

**Draft Analysis of U.S. West Coast Large Whale Entanglement Serious Injury and
Mortality Assessments for Use in Conservation Planning by States
NMFS West Coast Region Protected Resources Division**

Note: this document has been modified from its original form to meet California standards for document accessibility.

Background and Purpose

In 2019, Fish and Wildlife Departments from three U.S. West Coast States that manage commercial and recreational Dungeness crab fisheries (California, Oregon, and Washington) announced their intentions to pursue Incidental Take Permits (ITP) under the Endangered Species Act (ESA) through the Development of Conservation Plans that support and guide management of their Dungeness crab fisheries to minimize the risks of entangling ESA-listed species, including large whales, in their fisheries. Subsequently, NOAA Fisheries (NMFS) West Coast Region (WCR) Protected Resources Division (PRD) has been engaged in coordination efforts with all 3 States to discuss and execute the necessary steps that are involved in this significant regulatory process, both individually with each State and collectively with all States combined. We note the collective “Tri-State” coordination has been an invaluable venue for NMFS to effectively and efficiently coordinate with States on the cross-cutting issues that underlie the task of Conservation Planning for Dungeness crab fisheries for all States, and the opportunity for cross-pollination of ideas or approaches to Conservation Planning that can help lead the States and NMFS to ultimate completion of this process and the issuance of ESA permits, as appropriate.

One cross-cutting issue that emerged during coordination with States was the need for making informed assumptions regarding the potential fate of any whales that may be entangled in the future. The Conservation Plans that are being developed and associated permit consideration documents are required to describe and evaluate the potential impacts of entanglements on individuals and on populations. There are numerous other potential uses for this type of information within the Conservation Plans that may include monitoring the type/extent of injuries that are incurred during entanglements over time and measuring the performance of management measures on reducing the impact of entanglements. It

may also be possible this information could be used to help design new management measures based on shared characteristics of various gear configurations and/or other circumstances of entanglements that may be expected to reduce the severity and outcomes for entanglements based on the type/extent of injuries that have been documented in the past.

In order to help the States address this need, NMFS WCR agreed to provide the States updated information and analysis of previous entanglements to set a foundation for prediction of the outcomes of future entanglements (if nothing changes about gear or management of fisheries, etc.) and provide a basis for comparison for any aspects that do change over time. In order to do this, NMFS WCR relies upon the assessment of mortality and serious injury of reported U.S. West Coast whale entanglements, conducted by the NMFS Southwest Fisheries Science Center (SWFSC). The Marine Mammal Protection Act (MMPA) requires NMFS to document human-caused mortality (M), non-serious injury (NSI), and serious injury (SI) of marine mammals, as part of marine mammal stock assessments and to evaluate human-caused injury and mortality levels in the context of potential biological removal (PBR) levels under the MMPA within those assessments. In addition, human-caused serious injury and mortality levels are also considered in the context of “negligible impact thresholds” for the purposes of authorizing incidental take of certain stocks of marine mammals that are also protected under the ESA. NMFS defines SI as “any injury that will likely result in mortality”, and the criteria used by to assess SI are based on guidance from previous SI workshops, expert opinion, and analysis of historical injury cases to develop new criteria for distinguishing SI from NSI (Carretta et al. 2019). These criteria, along with the SI/M determinations for all human-caused injury and mortalities of all marine mammals along the U.S. West Coast that have been reported during the most recent 5 year period that has been evaluated, are published every year by SWFSC as a Technical Memorandum (SI/M report). The most recent SI/M report that has published (Carretta et al. 2019) contained SI/M assessment data for records from 2013 through 2017. In February 2020, a draft SI/M report was shared with the Pacific Scientific Review Group for their review and comment that contained SI/M assessment for records through 2018. This report is expected to publish in the summer of 2020.

