Estimated Humpback Whale Bycatch in the U.S. West Coast Groundfish Fisheries, 2002 – 2021

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Executive Summary

In accordance with the National Marine Fisheries Service (NMFS) Biological Opinion (BiOp) on Continuing Operation of the Pacific Coast Groundfish Fishery, this document provides a summary of observed takes of U.S. Endangered Species Act (ESA)-listed humpback whales (*Megaptera novaeangliae*; Borowski, 1781) in sectors of the west coast groundfish fishery from 2002–2021. Throughout this report, we use "take" and "bycatch" interchangeably; in both cases, this term reflects the MMPA and ESA definition of any act that attempts to or succeeds in harassing, hunting, capturing, or killing a marine mammal, regardless of lethality.

There have been three documented takes of a humpback whale in the Pacific Coast groundfish fisheries – one in the Limited Entry (LE) sablefish pot fishery sector in 2014, one in the Open Access (OA) pot fishery sector in 2016, and one in the OA hook-and-line fishery sector in 2021. We used Bayesian procedures to estimate mean annual fleet-wide bycatch and a running 5-year fleet-wide average in the fixed gear sectors where humpback whale takes were observed. The combined LE and OA pot gear fisheries exceeded the 5-year running average threshold of 2.34 takes per year from 2007 to 2010 (Figure 2, Table 5). In addition, if all three fixed gear sectors are combined, the estimated fleet-wide entanglements/takes in the combined sectors exceeded the annual threshold of 5 takes per year in three years (2005, 2009, and 2010) and exceeded the 5-year running average threshold of 2.34 takes per year in all 15 years for which 5-year fleet-wide averages were calculable (Figure 2, Table 5).

Acknowledgements

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Introduction and Background[4]

In accordance with the National Marine Fisheries Service (NMFS) Biological Opinion Regarding the Effects of the Continued Operation of the Pacific Coast Groundfish Fishery (NMFS 2012a, 2020) as governed by Pacific Coast Groundfish Fishery Management Plan, this document provides a reporting of observed takes of U.S. Endangered Species Act-listed humpback whales (*Megaptera novaeangliae*; Borowski, 1781) in U.S. west coast groundfish fishery sectors. This report updates assessments submitted in accordance with the Biological Opinion requirement, which reported on bycatch in the fisheries for 2010-2013, 2014-15, 2016-2017, and 2018-2019 (Hanson et al. 2015, 2017, 2019, 2021).

Humpback whales are baleen whales of the family Balaenopteridae. Humpback whales are found in all oceans of the world from tropical to temperate waters in the northern hemisphere and tropical to arctic waters in the southern hemisphere. All populations migrate seasonally within ocean basins between winter calving and breeding grounds and summer feeding grounds . Despite this potential for dispersal, interbreeding of individuals from different major ocean basins is extremely rare. Whales from the major ocean basins are differentiated by reproductive seasonality, behavior, color patterns, and genetics.

Humpback whales were listed worldwide as endangered under the ESA in 1970, and a Recovery Plan was finalized for this species in 1991 (NMFS 1991). Under the MMPA, humpback whales are classified as a strategic stock and considered depleted. NMFS initiated an ESA status review of humpback whales in August 2009 (74 FR 40568). The status review identified distinct population segments (DPS) of humpback whale and evaluated their risk of extinction (Bettridge et al. 2015). NMFS issued a final rule in 2016 revising the listing status of the species (81 FR 62259), in which 14 distinct population segments (DPS) were identified. Of these, nine did not warrant listing under the ESA, four were listed as endangered, and one was listed as threatened. In the North Pacific, there are four discrete and significant DPS, based on wintering areas: *Western North Pacific* (endangered), *Central America* (endangered), *Mexico* (threatened), and *Hawaii* (not listed).

Breeding locations in the North Pacific include offshore of Hawaii, the west coasts of Central America and Mexico, and the Ogasawara, Okinawa Islands and the Philippines. Feeding areas in the North Pacific range from California, USA to Hokkaido, Japan. Strong fidelity to both feeding and breeding sites has been observed, but movements are complex (Calambokidis et al. 2008; Barlow et al. 2011). In general, Asia and Mexico/Central America are the dominant breeding areas for humpback whales that migrate to feeding areas in lower latitudes, coastal California and Russia. The Revillagigedo and Hawaiian Islands are wintering areas for humpback whales that feed in more central and higher latitude areas (Calambokidis et al. 2008). Exceptions to this pattern exist, and complex population structure and strong site fidelity appear to coexist with lesser known but potentially high levels of plasticity in movements of humpback whales (Salden et al. 1999).

[4] This section is adapted from the NOAA Fisheries Humpback Whale Status Review (Bettridge et al. (2015) and the draft U.S. Pacific marine mammal stock assessment (https://www.fisheries.noaa.gov/s3/2023-01/Draft%202022%20Pacific%20SARs_final.pdf).

The *Hawaii DPS* is composed of humpback whales that winter within the main Hawaiian Islands and that use feeding grounds in southeast Alaska and northern British Columbia, the Gulf of Alaska, and the Bering Sea. The *Central America DPS* is composed of humpback whales that winter along the Pacific coast of Central America and that use feeding grounds almost exclusively offshore of California and Oregon, with a few individuals in northern Washington-southern British Columbia. The *Mexican DPS* is composed of humpback whales that winter along the Pacific coast of mainland Mexico, Baja California, and the Revillagigedo Islands and that use feeding grounds from California to the Aleutian Islands, with concentrations in California-Oregon, northern Washington-southern British Columbia, northern and western Gulf of Alaska and Bering Sea. The *Western North Pacific DPS* is composed of humpback whales that winter around Okinawa and the Philippines and others that transit the Ogasawara area but breed in an unknown location and use feeding grounds primarily off the Russian coast and some off the Aleutian Islands.

Recently, NMFS evaluated if North Pacific DPS contained one or more demographically independent populations (DIPs), where population dynamics are defined more by within-group births and deaths than among-group immigration or emigration (NMFS 2016). The delineation of four North Pacific DPS into three DIPs and four units (that may contain one or more DIPs, Table 1) is based on evaluation of genetics, movement data, and morphology (Martien et al. 2021, Taylor et al. 2021, Wade et al. 2021, Oleson et al. 2022). From these DIPs and units, NMFS proposed designating five stocks in January 2023 (88 FR 4162) to better align with humpback whale DPS under the ESA (Figure 1, Table 1); the public comment period on the proposed five stocks ends 24 April 2023.

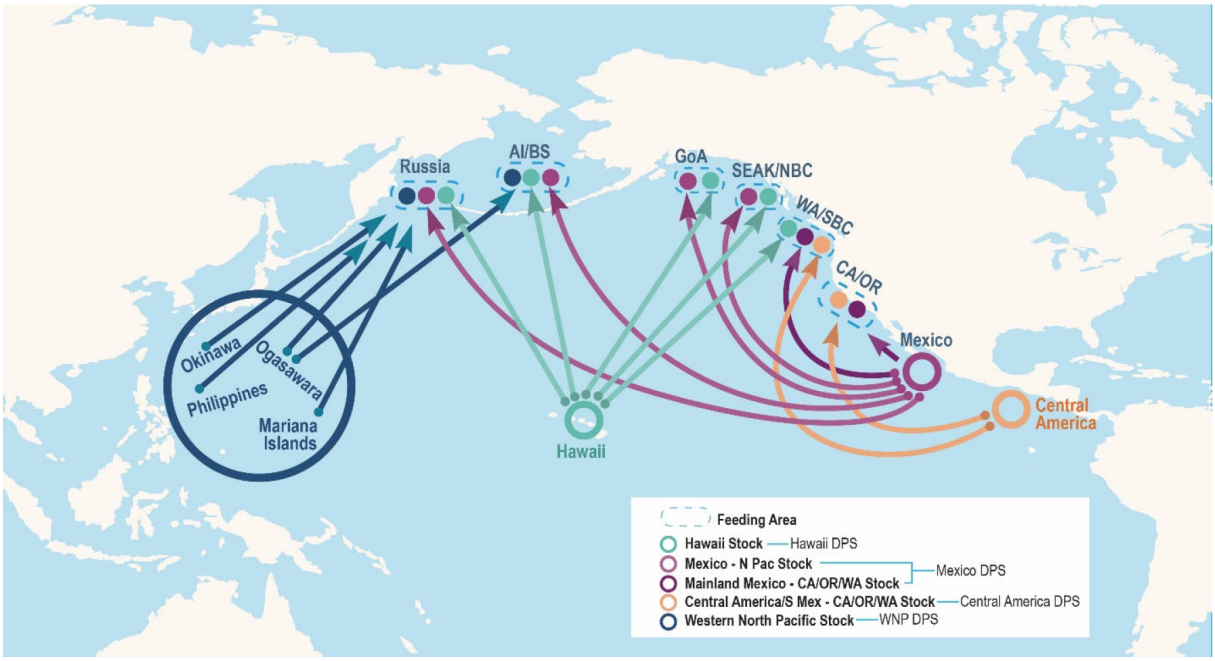

Figure 1. Pacific basin map showing wintering and feeding areas of five humpback whale stocks described above and in NOAA Fisheries (2022). Summer feeding areas include Russia, Aleutian Islands/Bering Sea (AI/BS), Gulf of Alaska (GoA), Southeast Alaska/Northern British Columbia (SEAK/NBC), Washington/Southern British Columbia (WA/SBC), and California/Oregon (CA/OR) (From NOAA Fisheries 2022).

