of vessel speed reductions and expansion of areas to be avoided should be considered.

Other human-caused mortality and serious injury

Carretta *et al*. (2021) summarize non-commercial serious injury and mortality totals during 2015-2019 for the following sources: recreational Dungeness crab pot (1.75), hook and line fisheries (0.75), marine debris (1.00), unidentified tribal gillnets (2.50), and Washington state tribal Dungeness crab pot (1.00). The sum of these non-commercial sources is 7 whales, or 1.4 whales annually for 2015 to 2019.

Habitat Concerns

Increasing levels of anthropogenic sound in the world's oceans (Andrew *et al*. 2002), such as those produced by shipping traffic, or LFA (Low Frequency Active) sonar, is a habitat concern for whales, as it can reduce acoustic space used for communication (masking) (Clark *et al.* 2009, NOAA 2016c). This can be particularly problematic for baleen whales that may communicate using low-frequency sound (Erbe 2016). Based on vocalizations (Richardson *et al*. 1995; Au *et al*. 2006), reactions to sound sources (Lien *et al*. 1990, 1992; Maybaum 1993), and anatomical studies (Hauser *et al*. 2001), humpback whales also appear to be sensitive to mid-frequency sounds, including those used in active sonar military exercises (U.S. Navy 2007). The impacts of marine heatwaves on the foraging activities of humpback whales, including changes in the abundance and distribution of prey and whale foraging locations, may increase risk of human interactions (Santora *et al*. 2020).

STATUS OF STOCK

Approximately 15,000 humpback whales were taken from the North Pacific from 1919 to 1987 (Tonnessen and Johnsen 1982), and, of these, approximately 8,000 were taken from the west coast of Baja California, California, Oregon and Washington (Rice 1978), presumably from this stock. Shore-based whaling apparently depleted the humpback whale stock off California twice: once prior to 1925 (Clapham *et al*. 1997) and again between 1956 and 1965 (Rice 1974). There has been a prohibition on taking humpback whales since 1966. As a result of commercial whaling, humpback whales were listed as "endangered" under the U.S. Endangered Species Conservation Act of 1969. This protection was transferred to the U.S. Endangered Species Act (ESA) in 1973. The humpback whale ESA listing final rule (81 FR 62259, September 8, 2016) established 14 distinct population segments (DPSs) with different listing statuses. The CA/OR/WA humpback whale stock primarily includes whales from the endangered Central American DPS and the threatened Mexico DPS, plus a small number of whales from the non-listed Hawaii DPS. Humpback whale stock delineation under the MMPA is under review, and until this review is complete, the CA/OR/WA stock will continue to be considered endangered and depleted for MMPA management purposes (e.g., selection of a recovery factor, stock status). Consequently, the California/Oregon/Washington stock is automatically considered as a "strategic" stock under the MMPA. Total annual human-caused serious injury and mortality of humpback whales is the sum of commercial fishery (24.9/yr) + non-commercial sources (1.4/yr) + estimated vessel strikes (22/yr), or 48.3 humpback whales annually. This exceeds the PBR estimate of 29.4 humpback whales. Other than the vessel strike estimates, most data on human-caused serious injury and mortality for this population is based on opportunistic

stranding and at-sea sighting data and represents a minimum count of total impacts. There is currently no estimate of the undocumented fraction of anthropogenic injuries and deaths to humpback whales on the U.S. west coast, but for vessel strikes, a comparison of observed vs. estimated annual vessel strikes suggests that ≤10% of vessel strikes are documented. Based on strandings and at-sea observations, annual humpback whale mortality and serious injury in commercial fisheries (24.9/yr) is less than the PBR of 29.4; however, if methods were available to correct for undetected serious injury and mortality, total fishery mortality and serious injury would likely exceed PBR. Observed and assigned levels of serious injury and mortality due to commercial fisheries (24.9) exceed 10% of the stock's PBR (29.4), thus, commercial fishery take levels are not approaching zero mortality and serious injury rate. Despite impacts of anthropogenic-related serious injury and mortality of humpback whales along the U.S. West Coast, the number of humpback whales in the region has been increasing at 8.2% annually since the late 1980s (Calambokidis and Barlow 2020).

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