Description of Records Use for Analysis of WCR Entanglement SI/M

For the purposes of this analysis, WCR decided to use the most updated information available, which includes SI/M assessment data from confirmed whale entanglements reported to WCR 2013 through 2018, which included information from the draft 2020 SI/M report as it stood in review as of May, 2020 (Carretta et al. 2020). We note that Carretta et al. (2019, 2020) contains additional stranding cases or other known human caused injuries or mortalities for whales that are not represented in the WCR entanglement database as confirmed cases for various reasons surrounding the type of human interactions that are implicated by the available information, along with the nature of the information and/or how it was reported. The criteria used by the WCR when evaluating entanglement reports received, which have been used as the foundation for the public reporting of West Coast confirmed entanglement data annually since 2015, are described in Saez et al. 2020. Initially we did review all confirmed WCR whale entanglement reports back to 2007 (281 confirmed WCR entanglement reports that had been evaluated for SI/M). Generally we consider the time period starting from 2013 moving forward to represent the “modern” era of entanglement documentation and reporting given the changes in the number and quality of entanglement reports received since 2013, along with extensive overall efforts by WCR since that time to improve the quality of documentation and evaluation of these events. This time period also generally coincides with the increasing availability of digital images/video from cell phones and similar technology to accompany entanglement reports, especially from members of the general public, compared to the nature of documentation that would typically accompany reports historically. Our initial assessment is that inclusion of the historical data back to 2007 does not influence the outcome of these analyses, which would be expected given that magnitude of reports received since 2013 has greatly increased and data from this more recent period primarily drives the analytical results across the entire time period. Given these factors, we settled on use of data from 2013 moving forward to provide the most updated analysis and serve as the most appropriate baseline from which to measure any future progress or changes in the underlying nature of how entanglements may be affecting humpback whale individuals and populations.

In total, 219 WCR confirmed whale entanglements from 2013-2018 evaluated for SI/M by Carretta et al. (2019, 2020) are included in this analysis.¹ This includes: 146 confirmed humpback whale entanglements, 52 confirmed gray whale entanglements, 7 confirmed blue whale entanglements, 3 confirmed fin whale entanglements, and 11 confirmed entanglement where the whale could not be identified. Additionally, 2 entanglements of transient killer whales off California that were evaluated for SI/M by the Alaska Fisheries Science Center (AKFSC; Delean et al. 2020) are also included in this analysis since both entanglement involved reports, and known gear origins, from California. All of these records serve as the underlying source of subsequent analyses that are presented. In addition to a final SI/M assessment for each entanglement report, Carretta et al. also provide an initial SI/M assessment based upon description of injuries from the initial report prior to any subsequent developments that may occur after, which includes human intervention (HI) or other changes in the characteristics or nature of the entanglement over time including self-release of the gear by whales. Analyses of SI/M data consist of summary tabulation and presentation of the following elements:

- Description of a category of WCR confirmed whale entanglement reports with a set of shared characteristics.
- Number (#) of WCR confirmed entanglements that qualify to meet the category description
- Sum of assigned SI/M (either final or initial) for all qualifying WCR confirmed entanglements.
- As specified by each table, calculated SI/M rates for each category of entanglements represent the average final or initial SI/M per qualifying entanglement report.

¹ There are 43 records of human-caused injury to large whales potentially associated with fishing gear that were evaluated for SI/M by Carretta et al. from 2013-2018 that are not considered confirmed entanglements reported to WCR, according to criteria described by Saez et al. 2020: 18 humpback whales; 12 gray whales; 11 unidentified whales; 2 blue whales; and 1 minke whale. These include records where no gear was reportedly observed (e.g., “scars only”) or could be confirmed as present on whales at the time of observation based on information provided to the WCR, as well as records not reported to the WCR.

- For each category in Tables 1 and 3, we calculate an overall SI/M rate for all WCR confirmed entanglement cases, and a separate SI rate² for only the entangled whales reported as alive.³
- For categories that reference multiple-trap gear, we include entanglement cases known to have involved fishing gear where more than one trap is attached together in one set, as opposed to many fisheries where traps are fished individually with one trap per one vertical line. These fisheries include: spot prawn, sablefish, and coonstripe shrimp pot and trap fisheries.
- For categories that reference more than one set of gear, we include entanglement cases known to have had at least two different “pieces” or “sets” of gear that were not connected to each other prior to the entanglement event. These cases may have involved multiple sets from one individual fisherman, or gear from different fisheries and/or other non-fishery origins.
- For categories that include entanglement cases involving Dungeness crab gear, we include entanglements that involved Dungeness crab gear reported from an area that may not have been positively attributed to any specific area. Saez et al. (2020) found that nearly 80% of reported entanglements originate from the same region where they were reported, when those origins could be identified. As a result, we conclude it is more likely than not that any given entanglement with Dungeness crab gear originated from the same region it is reported.
- For categories that involve entanglement cases where at least some entangling gear was removed through human intervention or released by the whale as a result of HI, the assessed SI rate (all live animals) based on the initial description of the entanglement before intervention and subsequent removal or release of gear is calculated, and then compared to the assessed SI rate based on the final description of injuries and outcomes of those cases (Table 2). In Table 2, we note the percentage of the entanglement cases where gear was removed or released as a

² For animals that are alive, injuries would be categorized as a serious injury or non-serious injury.

