REQUEST FOR REGULATIONS AND LETTERS OF AUTHORIZATION

FOR THE INCIDENTAL TAKING OF MARINE MAMMALS RESULTING FROM U.S. NAVY TRAINING AND TESTING ACTIVITIES IN THE HAWAII-SOUTHERN CALIFORNIA TRAINING AND TESTING STUDY AREA

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 Description of Specified Activity

1.1 Background

In October 2018, the United States (U.S.) Department of the Navy (Navy) issued a Final Environmental Impact Statement (EIS)/Overseas Environmental Impact Statement (OEIS) for Hawaii-Southern California Training and Testing (HSTT) pursuant to the National Environmental Policy Act (NEPA) of 1969 (42 U.S.C. 4321 et seq.) and Executive Order (EO) 12114. The Navy signed a Record of Decision (ROD) in December 2018. In support of the EIS/OEIS, the Navy requested authorization from National Marine Fisheries Service (NMFS) for incidental take of marine mammals under the Marine Mammal Protection Act (MMPA) of 1972, as amended (16 U.S.C. 1361 et seq.) associated with training and testing activities analyzed in the 2018 HSTT EIS/OEIS. On December 19, 2018, NMFS issued regulations and LOAs for incidental take of marine mammals resulting from Navy training and testing activities in the HSTT study area for the 5-year period 2018 through 2023. In August 2018, the MMPA was amended (section 316 of Public Law No. 115-232) to allow incidental take for military readiness activities to be issued for up to seven years. In July 2020, NMFS issued a revised HSTT Final Rule (NMFS 2020a) and associated LOAs for the 7-year period from December 19, 2018 through December 20, 2025.

1.2 LOA Modification Request

Pursuant to NMFS (2020a) Subpart H, §§ 218.76 & 77 (*Letters of Authorization & Renewals and modifications of Letters of Authorization*), the U.S. Navy (Navy) has new data derived from Navy vessel strikes of large whales incident to Navy vessel movement in the Southern California Range Complex (SOCAL) portion of the HSTT study area since July 2020. This data goes to the number of large whales that may be taken by an incidental Navy vessel strike during the LOA period, a required element of a LOA request (see 50 CFR § 216.104(a)(6)). Specifically, in June and July 2021, there were two separate Navy vessel strikes of an unidentified whale incidental to the movement of each vessel. The two whale strikes by the Navy do not exceed the serious injury or mortality take authorized in the current Rule and LOAs (2020a, 2020b). But, given that this new data changes the quantity of the Navy's requested injury or morality take authorization, resulting from strike incidental to Navy vessel movement within the study area during the period of the LOAs, the Navy requests that NMFS modify the July 10, 2020 LOAs for its testing and training activities.

A foreign sovereign vessel also struck two fin whales in Southern California waters in May 2021. Consistent with 16 U.S.C. 1371(a)(5) and 50 CFR § 216, Subpart I (*General Regulations Governing Small Takes of Marine Mammals Incidental to Specified Activities*), this strike was not incident to U.S citizen activity in the HSTT study area, and so is not new data derived from Navy activity that impacts the Navy's LOA requests. However, the data derived from that foreign strike is relevant to this modification request to the extent it informs the background on vessel strikes against large whales in the Southern California area.

This LOA application reanalysizes the quantity of large whale species that may be taken, by injury or mortality, incident to Navy vessel strike in the SOCAL portion of the HSTT study area in accordance with the applicable regulations of the MMPA, as amended by the National Defense Authorization Act for Fiscal Year 2004 (Public Law 108–136) and its implementing regulations. Only those large whale species in SOCAL that may be affected by Navy vessel strike are discussed in this application. No other stressors are reanalyzed, as best available science and Navy activities have not changed (Appendix A). Also, there are no other ship strike issues or changes to previous discussions of large whales in the Hawaii portion of HSTT.

2 Dates, Duration, and Specified Geographic Region

There are no changes to previous Navy submissions and NMFS authorizations for the dates, durations, region, and types of training and testing activities within HSTT. Therefore, the discussion below contains new information only on vessel activity within the SOCAL portion of HSTT.

Navy vessel movement associated with training and testing activities are conducted throughout the year based on unit level readiness needs, participation in specific exercises, and testing schedules. To further the discussion of potential ship strike risks specific to HSTT, the Navy analyzed shipping patterns and occupancy within the both the Hawaii and SOCAL portions of HSTT. Data was only available for the combined Hawaii and SOCAL portions and not individually. However, more civilian and Navy vessel traffic occurs within SOCAL although the exact quantification is not possible base on how the data was originally derived.