Humpback whale abundance for the U.S. West Coast based on 2015-2018 mark-recapture data resulted in an estimate of 4,973 whales (Calambokidis and Barlow 2020). Humpback whale abundance in California, Oregon, and Washington waters was also estimated based on habitat models and 1991-2018 line-transect data, resulting in a 2018 estimate of 4,784 whales (Becker et al. 2020). Carretta et al. (2022a) considered the former analysis the best estimate; it was more precise, and the latter's line-transect estimate reflected whale densities in the study area only during summer and autumn. The minimum population estimate for humpback whales in the California/Oregon/Washington stock (one of three in the 2021 SAR; Carretta et al. 2022a) was 4,776 whales (Calambokidid and Barlow 2020).

Subsequent analyses estimated the population size of whales wintering in southern Mexico and Central America; using spatial capture-recapture methods based on photographic data collected from 2019-2021, their abundance estimate was 1,494 whales, with a minimum population estimate of 1,282 whales (Curtis et al. 2022). This estimate represents the best estimate of abundance for the newly proposed Central America/Southern Mexico - CA-OR-WA humpback whale stock. For the newly proposed Mainland Mexico - CA-OR-WA stock, the abundance of humpback whales was estimated as the total abundance in the U.S. West Coast EEZ of 4,973 whales (Calambokidis and Barlow 2020) minus the Central America/Southern Mexico - CA-OR-WA humpback whale stock estimate, which resulted in a mean of 3,479 animals (Curtis et al. 2022).

Calambokidis and Barlow (2020) reported that humpback whale abundance appeared to have increased within the California Current at ~ 8.2% annually since the late 1980s. However, the authors note that the apparent increase in abundance from 2014 to 2018 was unlikely to represent real population growth and may reflect negatively-biased estimates from 2009 to 2014 as compared with 2018 (Calambokidis and Barlow 2020).

For the newly proposed Central America/Southern Mexico - CA/OR/WA stock, the 2019-2021 abundance estimate of Curtis et al. (2022) was approximately double the estimate derived from 2004-06 data that did not include whales from southern Mexico (755 whales; Wade 2021). This suggests an annual growth rate of ~ 4.7% (Curtis et al. 2022). The authors also calculated the population growth rate for Central America/Southern Mexico whales based on differences between the 2004-2006 estimate and the current estimate by excluding whales in southern Mexico waters in the spatial recapture model. The resulting annual growth rate was 1.8% (Curtis et al. 2022); however, the authors emphasized that the estimate had high uncertainty. A stock-specific population trend for the Mainland Mexico – CA-OR-WA stock of humpback whales has not been estimated (NOAA Fisheries 2022).

Humpback whales face a variety of threats, depending on the region in which they occur. Threats listed in the Recovery Plan include entrapment and entanglement in fishing gear, collisions with ships, acoustic disturbance, habitat degradation, and competition for resources with humans (NMFS 1991). Climate change and ocean acidification are also global threats to marine ecosystems that could indirectly affect humpback whales via trophic dynamics and available prey. Globally, entrapment and entanglement in fishing gear and collisions with ships represent most of the reported and observed serious injuries and mortalities for the species (review in Carretta et al. 2014b). The number of human-related

deaths and injuries for each humpback whale stock are unknown, but NMFS is exploring prorating human-caused mortality for stocks found in U.S. waters (NOAA Fisheries 2022). Entanglement data are available for most stocks of humpback whales worldwide. These entanglements result from humpback whale interactions with a variety of fisheries and gear types and generally result in some level of serious injury and mortality. The absolute number of humpback whale entanglements is likely under-represented by these data, in part because observer programs and stranding networks do not exist in many parts of the world.

Threats from Fishing Gear Entanglements

Humpback whales may break through, carry away, or become entangled in fishing gear. Whales carrying gear may later die, become debilitated or seriously injured, or have normal functions impaired, all without having been recorded. Of nations reporting to the IWC, 64.7% (n=11) reported humpback whale bycatch from 2003-2008 (Mattila and Rowles 2010). Some countries (e.g., U.S., Canada, Australia, South Africa) have well-developed reporting and response networks collecting information on entanglements. Still, <10% of humpback whale entanglements in the Gulf of Maine are reported, despite strong outreach and a response network (Robbins and Mattila 2004). For whales off the U.S. East Coast, 89% of removed gear was pots/traps or gillnet gear, although other gear types were observed (Johnson et al. 2005). A wide range of entangling gear has also been reported in the South Pacific (Neilson 2006; Lyman 2009), Newfoundland (Lien et al. 1992) and by the IWC (Mattila and Rowles 2010). In the North Pacific, entanglement is pervasive but highest among coastal populations (Robbins et al. 2007a; Robbins 2009).

Entanglement may result in only minor injury, or potentially may significantly affect individual health, reproduction or survival. Studies of the fate of entangled whales in the Gulf of Maine suggest that juveniles are less likely than adults to survive (Robbins et al. 2008), and observed entanglement deaths and serious injuries in that region are known to exceed what is considered sustainable for the population (Glass et al. 2009). Most deaths likely go unobserved and preliminary studies suggest that entanglement may be responsible for 3-4% of total mortality, especially among juveniles (Robbins et al. 2009).

Much more is known about fishing gear entanglement in the Northern Hemisphere than in the Southern Hemisphere. Off Japan, an entangled whale is legally allowed to be killed and sold on the market (Lukoschek et al. 2009), so entanglement often leads to death for humpback whales in this region. While the number of reported bycaught animals is not large, the number of reports has been increasing and may underestimate the actual number caught. The Mexico population has one of highest scar rates from nets and lines in the North Pacific, indicating a high entanglement rate (Bettridge et al. 2015). Based on this information, the severity of the threat of fishing gear entanglements varies among regions and ranges from low to high.

Entanglement Threat for Hawaii DPS

Studies indicate that the Hawaii DPS experiences a high rate of interaction with fishing gear (20-71%), with the highest rates recorded in southeast Alaska and northern British

Columbia (Neilson et al. 2009). Fatal entanglements of humpback whales in fishing gear have been reported in all areas, and observed fatalities are almost certainly under-reported. Studies in another humpback whale feeding ground, which has similar levels of scarring, estimate that the actual annual mortality rate may be as high as 3.7% (Angliss and Outlaw 2008). The level of threat from fishing is considered medium and is not expected to significantly diminish population growth.

Entanglement Threat for Central America DPS

Vessel collisions and entanglement in fishing gear pose the greatest threat to this population, especially off Panama, southern California, and San Francisco. Between 2004 and 2008, there were 18 reports of humpback whale entanglements in commercial fishing gear off California, Oregon, and Washington (Carretta et al. 2010), and the actual number of entanglements may be higher. Effective fisheries monitoring and stranding programs exist in California, but are lacking in Central America and much of Mexico. Levels of mortality from entanglement are unknown, but entanglement scarring rates indicate a significant interaction with fishing gear. The Central America DPS is therefore considered to be at moderate risk of extinction over the next three generations.

Entanglement Threat for Mexico DPS

Of the 17 records of stranded North Pacific humpback whales in the NMFS stranding database, three involved fishery interactions, two were attributed to vessel strikes, and in five cases the cause of death could not be determined (Carretta et al. 2011). Specifically, between 2004 and 2008, 14 humpback whales were reported seriously injured in commercial fisheries offshore of California and two were reported dead. What proportion of these represent the Mexican breeding population is unknown, but the fishing gear involved included gillnet, pot, and trap gear (Carretta et al. 2010). The Mexico DPS is considered to be "not at risk" of extinction, although some voted for "moderate risk" to reflect the threat of entanglement among other threats.

Entanglement Threat for Western North Pacific DPS

Whales along the coast of Japan and Korea are at risk of entanglement related mortality in fisheries gear, although overall rates of net and rope scarring are similar to other regions of the North Pacific (Brownell et al. 2000). The threat of mortality from such entanglement is high given the incentive for commercial sale allowed under Japanese and Korean legislation (Lukoschek et al. 2009). The reported number of humpback whale entanglements/deaths has increased for Japan since 2001 due to improved reporting, although the actual number of entanglements may be underrepresented in both Japan and Korea (Baker et al. 2006). The level of confidence in understanding the minimum magnitude of this threat is medium for the Okinawa/Philippines DPS and low for the Second West Pacific DPS, given the unknown wintering grounds and primary migratory corridors.