³ There are four entangled whales in this dataset that were known to have died after being reported entangled as alive: 2 gray whales and 2 humpback whales.

result of HI compared to all otherwise qualifying entanglement cases. In Table 3, we note the percentage of entanglements for each category where gear was not removed or released by HI.

- In Table 4, we combine the final SI/M from entanglements where there was no gear removed or released as a result of HI (Table 3), with the initial SI from entanglements where gear was removed or released as a result of HI (Table 2), for each qualifying case, to assess the overall SI/M rates for each category assuming no HI would have occurred that would have led to the removal or release of gear. An SI rate for only those entangled whales that were last reported as alive assuming no gear would have been removed or released as a result of HI is also calculated.

Analysis of WCR Entanglement SI/M

The analysis of WCR entanglement SI/M is presented in table form (Tables 1-4).

Table 1. SI/M rate calculations for 28 categories of entanglements reflecting *final* assessments of SI/M for each qualifying case, including an SI/M rate for all whales and an SI rate for those that were last reported as alive.

Confirmed whale entanglements 2013-2018	# of entanglements	Total SI/M	SI/M rate	# of dead whales	Live whale SI rate
All confirmed entanglements - all whales	221	160.25	0.73	18	0.70
All confirmed humpback whale entanglements	146	99.0	0.68	7	0.66
All confirmed gray whale entanglements	52	42.75	0.82	9	0.78
All confirmed blue whale entanglements	7	6.0	0.86	0	0.86
All confirmed fin whale entanglements	3	3.0	1.00	0	1.00

Confirmed whale entanglements 2013-2018	# of entanglements	Total SI/M	SI/M rate	# of dead whales	Live whale SI rate
All confirmed killer whale entanglements	2	1.0	0.50	1	0.00
All confirmed unidentified whale entanglements	11	8.5	0.77	1	0.75
All confirmed whale entanglements with Dungeness crab gear	68	46.5	0.68	9	0.64
All confirmed humpback whale entanglements with Dungeness crab gear	52	34.25	0.66	4	0.63
All confirmed gray whale entanglements with Dungeness crab gear	11	8.5	0.77	4	0.64
All confirmed blue whale entanglements with Dungeness crab gear	3	2.75	0.92	0	0.92
All confirmed whale entanglements with recreational pot gear (all with humpback whales)	3	1.75	0.58	0	0.58
All confirmed whale entanglements with multiple-trap gear (all with humpback whales)	13	5.75	0.44	1	0.40
All confirmed whale entanglements in more than one set of gear	13	9.75	0.75	3	0.68

Confirmed whale entanglements 2013-2018	# of entanglements	Total SI/M	SI/M rate	# of dead whales	Live whale SI rate
All confirmed humpback whale entanglements in more than one set of gear	12	8.75	0.73	2	0.68
All confirmed whale entanglements with gillnet/net gear	26	18.25	0.70	3	0.66
All confirmed humpback whale entanglements with unknown origins	68	51.0	0.75	1	0.75
All confirmed whale entanglements with CA commercial Dungeness crab gear (including entanglements with unknown origin Dungeness crab gear reported in CA)	50	33.5	0.67	6	0.63
All confirmed humpback whale entanglements with CA commercial Dungeness crab gear (including entanglements with unknown origin Dungeness crab gear reported in CA)	40	26.0	0.65	3	0.62