Table 2-1: Vessel Traffic Time Within HSTT

Vessel Traffic Source	Cumulative Total At- Sea Days 2014-2018	5-year Annual Average At-sea Days 2014-2018
Civilian	221,625	44,325
U.S. Navy	5,583	1,117
U.S. Coast Guard	625	125

Civilian commercial shipping accounts for 97% of all annual vessel movement within HSTT while the Navy accounts for 3%. In regard to ship speeds, for Navy vessels within the core coastal and continental shelf portion of SOCAL (Figure 2-2), average Navy ship speeds range from 5 to 15 knots.

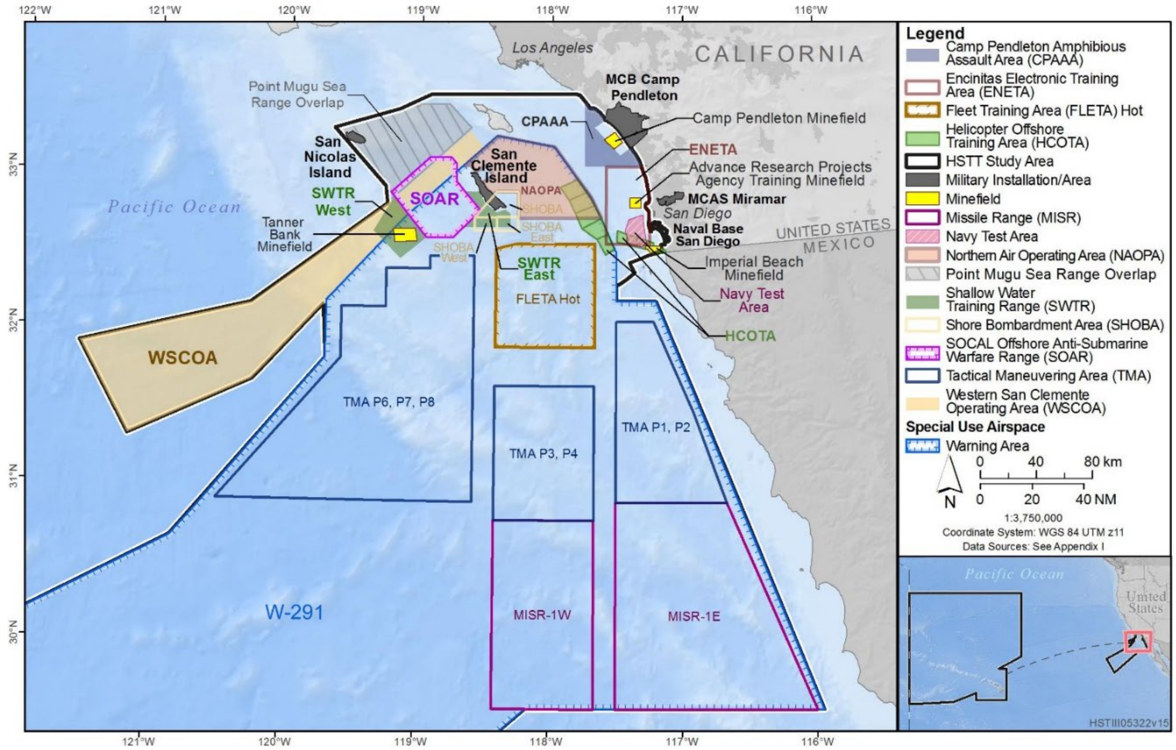

Figure 2-1. Southern California Portion of the HSTT Study Area

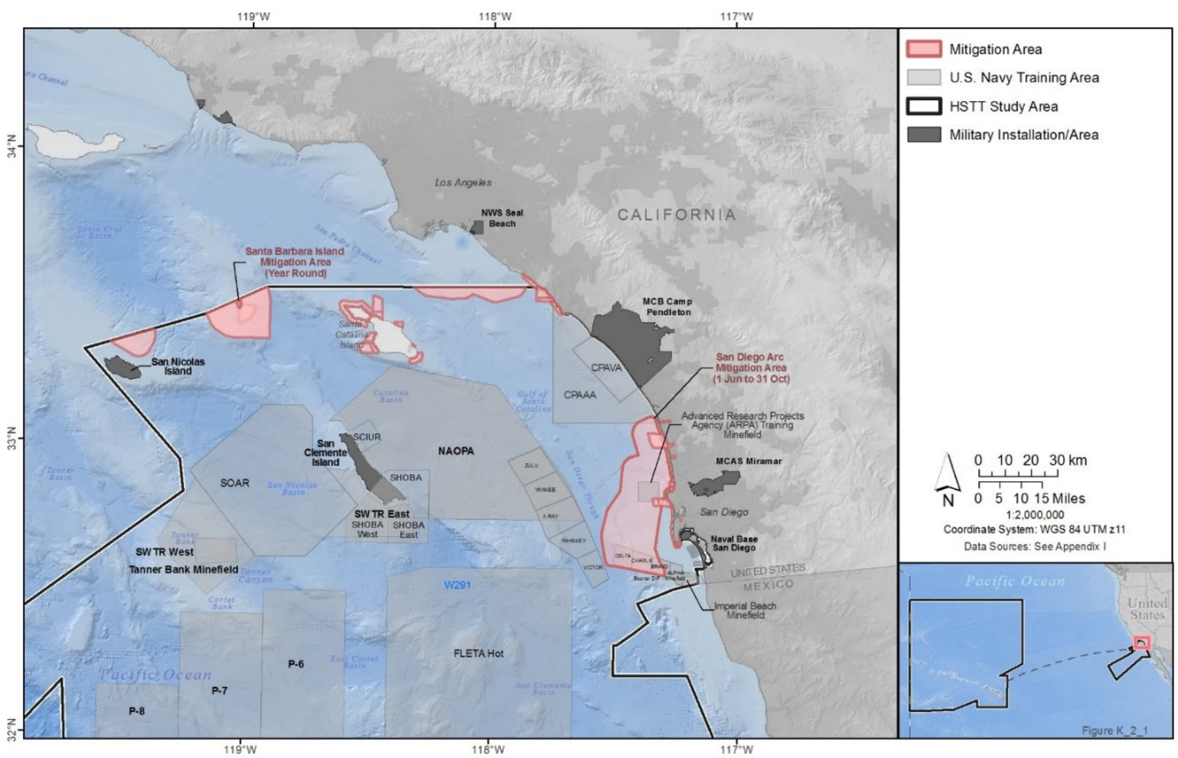

Figure 2-2. Northern Part of SOCAL Including Approved Geographic Mitigation Areas
(Spatial extent shown consists of the Navy core use areas with SOCAL in terms of vessel traffic)

3 Species and Numbers of Marine Mammals

There are eight species of large whales present in or transitory though the SOCAL portion of HSTT (Table 3-1). Transitory species include blue whales, gray whales, humpback whales, sei whales, and sperm whales. Year-round resident species include fin whales and minke whales. Seasonal species include Bryde’s whale during warm water periods and sei whales during cold water periods. Given long term climatic changes and potential for future warm water periods, sei whales would likely be even less frequent in Southern California.

New literature for these species in relation to biology as it could impact ship strike is presented in Chapter 4.

Table 3-1: Large Whale Occurrence Within the SOCAL Portion of The HSTT Study Area

Common Name	Scientific Name	Stock	MMPA Status	Abundance (CV)	Population Trend*	PBR*
Blue whale	*Balaenoptera musculus*	Eastern North Pacific	Protected, Depleted	1,496 (0.44)	Steady, Near carrying capacity	2.1
Bryde's whale	*Balaenoptera brydei/edeni*	Eastern Tropical Pacific	Protected	!	!	!
Fin whale	*Balaenoptera physalus*	CA, OR, WA	Protected, Depleted	9,029 (0.12)	Slight increase, Steady in SOCAL	81