Fishing gear entanglements are considered likely to moderately reduce the population size or the growth rate of the Hawaii, Central America, and Mexico DPSs and are likely to seriously reduce the population size or the growth rate of the Western North Pacific [Okinawa/Philippines] DPS.

U.S. West Coast Groundfish Fisheries

The west coast groundfish fishery (WCGF) is a multi-species fishery that utilizes a variety of gear types. The fishery harvests species designated in the Pacific Coast Groundfish Fishery Management Plan (PFMC 2011) and is managed by the Pacific Fishery Management Council. Over 90 species are listed in the groundfish FMP, including a variety of rockfish, flatfish, roundfish, skates, and sharks. These species are found in both federal (> 5.6 km off-shore) and state waters (0-5.6 km offshore). Groundfish are both targeted and caught incidentally by trawl nets, hook-&-line gear, and fish pots.

Under the FMP, the groundfish fishery consists of four management components:

- The Limited Entry (LE) component encompasses all commercial fishers who hold a federal limited entry permit. The total number of limited entry permits available is restricted. Vessels with an LE permit are allocated a larger portion of the total allowable catch for commercially desirable species than vessels without an LE permit.
- The Open Access (OA) component encompasses commercial fishers who do not hold a federal LE permit.
- The Recreational component includes recreational anglers who target or incidentally catch groundfish species. Recreational fisheries are not covered by this report.
- The Tribal component includes native tribal commercial fishers in Washington State that have treaty rights to fish groundfish. Tribal fisheries are not included in this report, with the exception of the observed tribal at-sea Pacific hake (*Merluccius productus*) (also known as whiting) sector.

These four components are further subdivided into sectors based on gear type, target species, permits and other regulatory factors (see Appendix 1). The analyses in this report focus on data from the Limited Entry (LE) fixed gear pot sector and the Open Access Fixed gear pot and line sectors.

Northwest Fisheries Science Center Groundfish Observer Program

The NWFSC Groundfish Observer Program's goal is to improve estimates of total catch and discard by observing commercial sectors of groundfish fisheries along the U.S. west coast that target or take groundfish as bycatch. The observer program has two units: the West Coast Groundfish Observer Program (WCGOP) and the At-Sea Hake Observer Program (A-SHOP). The WCGOP Program was established in May 2001 by NOAA Fisheries (a.k.a., National Marine Fisheries Service, NMFS) in accordance with the Pacific Coast Groundfish Fishery Management Plan (50 CFR Part 660) (50 FR 20609). This regulation requires all vessels that catch groundfish in the US EEZ from 3-200 miles offshore carry an observer when notified to do so by NMFS or its designated agent. The WCGOP and A-SHOP observe distinct sectors of the groundfish fishery. The WCGOP observes the following sectors: IFQ shore-based delivery of groundfish and Pacific hake, LE and OA fixed gear, and state-permitted nearshore fixed gear sectors. The WCGOP also observes several state-managed fisheries that incidentally catch groundfish, including the California halibut

trawl and ocean shrimp trawl fisheries. The A-SHOP observes the IFQ fishery that delivers Pacific hake at-sea including: catcher-processor, mothership, and tribal vessels (descriptions of all of these fisheries can be found in Appendix 1). Details on how fisheries observers operate in both the IFQ (Catch Share) and Non-IFQ sectors can be found on the NWFSC website.

Humpback Whale Bycatch in West Coast Groundfish Fisheries

The primary objective of this report is to provide estimates of bycatch of humpback whales in observed U.S. West Coast federally-managed groundfish fisheries since the last report (Hanson et al. 2021), which covered the years 2002–2019. Previous reports on marine mammal bycatch in West Coast groundfish fisheries (Jannot et al. 2022) have provided data on bycatch of humpback whales in U.S. west coast commercial fisheries.

Amount and Extent of Humpback Whale Take

The Biological Opinion Regarding the Effects of the Continued Operation of the Pacific Coast Groundfish Fishery (PCGF) (NMFS 2020) stated that:

"We anticipate that take of humpback whales would occur through entanglement with fishing gear as a result of the proposed continued operation of the PCGF, specifically with sablefish pot fishing gear…Our expectation is that information on the amount and extent of humpback whales incidentally taken in the PCGF will come primarily from the bycatch estimates produced by the NWFSC and Endangered Species Workgroup. Secondarily, opportunistic reports of humpback whale entanglements reported to the NMFS WCR Marine Mammal Stranding Program will be available to help ground truth these estimates, especially as a potential indicator of obvious discordance between estimated and known actual incidents of bycatch…Using this information, if more than 5 humpback whales are observed or estimated to have been incidentally captured in the PCGF in any one year, or if the 5-year running average of humpback whale bycatch exceeds 2.34 per year, then we would conclude that the incidental take of ESA-listed Mexico DPS and/or Central America DPS humpback whales would have been exceeded."

This biennial report represents the fulfillment of reporting on estimated humpback whale take and associated other reporting requirements.

Methods

Data Sources

Data sources for this analysis include onboard observer data from the WCGOP and the A-SHOP; landing receipt data, referred to as fish tickets; and electronic monitoring (EM) data. Fish ticket and EM data were obtained from the Pacific Fisheries Information Network (PacFIN).

NWFSC Observer Program Data

A list of fisheries, coverage priorities and data collection methods employed by WCGOP in each observed fishery can be found in the WCGOP training manual (NWFSC 2023). A-SHOP

information and documentation on data collection methods can be found in the A-SHOP sampling manual (NWFSC 2022).

The sampling protocol employed by the WCGOP is primarily focused on the discarded portion of catch. To ensure that the recorded weights for the retained portion of the observed catch are accurate, haul-level retained catch weights recorded by observers are adjusted based on trip-level fish ticket records. This process is described in detail in the annual groundfish mortality report (Somers et al. 2022). Data processing was applied prior to the analyses presented in this report. For a list of all of the groundfish species defined in the Pacific Coast Groundfish Fishery Management Plan see PFMC (2022).

Fish Ticket Data

For bycatch estimation, the landed amount of a particular fish species or species group is used as the effort metric. Thus, the retained landing information from sales receipts (known as fish tickets) is crucial for fleet-wide total bycatch estimation for all sectors of the commercial groundfish fishery on the U.S. west coast. Fish ticket landing receipts are completed by fish-buyers in each port for each delivery of fish by a vessel. Fish tickets are trip-aggregated sales receipts for market categories that may represent single or multiple species. Fish tickets are issued to fish-buyers by a state agency and must be returned to the issuing agency for processing. Fish tickets are designed by the individual states (Washington, Oregon, and California) with slightly different formats by state. In addition, each state conducts species-composition sampling at the ports for numerous market categories that are reported on fish tickets. Fish ticket and species-composition data are submitted by state agencies to the PacFIN regional database.

Annual fish ticket landings data, with state species composition sampling applied, were retrieved from the PacFIN database and subsequently divided into various sectors of the groundfish fishery. Observer and fish ticket data processing steps are described in detail in Appendix B of the annual groundfish mortality report (Somers et al. 2022). All data processing steps specific to this report are described in the bycatch estimation methods section below.

Designation of ‘take’ and ‘serious injury’ interactions

NMFS has established guidelines for distinguishing serious from non-serious injury of marine mammals pursuant to the Marine Mammal Protection Act through a policy directive (NMFS 2012b). Throughout this report, we use “take” and “bycatch” interchangeably; in both cases, this term reflects the MMPA and ESA definition of any act that attempts to or succeeds in harassing, hunting, capturing, or killing a marine mammal, regardless of lethality.

Estimating Humpback Whale Bycatch

Statistical Model

We used Bayesian time-series models to estimate annual means, and uncertainty in these estimates, of humpback whale bycatch. Probability-based methods are particularly useful when bycatch is dominated by zeroes; there is reduced bias from rare events, the methods incorporate uncertainty and are less reliant on assumptions. The model-based Bayesian approach also reduces volatility through its formal use of all information contained in the time series, reduces arbitrary decision-making about how many years of data to combine, and it enables probabilistic inference for bycatch and mortality within years, conditional on fishing effort (Martin et al. 2015). Bayesian time-series have been used with other rare bycatch species, including cetaceans, delphinids, pinnipeds, sea turtles, sharks, and seabirds (Jannot et al. 2021, Jannot et al. 2022, Martin et al. 2015).

We applied Bayesian time-series models to observer program data to characterize uncertainty in humpback whale bycatch estimation in the LE sablefish pot fishery (Table 2), OA pot fishery (Table 3), and the OA hook-and-line fishery (Table 4). Because only one humpback whale was documented as bycatch in each fishery sector, we were restricted to using simple statistical models while estimating variances of total bycatch.