Confirmed whale entanglements 2013-2018	# of entanglements	Total SI/M	SI/M rate	# of dead whales	Live whale SI rate
All confirmed whale entanglements with OR commercial Dungeness crab gear (including entanglements with unknown origin Dungeness crab gear reported in OR)	6	2.0	0.33	0	0.33
All confirmed humpback whale entanglements with OR commercial Dungeness crab gear (including entanglements with unknown origin Dungeness crab gear reported in OR)	4	1.0	0.25	0	0.25
All confirmed whale entanglements with WA commercial Dungeness crab gear (including entanglements with unknown origin Dungeness crab gear reported in WA)	9	8.25	0.92	3	0.88
All confirmed humpback whale entanglements with WA commercial Dungeness crab gear (including entanglements with unknown origin Dungeness crab gear reported in WA)	5	4.5	0.90	1	0.88

Confirmed whale entanglements 2013-2018	# of entanglements	Total SI/M	SI/M rate	# of dead whales	Live whale SI rate
All confirmed humpback whale entanglements with OR and WA (PNW) Dungeness crab gear (including tribal; including entanglements with unknown origin Dungeness crab gear reported in PNW)	10	6.5	0.65	1	0.61
All confirmed whale entanglements reported in CA	178	128.25	0.72	11	0.70
All confirmed humpback whale entanglements reported in CA	119	79.0	0.66	3	0.66
All confirmed whale entanglements reported in PNW	35	24.5	0.70	6	0.64
All confirmed humpback whale entanglements reported in PNW	19	12.5	0.66	3	0.59

Table 2. SI rate calculations for 11 categories of entanglements reflecting a comparison of *initial and final* assessments of SI for each qualifying case. Parenthetical values in column 2 are the percent of qualifying cases where at least some gear is removed or released as a result of HI.

Confirmed whale entanglements 2013-2018	# of entanglements (% of cases)	Total SI (Final)	SI rate (Final)	Total SI (Initial)	SI rate (Initial)
All confirmed whale entanglements where at least some gear was removed or released as a result of HI	41 (19)	21.5	0.52	36	0.88
All confirmed humpback whale entanglements where at least some gear is removed or released as a result of HI	30 (21)	13.25	0.44	26.25	0.88
All humpback whale entanglements with Dungeness crab gear where at least some gear is removed or released as a result of HI	18 (35)	7.75	0.43	15.25	0.85
All confirmed humpback whale entanglements with CA commercial Dungeness crab gear where at least some gear is removed or released as a result of HI	10 (25)	3.25	0.33	7.75	0.78
All confirmed humpback whale entanglements with OR commercial Dungeness crab gear where at least some gear is removed or released as a result of HI	4 (100)	1	0.25	4	1.00

Confirmed whale entanglements 2013-2018	# of entanglements (% of cases)	Total SI (Final)	SI rate (Final)	Total SI (Initial)	SI rate (Initial)
All confirmed humpback whale entanglements with WA commercial Dungeness crab gear where at least some gear is removed or released as a result of HI	2 (40)	1.5	0.75	1.5	0.75
All confirmed humpback whale entanglements with PNW Dungeness crab gear (including tribal) where at least some gear is removed or released as a result of HI	7 (70)	3.5	0.50	6.5	0.93
All confirmed humpback whale entanglements with multiple-trap gear where at least some gear is removed or released as a result of HI	8 (62)	3	0.38	7.25	0.91
All confirmed humpback whale entanglements with multiple-trap gear	13 (n.a.)	5.75	0.44	12	0.92
All confirmed humpback whale entanglements in more than one set of gear where at least some gear is removed or released as a result HI	5 (42)	1.75	0.35	3.75	0.75
All confirmed humpback whale entanglements in more than one set of gear	12 (n.a.)	8.75	0.73	10.75	0.90

Table 3. SI/M rate calculations for 9 categories of entanglements reflecting *final* assessments of SI/M for each qualifying case, including an SI/M rate for all whales and an SI rate for those that were last reported as alive. Parenthetical values in column 2 are the percent of qualifying cases where at least some gear is removed or released as a result of HI.

Confirmed whale entanglements 2013-2018	# of entanglements (% of cases)	Total SI/M	SI/M rate	# of dead whales	Live whale SI rate
All confirmed whale entanglements where no gear is removed or released as a result of HI	180 (81)	137.75	0.77	18	0.74
All confirmed humpback whale entanglements where no gear was removed or released as a result of HI	116 (79)	84.75	0.73	7	0.71
All humpback whale entanglements with Dungeness crab gear where no gear is removed or released as a result of HI	34 (65)	26.5	0.78	4	0.75
All confirmed humpback whale entanglements with CA commercial Dungeness crab gear where no gear is removed or released as a result of HI	30 (75)	22.75	0.76	3	0.73
All confirmed humpback whale entanglements with OR commercial Dungeness crab gear where no gear is removed or released as a result of HI	0 (0)	n.a.	n.a.	0	n.a.