We modeled the three fisheries separately. For each of the three models, there are three parameterization choices to be made. The first is the effort metric, of which there are three possible choices: the number of gear deployments (sets), the number of gear units (pots or hooks), or the observed mass of retained catch. The second parameter is the type of bycatch rate: a constant rate or a time-varying rate. The third parameter is the type of bycatch-generating process: Poisson or negative binomial. We compared models incorporating all combinations of the above effort metrics, bycatch rates, and bycatch-generating processes. We use methods from the `loo` package as implemented in the `bycatch` package (Vehtari et al. 2019, Ward and Jannot 2023) to compare among models with different parameter combinations within each fishery. Final estimates are presented for each of the three fisheries from the single model that best fits the data within each fishery. Estimates from the three fisheries were summed to obtain a single estimate for both fisheries combined.

For each fishery, the base model assumed bycatch rate was constant and inferred annual expected mortality, given a specified level of effort, using a simple Poisson process model, where the total number of bycatch events were assumed to follow a Poisson distribution,

$$n_{take,y} \sim \left(\lambda_y = \theta \cdot E_y\right)$$

where:

$n_{take,y}$ = number of observed bycatch events (or take events) in year y

λ_y = expected observed bycatch

θ = estimated observed bycatch rate
E_y = observed effort in year y

In the simplest case, the estimated bycatch rate θ is assumed constant through time, but the quantity $\theta \cdot E_y$ includes uncertainty, as θ is estimated. Thus, a time series of the mean bycatch can be generated for a given species, with a given metric of effort. All uncertainty in the time series originates from fluctuating levels of effort through time (percent observer coverage only affects the expansion). We used a Bayesian model (Martin et al. 2015, Jannot et al. 2022) to generate mean and 95% CIs of the bycatch rate parameter, θ, as well as for the expected bycatch, $\theta \cdot E_y$.

We built upon the simplified model above with the goal of finding the model that most accurately estimates bycatch and variance within each fishery. To do that, we compared models to: (a) find the most suitable effort metric; (b) test the assumption that θ is constant through time; and (c) compare distributions (Poisson to negative binomial). For fishery there are a total of 12 possible models (three effort metrics, two bycatch rate assumptions, two distributions). To compare among these models, we used two model diagnostic tools (`Pareto-K` & `p-LOO`) and a model comparison method (`LOOIC`) from the `loo` package (Vehtari et al. 2019) as implemented in the `bycatch` package (Ward and Jannot 2023) and described in Jannot et al. (2022).

In this report, we present results from the single best model that uses the best effort metric, bycatch rate, and bycatch process, as judged by diagnostic statistics described in Jannot et al. (2022).

Expanding Bycatch to Unobserved Portion of Fleet

Because observer coverage is less than 100% in some fleets, and variable through time, we need to expand the estimated bycatch in the observed portion of the fleet, $\theta \cdot E_y$, to the fleet-wide level within each fishery. One approach for expansion would be to divide $\theta \cdot E_y$ by the percent observer coverage; however, this ignores uncertainty in the expansion. We accounted for this uncertainty by estimating the posterior predictive distribution of unobserved takes, given unobserved effort and estimated parameters, and simulating posterior predictive values to generate 95% CIs for the predicted total bycatch in each year. Details on the implementation can be found in Jannot et al. (2021) and the *bycatch* package (Ward and Jannot 2023). Five year means of the estimates were then calculated from the annual estimates for each fishery separately, as well as for the three fisheries combined.

Statistical Software

The statistical software `R` (R Core Team 2022) was used to produce the analyses, tables, figures in this report. Specifically, we relied heavily on the `R` packages:

- *bycatch* (Ward and Jannot 2023) for modeling and simulation,
- *ggplot2* (Wickham 2016) for plotting figures,

- *loo* (Vehtari et al. 2019) as implemented in *bycatch* for model comparisons,
- *knitr* (Xie 2023) for tables and dynamic reporting, and
- *tidyverse* (Wickham et al. 2019) & *dplyr* (Wickham et al. 2023) for data wrangling.

Results and Discussion

Estimating Humpback Whale Bycatch

Using the statistical models described above, we estimated mean annual fleet-wide bycatch of humpback whales for 2002-2021 for the LE pot gear, OA pot gear, and OA hook-and-line gear sectors separately (Tables 2-4). OA hook-and-line is now included in this report due to a documented take in 2021. Based on the annual estimates from the models, we also calculated a running 5-year average of bycatch for each of the sectors separately (Figure 2, Tables 2-4). Finally, to align with the incidental take statement in the 2020 Biological Opinion, we calculated the 5-year running average for the combined sectors by summing the individual sector estimates for both pot gear fisheries. Although the incidental take statement did not anticipate take in the OA hook-and-line sector, we summed all three fixed gear fisheries together for illustration purposes (Figure 2, Table 5). We also calculated confidence intervals around these estimates; this uncertainty often reflects the variability in observer coverage rates (Appendices 2-4).

For 2021, the LE pot and OA pot fishery sectors did not exceed the annual incidental take threshold separately or when combined; including the OA hook-and-line sector also did not exceed the annual incidental take threshold. For 2017-2021 (the most recent 5 year running average frame), the LE and OA pot fishery sectors combined did not exceed the 5-year running average incidental take threshold. However, if the OA hook-and-line fishery is included, the fixed gear sectors collectively would have exceeded the 5-year running average incidental take threshold.

In the 100% monitored catch shares fisheries (Appendix 1), no humpback whale takes were observed (Appendix 5).

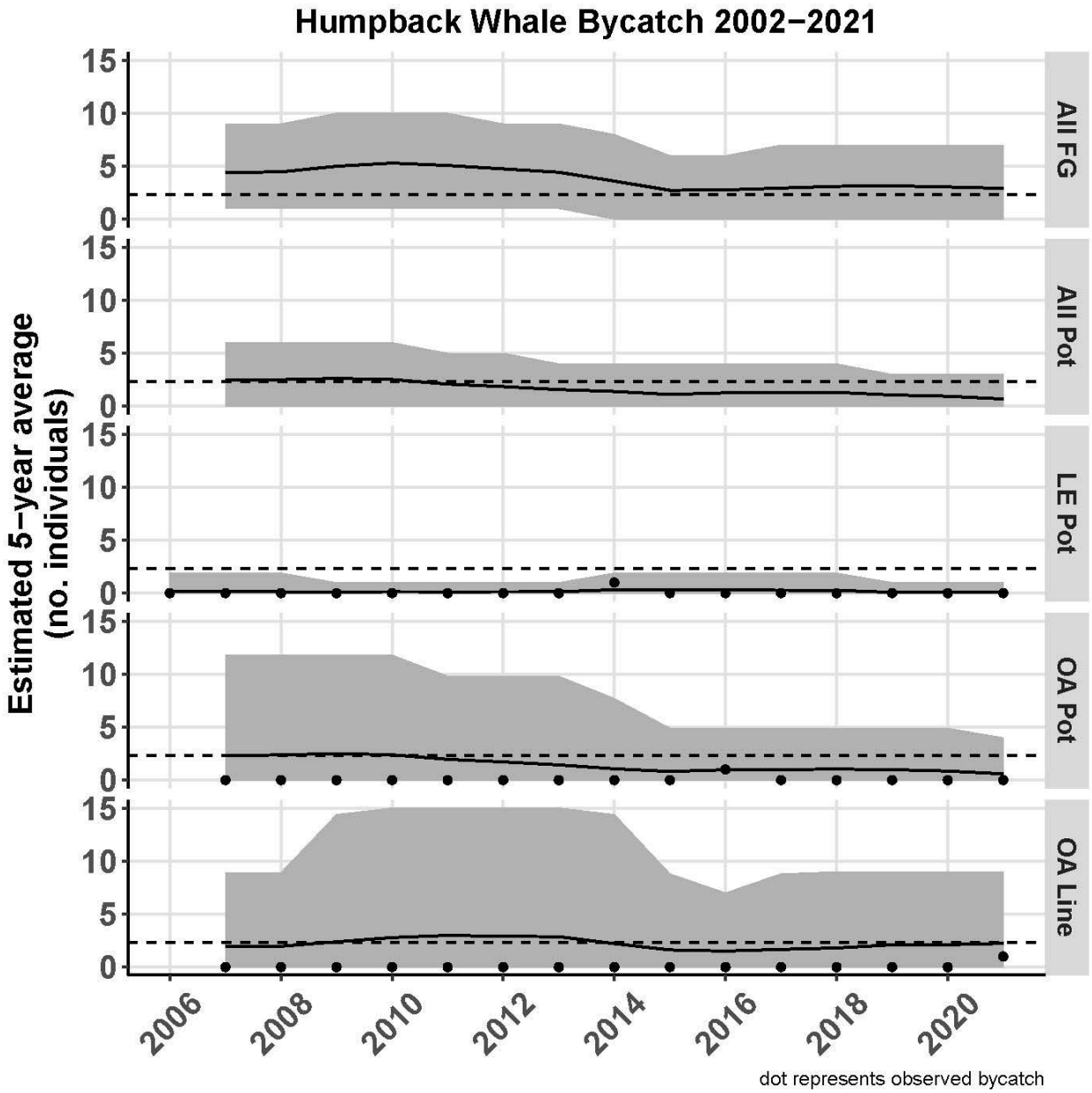

Figure 2: Estimated 5-year means for humpback whale takes in the individual and combined sectors where takes have been observed. Black dots represent observed bycatch. Solid lines represent the estimated 5-year running mean of fleet-wide bycatch of humpback whales; gray areas represent 95% confidence limits. Dotted lines represent the current 5-year incidental take limit of 2.34 for the sablefish pot fishery.

Interactions with commercial fisheries likely to take humpback whales

The impact of fisheries (commercial and recreational) on the CA/OR/WA humpback whale stock is likely underestimated, since mortality or serious injury of large whales due to entanglement in gear may often go unobserved. This can occur because whales swim away with a portion of the net, line, buoys, or pots or because the entanglement may occur in a

remote area of the coast or far offshore. Pot and trap fisheries in general are the most commonly documented source of serious injury and mortality of humpback whales in U.S. west coast waters (Carretta et al. 2013, 2014a,b, 2017, 2018a, 2020a), and reports have increased substantially since 2014 (Carretta et al. 2018b).

Humpback whales continued to be the cetaceans with the most confirmed entanglements in 2020 (n=10; NOAA Fisheries 2020) and 2021 (n=17; NOAA Fisheries 2021). While confirmed entanglements were lower than the peak in 2015-16 (n=48-49), the number continues a trend of being greater than pre-2014 levels, when confirmed entanglements averaged <10 per year (NOAA Fisheries 2021). In addition, the COVID-19 pandemic affected observations, reporting, and response in 2020 and 2021.

From 2016 to 2020, Humpback whale injuries and mortality in U.S. West Coast waters were most often reported from entanglements in pot/trap fisheries (n=70), followed by unidentified fishing gear (likely pot/trap gear; n=58), vessel strikes (n=14), gillnet fisheries (n=9), hook-and-line fisheries, and marine debris (n=1) (Table 5 in Carretta et al. 2022b). Documented mortality from, serious injury, plus prorated injury totals (i.e. entangled humpback whales with an injury score <1) for pot/trap fisheries were: California Dungeness crab pot (23.75), unidentified pot/trap fishery (9.5), Washington Dungeness crab pot fishery (5.5), California spot prawn pot fishery (3.25), commercial Dungeness crab pot fishery (2.0), Oregon Dungeness crab pot fishery (1.75), Washington/Oregon/California sablefish pot fishery (1.5), and recreational Dungeness crab pot fishery (1.0), and tribal pot fishery (1.0; Table 5 in Carretta et al. 2022b).

The increase in entanglements in commercial crab fisheries in recent years led the California Department of Fish and Wildlife to issue a declaration to close the California Dungeness crab fishery statewide on April 15, 2019 in all commercial fishery management zones. The closure was needed due to a greater risk of whales becoming entangled in commercial Dungeness crab pots, lines, and buoys during the spring and summer months.

The California Dungeness Crab Fishing Gear Working Group piloted the Risk Assessment and Mitigation Program (RAMP) on November 1, 2020 to assess monthly entanglement risk for humpback whales, blue whales, and Pacific leatherback sea turtles using information from confirmed entanglements and marine life density data from aerial and vessel surveys and satellite telemetry. When risk is elevated, CDFW will consult with the Working Group to implement management actions such as: fleet advisories, fishing depth constraints, vertical line reductions, fishery closures, or use of approved alternative gear.

Changes in Humpback Whale occurrence

In recent years the distribution and duration of time humpback whales stay on the feeding grounds has changed. More humpback whales have been observed in Puget Sound, the mouth of the Columbia River, San Francisco Bay, and closer to shore in general than has been observed since the end of commercial whaling (Calambokidis et al. 2017). Hydrophones and vessel surveys have also reported humpback whale detections later into the winter that has been observed in the past with some evidence that individuals may be over-wintering (Calambokidis et al. 2017). Some of the changes in whale occurrence

(expansion into more peripheral habitats, greater time on feeding grounds to meet nutritional needs, and more animals overwintering or arriving early in the season) may signal reaching carrying capacity and be causing greater overlap with Dungeness crab fisheries in winter and early spring and more entanglements (Calambokidis et al. 2017). The 2014-2016 marine heat wave in the northeast Pacific Ocean changed humpback whale prey distribution and abundance, resulting in a habitat compression for the species with a coastward shift in distribution. By shifting closer to the coast, humpback whales were more likely to encounter coastal fisheries, which may have resulted in an increase in humpback whale entanglements in recent years (Santora et al. 2020). The uptick in humpback whale entanglements beginning in 2014 appears not to be due to increases in fishing activity or changes in fisheries footprints (Feist et al. 2021). However, the spatial overlap of humpbacks and crab fishery gear was intensified in 2016, when domoic acid contamination prompted an unprecedented delay in the opening of California's Dungeness crab fishery (Santora et al. 2020. Feist et al. 2021).

Status of Stock

The status of the CA/OR/WA humpback whale stock, still recognized as one stock in the 2021 SAR and summarized in Carretta et al. (2022), was considered a "strategic" stock under the MMPA. Total annual human-caused serious injury and mortality of humpback whales from 2015-2019 from commercial fisheries (24.9/yr), non-commercial sources (1.4/yr), and estimated vessel strikes (22/yr) totalled 48.3 humpback whales, exceeding the PBR estimate (29.4/yr). Mortality and serious injury from commercial fisheries alone is close to the PBR estimate, and if methods were available to correct for undetected serious injury and mortality, total fishery mortality and serious injury might exceed PBR.

Humpback whale stock delineation under the MMPA is under review and will affect status of newly proposed stocks. As the proposed Central America/Southern Mexico - CA-OR-WA stock of humpback whales is a DIP delineated from the 'Central America DPS' listed as endangered under the ESA (Bettridge et al. 2015, Taylor et al. 2021), it would therefore be considered 'depleted' and 'strategic' under the MMPA. As the proposed Mainland Mexico - CA-OR-WA stock of humpback whales is a DIP delineated from the 'Mexico DPS' listed as threatened under the ESA (Bettridge et al. 2015, Martien et al. 2021), it would therefore be considered 'depleted' and 'strategic' under the MMPA.

Status of Actions on the BiOp/RPMs and Conservation Measures

In the incidental take statement in the 2020 Biological Opinion, NOAA Fisheries included reasonable and prudent measures for management planning and take reporting that are applicable to all species considered. "Reasonable and prudent measures" are nondiscretionary measures to minimize the amount or extent of incidental take (50 CFR 402.02). "Terms and conditions" implement the reasonable and prudent measures (50 CFR 402.14). These must be carried out for the exemption in section 7(o)(2) to apply. Here we provide the reasonable and prudent measure from the 2020 Biological Opinion specific to humpback whales, followed by additional information on the status of each measure:

RPM 1: NMFS shall monitor the PCGF to ensure compliance with the regulatory and conservation measures included in the proposed action and the identified amount or extent of incidental take, including collection and evaluation of data on the capture, injury, and mortality of humpback whales.

T&C 1 for RPM 1: NMFS SFD, in cooperation with the PFMC and NMFS PRD as necessary, shall investigate the methods and feasibility associated with implementing additional pot gear marking regulations for the PCGF. The feasibility study shall consider whether additional gear marking would increase NMFS' ability to attribute humpback whale entanglements to specific fisheries and assist in identifying potential modifications to the pot gear regulations that could reduce incidental take of humpback whales. The feasibility study shall be completed by March 2023 and the findings given consideration by the PFMC for potential changes to the pot gear marking regulations by March 2024. Completion dates may be revised by mutual agreement by NMFS SFD, PFMC, and NMFS PRD. The following methods shall be evaluated, as well as any other potential methods identified by NMFS SFD, the PFMC, or NMFS PRD as part of the investigation process: a. Line marking - as an example, proposed Washington Department of Fish and Wildlife Dungeness crab regulations (October 2, 2019).* b. Additional markings on buoys/surface gear – as an example, California Department of Fish and Wildlife Commercial Trap Gear marking regulations.**	*At its April 2020 meeting, the Council made multiple recommendations regarding the humpback whale BiOp for NMFS to consider as it moves forward with satisfying the terms and conditions of the Incidental Take Statement. The Council recommended that NMFS should hold workshops with fishing industry members to develop any potential new management measures related to the humpback whales. The Council also recommended that dedicated Council meeting agenda items should be used to consider and provide input to NMFS on draft new management measures prior to finalization of any regulatory changes.* *At its April 2021 meeting, the Workgroup supported and encouraged the workshop and other efforts to get robust industry engagement.* ***Oregon Sea Grant, through funding from NOAA, held a workshop in November 2022 which informed the development of a feasibility report. This report and summary of finds was presented to the PFMC at its March 2023 meeting.***