Confirmed whale entanglements 2013-2018	# of entanglements (% of cases)	Total SI/M	SI/M rate	# of dead whales	Live whale SI rate
All confirmed humpback whale entanglements with WA commercial Dungeness crab gear where no gear is removed or released as a result of HI	3 (60)	3	1.00	1	1.00
All confirmed humpback whale entanglements with PNW Dungeness crab gear (including tribal) where no gear is removed or released as a result of HI	3 (30)	3	1.00	1	1.00
All confirmed humpback whale entanglements with multiple-trap gear where no gear is removed or released as a result of HI	5 (38)	2.75	0.55	1	0.44
All confirmed humpback whale entanglements in more than one set of gear where no gear is removed or released as a result of HI	7 (58)	8	1.00	2	1.00

Table 4. SI/M rate calculations for 9 categories of entanglements reflecting *overall SI/M rates* assuming no HI would have occurred that would have led to the removal or release of gear for each qualifying case, including a SI rate for those entangled whales that were last reported as alive.

Confirmed whale entanglements 2013-2018	# of entanglements	Final SI/M - no gear removed or released by HI	# of dead whales	Initial SI/M - HI led to gear removed or released	SI/M rate - no HI	SI/M rate for live whales - no HI
All confirmed entanglements - all whales	221	137.75	18	36	0.79	0.77
All confirmed humpback whale entanglements	146	84.75	7	26.25	0.76	0.75
All confirmed humpback whale entanglements with Dungeness crab gear	52	26.5	4	15.25	0.80	0.79
All confirmed humpback whale entanglements with CA commercial Dungeness crab gear (including entanglements with unknown origin Dungeness crab gear reported in CA)	40	22.75	3	7.75	0.76	0.74

Confirmed whale entanglements 2013-2018	# of entanglements	Final SI/M - no gear removed or released by HI	# of dead whales	Initial SI/M - HI led to gear removed or released	SI/M rate - no HI	SI/M rate for live whales - no HI
All confirmed humpback whale entanglements with OR commercial Dungeness crab gear	4	0	0	4	1.00	1.00
All confirmed humpback whale entanglements with WA commercial Dungeness crab gear	5	3	1	1.5	0.90	0.88
All confirmed humpback whale entanglements with PNW Dungeness crab gear (including tribal)	10	3	1	6.5	0.95	0.94
All confirmed humpback whale entanglements with multiple-trap gear	13	2.75	1	7.25	0.77	0.75

Confirmed whale entanglements 2013-2018	# of entanglements	Final SI/M - no gear removed or released by HI	# of dead whales	Initial SI/M - HI led to gear removed or released	SI/M rate - no HI	SI/M rate for live whales - no HI
All confirmed humpback whale entanglements in more than one set of gear	12	7	2	3.75	0.90	0.88

Outline of the Key Results

- Overall, the average final SI/M rate for WCR confirmed entanglements across most of the different categories described in Table 1 generally falls within a similar range (~0.6-0.8) centering around 0.7, with certain limited exceptions for species and gear type categories with relatively fewer entanglements and SI/M data from which to work with. In particular we note that the lower average final SI/M rates are associated with humpback whales compared to gray whales and blue whales, although we note the limited sample size of reported blue whale entanglements.
 - One potential explanation for the high final SI/M rate for entangled blue whales could be related to a potential bias in the detection of more severe entanglements for blue whales, if given their size and strength they are able to relatively easily release themselves from less severe and/or complicated entanglements that may occur, compared to other smaller whales.
- Analyses were done with all cases including dead whales, and with only cases involving live whales for comparison. Removing dead whales (with automatic SI/M scores of 1) reduces the overall expected final SI rate for live whales by a relatively small amount, as dead whales are relatively uncommon across most all categories described, making up only ~8% of all confirmed entanglements 2013-2018.