T&C 2 for RPM 1: NMFS SFD, in cooperation with the PFMC and NMFS PRD, shall review the Terms of Reference for the Groundfish Endangered Species Workgroup. NMFS SFD, PRD, and the PFMC will review the priority of needs associated with incidental humpback whale bycatch in the PCGF and provide any recommendations to the Workgroup. The review shall be completed by March 2021, or some other mutually agreeable date.	*The due date for this T&C was extended by mutual agreement to April 2021 to coincide with the next Groundfish Endangered Species Workgroup meeting. Prior to the Workgroup meeting, NMFS PRD, NMFS SFD, and Council Staff met to discuss if any changes to the Workgroup's terms of reference (Appendix B) were needed to comply with Term and Condition 2 from the BiOp. They concluded the terms of reference provided flexibility to address the needs of the humpback whale BiOp through development of the Workgroup agenda, and there was not an immediate/obvious need for changes to the terms of reference. The Workgroup agreed with this approach at its April 2021 meeting.*
T&C 3 for RPM 1: NMFS SFD, in coordination with the NWFSC WCGOP, shall ensure observer coverage in the PCGF's fixed gear fishery maintains the capability to provide scientifically defensible humpback whale bycatch estimates across all sectors to confirm that the take exemption for the proposed action is not exceeded. When feasible, NMFS SFD should consider observer deployment options to reduce uncertainty in humpback whale bycatch estimates and increase the understanding of the fishery dynamics in the fixed gear fishery.	*This was relayed to the WCGOP for consideration as part of their annual determination of coverage rates across various fisheries.*
T&C 4 for RPM 1: NMFS SFD, in cooperation with the PFMC and NMFS PRD as necessary, shall review and consider measures for maximizing the utility and benefit of EM with respect to gathering information from any future bycatch events of humpback whales. NMFS SFD shall complete this review and make a report of the findings available to PFMC and NMFS PRD by March 2023. Completion dates may be revised by mutual agreement by NMFS SFD, PFMC, and NMFS PRD. Factors that could be considered include, but are not limited to, the following: a. Placement of EM technology. b. Review protocols, including the amount of review and extent of analysis to be provided. c. Options for supplemental documentation and data collection.	*NMFS SFD briefed the PFMC on the Biological Opinion at the April 2021 PFMC meeting. The Council recommended NMFS consider including EM in the industry workshops noted under Term & Condition 1.* ***NMFS SFD, in coordination with PRD, provided a report to the PFMC at its March 2023 meeting.***

* https://www.psmfc.org/crab/2019%20-2020%20files/letter%20to%20license%20holders_Oct%202%202019%20FINAL.pdf

** https://wildlife.ca.gov/Notices/Regulations/Marking

Section 7(a)(1) of the ESA directs Federal agencies to use their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of the threatened and endangered species. Specifically, conservation recommendations are suggestions regarding discretionary measures to minimize or avoid adverse effects of a proposed action on listed species or critical habitat or regarding the development of information (50 CFR 402.02). The following conservation recommendations replace those for humpback whales in the 2012 Opinion. Implementing these updated recommendations would provide information for future considerations of how to reduce the effects of the PCGF on Central America DPS and Mexico DPS humpback whales:

(1) Scientific tools and frameworks: To reduce real-time geographic overlap of whales and the PCGF pot fishery, which increases the entanglement risk of Central America DPS and Mexico DPS of humpback whales, NMFS should encourage the exploration and implementation of new and existing scientific tools and frameworks in coordination with the PFMC, including consideration of using: a. Near-real time environmental data streams to predict whale concentrations (e.g., Forney et al. in prep, Abrahms et al. 2019) and forage conditions (e.g., Santora et al. 2020). b. Environmental data to predict patterns of fishing effort. c. Observational/survey data and other tools to identify spatial/temporal areas of concern to avoid in a dynamic management approach.	*NMFS SFD briefed the PFMC on this conservation measure at the April 2021 PFMC meeting. At its April 2021 meeting, the Workgroup supported potential further development of this conservation measure.*

(2) Gear modifications: To reduce the severity and frequency of Central America DPS and Mexico DPS humpback whale entanglements with groundfish pot gear, NMFS should encourage the development and testing of gear modifications in coordination with the PFMC as necessary, including but not limited to: a. Weak links – as an example, see NOAA Fisheries Atlantic Large Whale Take Reduction Plan – Supplement B: Weak Links & Anchoring Techniques.11 b. Reduction of the maximum breaking strength of ropes used in the sablefish pot fishery – similar to a recent study conducted on the U.S. East Coast (Knowlton et al. 2016).12 c. Pop-up/on demand gear retrieval innovation.	*NMFS SFD briefed the PFMC on this conservation measure at the April 2021 PFMC meeting.* *At its April 2021 meeting, the Workgroup supported potential further development of this conservation measure.* *Based on the outcome of the feasibility workshop, the PFMC is expected to start scoping an action that may consider changing the vertical line requirements for the fixed gear fisheries so that marking both ends of the set is not required.*
(3) Logbook requirements: To improve bycatch estimates for Central America DPS and Mexico DPS humpback whales and better understand the distribution of fishing effort, NMFS should complete ongoing efforts to implement a coast-wide Federal fixed gear logbook requirement for all fixed gear sectors, including pot gear. As part of this effort, NMFS should consider implementation of automated/electronic logbook reporting system that can provide comprehensive fishery effort information at fine spatial scales that could readily feed into other available data streams on whale distributions and forage conditions allowing for more rapid assessment of fishing dynamics and potential entanglement risks of the PGGF fixed gear fisheries than current approaches allow.	***NMFS developed an electronic logbook and carried out the associated rulemaking. The logbook requirement is in place as of January 1, 2023.***

(4) To better understand fishery gear configurations and how they might contribute to the likelihood of Central America DPS and Mexico DPS humpback whale entanglements and the severity of those encounters (likelihood of mortality), NMFS should consider any needs to collect information on gear configuration and characteristics in the sablefish fishery as part of their ongoing effort to catalog and understand the characteristics of all West Coast fixed gear fisheries relative to entanglement risk and/or reported entanglements. Based on this review, NMFS should track gear configuration characteristics through the logbook and/or WCGOP. This information could result in the development of innovative gear that reduces the frequency and severity of WCGF encounters with humpback whales.	*Gear configuration is tracked by the WCGOP.* ***NMFS has developed a logbook and associated rulemaking (requirement is in place as of January 1, 2023)****.*
(5) NMFS, in concert with the PFMC, should further investigate the potential for interactions between whales and trawl gear, including review of the underlying circumstances associated with the recent events documented in the Pacific whiting trawl fishery documented in this biological opinion. In addition to assessment of the risks of interactions, measures and/or data collection protocols should be developed by NMFS to help increase the capabilities to make determinations regarding the underlying circumstances of any future events where dead whales are encountered in trawl nets in the PCGF.	*NMFS SFD briefed the PFMC on these conservation measures at the April 2021 PFMC meeting.* *At its April 2021 meeting, the Workgroup supported potential further development of this conservation measure.*

Tables

Table 1. *Distinct population segments (DPS) of origin for North Pacific humpback whale proposed demographically independent populations (DIP), units, and stocks. Names are based on their general winter and summering area linkages. (From Draft U.S. Pacific marine mammal stock assessments (NOAA Fisheries 2022)*

DPS	DIPs / units	Stocks	ESA Status
Central America	Central America - CA-OR-WA DIP	Central America/Southern Mexico - CA-OR-WA stock	Endangered
Mexico	Mainland Mexico - CA-OR-WA DIP	Mainland Mexico - CA-OR-WA stock	Threatened
	Mexico - North Pacific unit	Mexico -North Pacific stock	
Hawai‘i	Hawai‘i - North Pacific unit	Hawai‘i stock	Not Listed
	Hawai‘i - Southeast Alaska/ Northern British Columbia DIP		
Western North Pacific	Philippines/Okinawa - North Pacific unit	Western North Pacific stock	Endangered
	Marianas/Ogasawara - North Pacific unit		

Table 2. *Summary of humpback whale take estimates in the limited entry pot sector, including lower (LCI) and upper (UCI) 95% confidence intervals for annual and 5-year mean estimates. The best model used number of pots as the effort metric, the Poisson distribution for error, and a constant bycatch rate. Shaded cells indicate years when the annual mean exceeded the current 5 take threshold or the current 5-year mean exceeded the 2.34 take threshold.*