- We note that entanglements involving multiple trap gear have lower final SI/M rates than other gear types (Table 1), although removal/release of gear prevents this category from having higher final SI/M rates (see more below). Removal of gear may occur as a result of HI, but also from the self-release of gear by whales.
- We note the average final SI/M rate for Dungeness crab entanglements, mostly involving humpback whales, is relatively similar across the U.S. West Coast when entanglements from Oregon and Washington are combined as PNW (≤ 0.67 for all humpback whale entanglements; ≤ 0.63 for live humpback whale entanglements; Table 1). Although these final SI/M rates do reflect our assessment of the average outcomes of entanglements historically, they are not necessarily useful for consideration with the MMPA Negligible Impact criteria because they factor in the potential benefit of HI to reduce the severities of injuries.
- We note that average final SI/M rates are slightly higher for whale entanglements of unknown origins (0.75 for humpback whales; Table 1). We believe this could be related to how response, HI, and potential subsequent removal/release of gear helps reduce the final assessment of SI/M for entanglements (see more below). Responses improves our ability to identify gear belonging to specific fisheries such as Dungeness crab gear, and to more precisely evaluate the extent of injuries that may have been incurred as a result of the entanglement.
- Removal or release of at least some gear from entangled whales associated with HI to some degree occurs in about ~20% of all WCR confirmed entanglement cases.
 - In Table 2, we note that there is a higher rate of gear removal or release in humpback whale entanglements with Dungeness crab gear as a result of HI (35%), and an even higher rate for entanglements with Dungeness crab gear in the PNW (70%) compared to entanglements with commercial Dungeness crab in CA (25%). We believe there is a positive relationship between entanglement cases where there is some response, which may lead to subsequent removal or release of gear, and the ability to positively identify the origins of entangling gear based on the enhanced documentation that is gathered from responses.

- In Table 2, we note that the rate of gear removal or release in humpback whale entanglements as a result of HI is especially high in entanglements that are known to have originated in multiple-trap fishing gear (62%). This is likely due in part to whales that get entangled in heavier gear such as long strings of traps being anchored in place instead of free-swimming and thus potentially easier for responders to address. It may also be more likely that over time, entanglements caused by heavier gear persist longer providing more opportunities for detection and response than entanglements that are less severe. Whales that are anchored are also likely more obviously in distress compared to free-swimming whales that may be entangled but not necessarily obviously entangled to all ocean users without close examination.
- The impact of gear removal or release as a result of HI on the final determination of SI is significant. These results indicate that removal or release of gear by HI reduces the final assessment of SI by ~50% on average for the entanglements this occurred across most all of the categories that were described (Table 2). For example, the initial SI assessment for all confirmed humpback whale entanglements where at least some gear is removed or released as a result of HI is 0.88, whereas the final SI assessment is 0.44 (Table 2). In the case of humpback whale entanglements in CA Dungeness crab gear, the average final SI rate was reduced by 58% by HI (initial SI rate of 0.78 vs final SI rate of 0.33). For humpback whale entanglements with multiple-trap fishing gear, average SI was also reduced by 58% (initial SI rate of 0.91 vs final SI rate of 0.38). In these cases, the initial SI assessment is higher than other categories (0.91), as more severe injuries could be expected to occur in some entanglements with heavier gear. If no gear is removed or released by HI, the final SI rate for multiple trap gear entanglements was 0.55 (Table 3), resulting in part from a couple of self-releases of gear by whales without HI.⁴

⁴ There are 10 confirmed whale entanglement cases from 2013-2018 that are associated with a self-release of gear by the whale without any HI, as follows: 7 humpback whales, 1 gray whale, 1 blue whale, and 1 killer whale. Six of these involved CA Dungeness crab gear, 2 involved multiple-trap CA spot prawn gear (1 recreational and 1 commercial), and 2 involved unidentified gear.

- For entanglements involving more than one set of gear, SI rates were reduced by 53% by gear removal or release as a result of HI (initial SI rate of 0.75 vs final SI rate of 0.35). If gear was not removed or released by HI, all of these cases would have been deemed SI (Table 3).
- Initial injury SI assessments for humpback whale entanglements with Dungeness crab gear in the PNW when there has been HI (0.93) have typically been higher on average compared to humpback whale entanglements with CA Dungeness crab gear where there has been HI (0.78), although far fewer PNW Dungeness crab entanglements of humpback whales have been reported and confirmed (Table 2). There has previously been acknowledgement that there is potential for bias for less observation and reporting of entanglements from more remote areas (Saez et al 2020).
 - One way this bias may be realized is if it's more likely for more severe entanglements to ultimately be detected and documented than less severe entanglements given that more severe entanglements are likely to persist longer if the whale is unable to shed the gear on it's own, which is presumably more likely to occur with less severe entanglements. In remote areas, such as much of the PNW, this potential bias may be exaggerated by the relative lack of "eyes on the water" throughout large portions of the area compared to coastal areas in some portions of California with huge population centers, especially considering prevailing weather conditions during much of the year.
 - This could also be related to the duration of time between an entanglement occurring and its ultimate detection. The longer an entanglement persists before detection, the greater the opportunity for injuries to accumulate (and be documented), and for the nature of the entanglement to evolve into increasingly severe orientations involved to continue to develop of the entangling gear to
 - We acknowledge that severe entanglements may lead to quicker death which could work to counter this bias to some degree. We also acknowledge that whales who survive entanglements (both reported and unreported entanglements) and subsequently are photographed or observed with signs of

previous entanglement (*i.e.*, scarring), must sometimes manage to lessen the severity of the entanglement over time when they are able to release themselves from the gear.

- Analysis specifically of the final SI/M rates for entanglement cases where gear is not removed or released by HI reiterates the impact of gear removal or release (Table 3). Average final SI rates for entanglements in these categories are higher (0.75 for live humpback whale entanglements with Dungeness crab gear) than if considering the final SI rate of all otherwise qualifying cases including removal or release of gear (0.63; Table 1).
- The average final SI/M rates for all whale entanglements (Table 1) that are known to involve gillnet or other nets (0.70) are comparable to those from all origins (0.73), and are similar to those known to involve Dungeness crab gear (0.68).

Discussion and Recommendations

The results of this analysis provide useful insight into the varying impact of different types and categories of entanglements for individuals and populations of whales that become entangled in fixed fishing gear on the U.S. West Coast. By using the assessed SI/M from previous entanglements and the subsequent average SI/M rate calculated for all entanglements of a relevant category, we are able to generate expectations for what the SI/M rates of entangled whales of relevant categories may be in the future for use predicting the population-level impacts of entanglements. In addition, the average SI/M rates for varying categories could be used to generate preliminary expectations for actual entanglements that occur to support in-season management actions or spur implementation of new management measures in advance of a formal determination of SI/M by NMFS through its normal evaluation process. These results also offer a baseline of historic impact (SI/M rates) that can be used to monitor the effectiveness of any management measures or changes in fishing practices that are implemented. In general, the results suggest that average final SI/M rates for many broader categories of entanglements are relatively similar coastwide, including in particular humpback whale entanglements with Dungeness crab fisheries. This reflects the nature of injuries from the types of entanglements that are observed and reported, along with the influence of

response on the level of information that is available, as well as the ultimate outcomes of entanglements. In June, 2020, NMFS finalized a procedural directive criteria for determining Negligible Impact to ESA-listed stocks of marine mammals as a result of incidental takes by commercial fisheries (NMFS 2020). In this directive, it was made clear that when NMFS is making determinations of Negligible Impact for commercial fisheries, any SI/M that would have occurred absent HI must be considered (*i.e.*, initial SI determination from those cases). Based on these criteria, we combined the available information from final SI/M assessments with initial SI/M assessments of entanglement where removal or release of gear could be associated with HI to calculate historical SI/M rates that most directly relate to the Negligible Impact criteria (Table 4). As would be expected, removing the impact of HI increases the rates of SI/M associated with entanglements. For example, for all humpback whale entanglements with Dungeness crab gear, the average overall SI/M rate for entanglements assuming no HI is 0.80 (Table 4), compared to the final SI rate of 0.68 for these entanglements including the impact of HI when removal of gear due to HI is considered. For categories of entanglements where HI is more common, the difference in overall SI/M rates when HI is factored out is even greater (e.g., humpback whale entanglements that involve Oregon Dungeness crab gear have an average final SI/M rate of 0.25 with HI, and an initial SI rate of 1.0 without HI). Given the results of this analysis, there are a number of potential uses for this information. Foremost among these are more immediate uses of the data to support Conservation Planning efforts for State-managed fisheries, and specifically to incorporate the analysis of SI/M rates into findings of Negligible Impact for marine mammal stocks under the MMPA. We find it reasonable to suggest the following possible courses of actions for States to consider when making assumptions about the future SI/M of entangled whales when developing their Conservation Plans:

1. Each State could rely upon their State-specific overall SI/M rate for appropriate categories of entanglement assuming no HI would have occurred that would have led to the removal or release of gear for these entanglements (Table 4). These overall SI/M rates for humpback whales in Dungeness crab fisheries are respectively:

- California Dungeness crab fisheries - 0.76 for all humpback whale entanglements; 0.74 for entangled humpback whales that are alive.
 - Oregon Dungeness crab fisheries - 1.00 for all humpback whale entanglements, including for entangled humpback whales that are alive.
 - Washington Dungeness crab fisheries - 0.90 for all humpback whale entanglements; 0.88 for entangled humpback whales that are alive.
2. States could rely upon the data gathered across all Dungeness crab fisheries along the U.S. West Coast and use a standard overall SI/M rate for appropriate categories of entanglement assuming no HI would have occurred that would have led to the removal or release of gear for these entanglements (Table 4):
 - The overall SI/M rate for all humpback whale entanglements with Dungeness crab gear – 0.80 for all humpback whale entanglements; 0.79 for entangled humpback whales that are alive.
 3. For blue whales, the only origin of Dungeness crab gear involved in their entanglements that has been identified to date is from California. As a result, all States could rely upon the same overall SI/M rate for all blue whale entanglements with Dungeness crab gear (Table 1) – 0.86 for all blue whale entanglements. Up till now there has not been any HI that has led to removal or release of gear for blue whale entanglements.
 4. For recreational crab fisheries, there have been very few entanglements documented and evaluated for SI/M. As a result, we recommend relying upon the overall SI/M rates for Dungeness crab fisheries each State or coastwide that have been derived exclusively or almost entirely from commercial crab fisheries, as described in this section, when considering the potential overall SI/M rates for entanglements with recreational crab fisheries .

There are numerous other examples of possible assumed SI/M rates for various categories of entanglements that can be drawn or inferred from these results upon further consultation with NMFS.

The results of this analysis also offer insights into potential opportunities to reduce the overall total SI/M of future entanglements through changes in gear and fishing practices or

management. Generally, it has been well demonstrated how instances of gear removal or release can lower the expected SI/M rates for most categories of entanglements by half or more. In addition to supporting improved response capabilities, which may not be factored into determinations of Negligible Impact under the current criteria, States should consider the development and implementation of modifications to gear or fishing practices that can facilitate the release of gear by entangled whales on their own without or before more serious injuries can occur. Investments to support investigations of the use of “weak lines” or “weak links” in U.S. West Coast crab fisheries may produce results that can help guide future implementation of these innovations to reduce overall SI/M rates for entangled whales.

It also appears that some transitioning away from the mandated use of one trap per vertical line that exists in many West Coast fixed gear fisheries toward use of multiple-trap setups for gear that commonly interacts with whales (i.e., Dungeness crab gear) could reduce the expectations for overall total SI/M from future entanglements, if the reduced numbers of vertical lines in the water over time leads to a reduced number of total entanglements through a reduced co-occurrence and accumulated probability of interaction and opportunity for entanglements to occur. This would be accurate even without assuming any potential benefit of increased detection, response, or release of whales entangled with multiple-trap gear, which is suggested to some degree by the data analyzed. Even if worst-case scenarios involving the potential for increased SI/M rates associated with multiple-trap gear entanglements without HI are assumed (initial SI/M rates for entanglements where gear was removed was 0.91 from Table 3), those overall SI/M rates would only be marginally higher than entanglements with only one trap per vertical line assuming no gear was or would be removed.

While it appears that the use even shorter strings of gear with at least 2 traps with one vertical line (where appropriate) could reduce the overall risks of SI/M from entanglement, currently there aren't enough data from previous entanglements with relatively short strings of gear (5 or less traps) to more fully evaluate expectations for how the use of them (or varying configurations of them) might impact the relative severity of injuries. Ultimately, we acknowledge that any assumptions made about detection and the severity of injuries for multiple-trap gear entanglements gear should be further evaluated and/or closely monitored

if relied upon for the basis of any management decisions that increase the use of these gear configurations.

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