Year	Sector	Mean	LCI	UCI	5-year Mean	5-year LCI	5-year UCI
2002	LE Pot	0.11	0.00	1.00	0.00	0.00	0.0
2003	LE Pot	0.16	0.00	1.00	0.00	0.00	0.0
2004	LE Pot	0.21	0.00	2.00	0.00	0.00	0.0
2005	LE Pot	0.10	0.00	1.00	0.00	0.00	0.0
2006	LE Pot	0.13	0.00	1.00	0.14	0.00	1.9
2007	LE Pot	0.14	0.00	1.00	0.15	0.00	1.9
2008	LE Pot	0.06	0.00	1.00	0.13	0.00	1.9
2009	LE Pot	0.14	0.00	1.00	0.11	0.00	1.0
2010	LE Pot	0.18	0.00	1.00	0.13	0.00	1.0
2011	LE Pot	0.10	0.00	1.00	0.12	0.00	1.0
2012	LE Pot	0.16	0.00	1.00	0.13	0.00	1.0
2013	LE Pot	0.07	0.00	1.00	0.13	0.00	1.0
2014	LE Pot	1.10	1.00	2.00	0.32	0.00	1.9
2015	LE Pot	0.04	0.00	1.00	0.29	0.00	1.9
2016	LE Pot	0.05	0.00	1.00	0.29	0.00	1.9
2017	LE Pot	0.10	0.00	1.00	0.27	0.00	1.9
2018	LE Pot	0.04	0.00	1.00	0.27	0.00	1.9
2019	LE Pot	0.12	0.00	1.00	0.07	0.00	1.0
2020	LE Pot	0.11	0.00	1.00	0.08	0.00	1.0
2021	LE Pot	0.09	0.00	1.00	0.09	0.00	1.0

Table 3. *Summary of humpback whale take estimates in the open access pot sector, including lower (LCI) and upper (UCI) 95% confidence intervals for annual and 5-year mean estimates. The best model used the number of sets (number of gear deployments) as the effort metric, the Poisson distribution for error, and a constant bycatch rate. Shaded cells indicate years when the annual mean would have exceeded the current 5 take threshold or the 5-year mean would have exceeded the current 2.34 take threshold.*

Year	Sector	Mean	LCI	UCI	5-year Mean	5-year LCI	5-year UCI
2003	OA Pot	1.69	0.00	7.00	0.00	0.00	0.00
2004	OA Pot	1.97	0.00	8.00	0.00	0.00	0.00
2005	OA Pot	2.65	0.00	10.00	0.00	0.00	0.00
2006	OA Pot	3.24	0.00	12.00	0.00	0.00	0.00
2007	OA Pot	2.01	0.00	8.00	2.31	0.00	11.80
2008	OA Pot	1.99	0.00	8.00	2.37	0.00	11.80
2009	OA Pot	2.61	0.00	10.00	2.50	0.00	11.80
2010	OA Pot	2.07	0.00	8.00	2.38	0.00	11.80
2011	OA Pot	1.10	0.00	5.00	1.96	0.00	9.80
2012	OA Pot	0.80	0.00	4.00	1.72	0.00	9.80
2013	OA Pot	0.58	0.00	3.00	1.43	0.00	9.80
2014	OA Pot	0.77	0.00	4.00	1.07	0.00	7.70
2015	OA Pot	0.80	0.00	4.00	0.81	0.00	4.90
2016	OA Pot	1.90	1.00	5.00	0.97	0.00	4.90
2017	OA Pot	0.91	0.00	4.00	0.99	0.00	4.90
2018	OA Pot	0.79	0.00	4.00	1.03	0.00	4.90
2019	OA Pot	0.52	0.00	3.00	0.98	0.00	4.90
2020	OA Pot	0.14	0.00	1.00	0.85	0.00	4.90
2021	OA Pot	0.57	0.00	3.00	0.59	0.00	4.00

Table 4. *Summary of humpback whale take estimates in the open access hook-and-line sector, including lower (LCI) and upper (UCI) 95% confidence intervals for annual and 5-year mean estimates. The best model used landings as the effort metric, the Poisson distribution for error, and a constant bycatch rate. Shaded cells indicate years when the annual mean would have exceeded the current 5 take threshold or the 5-year mean would have exceeded the current 2.34 take threshold for the sablefish pot fishery.*

Year	Sector	Mean	LCI	UCI	5-year Mean	5-year LCI	5-year UCI
2003	OA Line	1.99	0.00	8.00	0.00	0.00	0.00
2004	OA Line	2.11	0.00	8.00	0.00	0.00	0.00
2005	OA Line	2.27	0.00	9.00	0.00	0.00	0.00
2006	OA Line	1.37	0.00	6.00	0.00	0.00	0.00
2007	OA Line	2.02	0.00	8.00	1.95	0.00	8.90
2008	OA Line	2.04	0.00	8.00	1.96	0.00	8.90
2009	OA Line	4.20	0.00	15.00	2.38	0.00	14.40
2010	OA Line	4.26	0.00	15.00	2.78	0.00	15.00
2011	OA Line	2.41	0.00	9.00	2.99	0.00	15.00
2012	OA Line	1.60	0.00	6.00	2.90	0.00	15.00
2013	OA Line	1.84	0.00	7.00	2.86	0.00	15.00
2014	OA Line	0.93	0.00	4.00	2.21	0.00	14.40
2015	OA Line	1.31	0.00	6.00	1.62	0.00	8.80
2016	OA Line	1.86	0.00	7.00	1.51	0.00	7.00
2017	OA Line	2.38	0.00	9.00	1.67	0.00	8.80
2018	OA Line	2.50	0.00	9.00	1.80	0.00	9.00
2019	OA Line	2.41	0.00	9.00	2.09	0.00	9.00
2020	OA Line	1.37	0.00	6.00	2.10	0.00	9.00
2021	OA Line	2.50	1.00	7.00	2.23	0.00	9.00

Table 5. *Summary of total humpback whale take estimates in sectors where takes have been observed, including lower (LCI) and upper (UCI) 95% confidence intervals for annual and 5-year mean estimates. Shaded cells indicate years where the annual mean would have exceeded the current 5-take threshold or the 5-year mean would have exceeded the current 2.34-take threshold for the sablefish pot fishery. Note: the biological opinion anticipates future takes that occur after it is completed, and information about take estimates from time periods before the biological opinion was completed aren't necessarily applicable to evaluating whether or not the anticipated take has been exceeded.*

	Combined Pot Gear						Combined Fixed Gear					
Year	Mean	LCI	UCI	5-year Mean	5-year LCI	5-year UCI	Mean	LCI	UCI	5-year Mean	5-year LCI	5-year UCI
2002	0.11	0.00	1.00	0.00	0.00	0.00	0.11	0.00	1.00	0.00	0.00	0.00
2003	1.84	0.00	5.00	0.00	0.00	0.00	3.83	1.00	8.00	0.00	0.00	0.00
2004	2.18	0.00	5.00	0.00	0.00	0.00	4.29	1.00	9.00	0.00	0.00	0.00
2005	2.74	0.00	6.00	0.00	0.00	0.00	5.01	1.00	10.00	0.00	0.00	0.00
2006	3.37	0.00	7.00	0.14	0.00	1.00	4.74	1.00	9.00	0.14	0.00	1.00
2007	2.14	0.00	5.00	2.46	0.00	6.00	4.16	1.00	9.00	4.41	1.00	9.00
2008	2.05	0.00	5.00	2.50	0.00	6.00	4.09	1.00	8.00	4.46	1.00	9.00
2009	2.76	0.00	6.00	2.61	0.00	6.00	6.96	2.00	13.00	4.99	1.00	10.00
2010	2.25	0.00	6.00	2.51	0.00	6.00	6.51	2.00	12.00	5.29	1.00	10.00
2011	1.20	0.00	4.00	2.08	0.00	5.00	3.61	0.00	8.00	5.07	1.00	10.00
2012	0.96	0.00	3.00	1.84	0.00	5.00	2.56	0.00	6.00	4.74	1.00	9.00
2013	0.65	0.00	3.00	1.56	0.00	4.00	2.49	0.00	6.00	4.43	1.00	9.00
2014	1.87	0.00	5.00	1.39	0.00	4.00	2.80	0.00	6.00	3.59	0.00	8.00
2015	0.84	0.00	3.00	1.10	0.00	4.00	2.15	0.00	5.00	2.72	0.00	6.00
2016	1.96	0.00	5.00	1.26	0.00	4.00	3.82	1.00	8.00	2.76	0.00	6.00
2017	1.01	0.00	3.00	1.27	0.00	4.00	3.39	0.00	7.00	2.93	0.00	7.00
2018	0.83	0.00	3.00	1.30	0.00	4.00	3.33	0.00	7.00	3.10	0.00	7.00
2019	0.63	0.00	3.00	1.05	0.00	3.00	3.04	0.00	7.00	3.15	0.00	7.00
2020	0.24	0.00	2.00	0.94	0.00	3.00	1.61	0.00	4.00	3.04	0.00	7.00
2021	0.66	0.00	3.00	0.68	0.00	3.00	3.16	0.00	7.00	2.91	0.00	7.00

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Appendices

Appendix 1. *A description of permits, gears used, target groups, vessel length range, fishing depth range, and management of catch share fishery sectors and subsectors in federally managed and monitored West Coast groundfish fisheries. Catch share sectors use individual fishing quotas (IFQ) to manage certain species. Observer coverage in these is 100%, except for vessels using electronic monitoring (EM). The IFQ program began in 2011; regulations prior to 2011 are excluded. For brevity, management descriptors are generalized and are not meant to be complete or comprehensive. Vessel lengths and fishing depths are based on observed vessels and might not represent the fleet as a whole.*

Sector	Sub-sector	Permits[a]	Gears	Targets	Vessel length (m)	Depth (m)	Management
Limited Entry (LE) Trawl	LE Trawl	LE permit with trawl endorsement	Bottom Trawl, Hook & Line, Pot	Groundfish[b]	15-40	10-1600	IFQ; some vessels use EM in lieu of 100% observer coverage
Limited Entry (LE) Trawl	Midwater Rockfish	LE permit with trawl endorsement	Midwater Trawl	Midwater rockfish[c]	15-33	>70	IFQ; some vessels use EM in lieu of 100% observer coverage
Limited Entry (LE) Trawl	Midwater Hake	LE permit with trawl endorsement	Midwater Trawl	Pacific hake[d]	17-40	>70	IFQ; some vessels use EM in lieu of 100% observer coverage
At-Sea Hake	Mothership-catcher vessels (MSCV)	LE permit with MSCV endorsement	Midwater Trawl	Pacific hake[d]	8-138[e]	53-460[e]	IFQ; some vessels use EM in lieu of 100% observer coverage
At-Sea Hake	Catcher-processors (CP)	LE permit with CP endorsement	Midwater Trawl	Pacific hake[d]	82-115	60-570	IFQ
At-Sea Hake	Tribal	None	Midwater Trawl	Pacific hake[d]	<38	53-460	IFQ

[a] A.k.a. LE permit. All LE permits are issued by NOAA.

[b] Vessels with a California halibut permit, issued by the state of California, can land CA halibut under California's CA halibut fishery regulations.

[c] *Sebastes* spp.

[d] *Merluccius productus*

[e] Average values for catcher vessels

Appendix 1, cont'd. *A description of permits, gears used, target groups, vessel length range, fishing depth range, and management of non-catch share fishery sectors and subsectors in federally managed and observed U.S. West Coast groundfish fisheries. Observer coverage on these vessels is less than 100%. For brevity, management descriptors are generalized and are not meant to be complete or comprehensive. Vessel lengths and fishing depths are based on observed vessels and might not represent the fleet as a whole.*

Sector	Sub-sector	Permits	Gears	Targets	Vessel Length (m)	Depth (m)	Management
Non-Nearshore Fixed Gear	Sablefish endorsed	LE permit with fixed gear endorsement and sablefish quota[a]	Longlines, Pots	Sablefish[c]	7-32	20-1300	Sablefish tier quotas; Seven-month season
Non-Nearshore Fixed Gear	Sablefish non-endorsed (a.k.a. Zero Tier)	LE permit with fixed gear endorsement w/o sablefish quota	Longlines, Pots	Sablefish, rockfish, flatfish[d, e]	7-32	20-1300	Trip limits
Non-Nearshore Fixed Gear	Open Access	None	Longlines, Pots	Sablefish, other groundfish	3-30	20-1300	Trip limits

[a] A.k.a. LE permit. All LE permits are issued by NOAA.

[b] Issued by the International Pacific Halibut Commission (IPHC)

[c] *Anoploma fimbria*

[d] *Sebastes* spp.

[e] Pleuronectiformes

[f] *Hippoglossus stenolepis*

Appendix 2. *Observed fishing effort, sablefish landings, % of landings observed, and humpback whale takes in the limited entry pot fleet from 2002-2021.*

Year	Vessels	Trips	Sets	Sablefish Landings (mt)	Coverage Rate	Humpback Whale Takes
2002	6	23	247	82	23%	0
2003	6	35	362	148	25%	0
2004	3	13	139	83	13%	0
2005	7	39	492	281	46%	0
2006	7	39	289	200	33%	0
2007	4	30	154	90	21%	0
2008	6	24	329	245	57%	0
2009	3	27	67	66	14%	0
2010	7	43	314	140	28%	0
2011	3	22	227	137	37%	0
2012	5	19	351	101	35%	0
2013	3	14	47	41	14%	0
2014	4	16	195	104	31%	1
2015	9	35	299	219	61%	0
2016	7	55	596	263	72%	0
2017	3	14	186	115	31%	0
2018	7	36	523	292	72%	0
2019	5	24	425	207	47%	0
2020	9	34	461	251	47%	0
2021	8	25	274	222	39%	0

Appendix 3. *Observed fishing effort, sablefish landings, % of landings observed, and humpback whale takes in the open access pot fleet from 2003-2021.*

Year	Vessels	Trips	Sets	Groundfish Landings (mt)	Coverage Rate	Humpback Whale Takes
2003	7	16	50	3	2%	0
2004	17	96	185	17	9%	0
2005	14	43	50	11	3%	0
2006	15	38	39	8	2%	0
2007	21	46	75	9	3%	0
2008	20	55	75	10	4%	0
2009	18	30	45	9	2%	0
2010	26	40	71	11	3%	0
2011	29	61	85	19	7%	0
2012	19	35	70	9	7%	0
2013	17	25	48	6	9%	0
2014	21	41	63	12	8%	0
2015	17	49	64	15	7%	0
2016	27	55	73	15	7%	1
2017	44	87	126	25	12%	0
2018	33	58	89	17	10%	0
2019	26	46	70	17	11%	0
2020	7	11	22	4	7%	0
2021	6	9	25	4	5%	0

Appendix 4. *Observed fishing effort, sablefish landings, % of landings observed, and humpback whale takes in the open access line fleet from 2003-2021.*

Year	Vessels	Trips	Sets	Groundfish Landings (mt)	Coverage Rate	Humpback Whale Takes
2003	13	41	49	17	3%	0
2004	14	42	52	16	3%	0
2005	10	34	37	10	2%	0
2006	7	10	11	4	1%	0
2007	25	51	67	10	4%	0
2008	33	58	68	16	4%	0
2009	34	69	104	22	3%	0
2010	37	70	105	23	3%	0
2011	40	69	101	20	5%	0
2012	24	34	53	11	4%	0
2013	14	23	30	5	2%	0
2014	21	28	39	12	5%	0
2015	20	38	54	17	5%	0
2016	31	57	78	16	5%	0
2017	43	62	79	15	4%	0
2018	43	83	104	16	5%	0
2019	30	50	80	12	4%	0
2020	11	24	34	7	3%	0
2021	28	47	63	15	5%	1

Appendix 5. *Gear*, o*bserved fishing effort, groundfish landings, % of landings observed, and humpback whale takes in the catch shares fixed gear fleet. EM = electronic monitoring.*

Sector	Gear	Year	Vessels	Trips	Sets	Pots or Lines (#)	Landings (mt)	Coverage Rate	HBW Takes
Catch Shares	Line	2011	11	94	624	2,247,803	334	99%	0
Catch Shares	Line	2012	8	32	501	1,457,954	239	99%	0
Catch Shares	Line	2013	8	29	215	587,238	79	100%	0
Catch Shares	Line	2014	8	31	219	579,183	85	87%	0
Catch Shares	Line	2015	5	16	180	577,070	133	97%	0
Catch Shares	Line	2016	5	30	322	1,005,900	177	92%	0
Catch Shares	Line	2017	4	13	145	464,557	113	97%	0
Catch Shares	Line	2018	4	10	135	473,437	152	93%	0
Catch Shares	Line	2019	3	10	141	452,294	129	91%	0
Catch Shares	Pot	2011	17	233	1535	41,310	814	100%	0
Catch Shares	Pot	2012	19	278	1704	52,116	739	100%	0
Catch Shares	Pot	2013	10	100	1080	29,982	468	99%	0
Catch Shares	Pot	2014	14	118	1284	31,754	678	100%	0
Catch Shares	Pot	2015	8	62	575	18,556	402	99%	0
Catch Shares	Pot	2016	8	61	580	15,632	385	99%	0
Catch Shares	Pot	2017	6	44	572	16,258	365	100%	0
Catch Shares	Pot	2018	6	24	309	11,510	293	100%	0
Catch Shares	Pot	2019	6	35	488	16,667	368	98%	0
Catch Shares EM	Pot	2015	7	18	184	4,272	102	30%	0
Catch Shares EM	Pot	2016	6	19	249	6,275	152	34%	0
Catch Shares EM	Pot	2017	7	22	270	7,147	184	37%	0
Catch Shares EM	Pot	2018	5	24	318	6,740	164	40%	0
Catch Shares EM	Pot	2019	6	30	194	5,563	126	26%	0
Catch Shares All	Pot	2020	4	15	244	11,156	104	14%	0
Catch Shares All	Pot	2021	6	25	256	9,418	239	35%	0