Gray whale	*Eschrichtius robustus*	Eastern North Western North Pacific	Pacific Protected Protected, Depleted	26,960 (0.05) 290 (-)	Increasing Increasing 2-5% annually	801 0.12
Humpback whale	*Megaptera novaeangliae*	CA, OR, WA	Protected, Depleted	2,900 (0.048)	Increasing 6-7% annually	16.7
Minke whale	*Balaenoptera acutorostrata*	CA, OR, WA	Protected	636 (0.72)	!	3.5
Sei whale	*Balaenoptera borealis*	Eastern North Pacific	Protected, Depleted	519 (0.4)	!	0.75
Sperm whale	*Physeter macrocephalus*	CA, OR, WA	Protected, Depleted	1,997 (0.57)	!	2.5

CA, OR, WA = California, Oregon, Washington
CV = Coefficient of Variation
* = Population Trend and Potential Biological Removal (PBR) per NMFS's 2020 Final Pacific Marine Mammal Stock Assessment (Carretta et al. 2021a)
! = not enough scientific data to support a value

4 Affected Species Status and Distribution

4.1 Blue Whale

Abrahms et al. (2019) documented higher blue whale occurrence north of HSTT SOCAL with critical areas associated with Santa Barbara shipping channels to and from the Ports of Los Angeles/Long Beach. Szesciorka et al. (2020) investigated Southern California blue whale migration timing, environmental conditions, and prey concentrations. Their findings included the fact that blue whales are arriving up to one month earlier but not departing earlier, leading to longer residency times. Based on acoustic call detections over 10-years (2008-2017), blue whales arrive in May and depart in November, remaining at the feeding grounds an average of 8.4 months. Blue whales demonstrated a flexible response to prey availability on an interannual basis based strongly on sea surface temperatures which are also correlated with krill biomass. In the paper and supplementary information files associated with the paper online, the authors did not designate what constituted California blue whale feeding areas. Szesciorka (2021) concluded that based on acoustic and tagging data, blue whales appeared to not show any behavioral responses to close vessel passages. This is similar to lack of blue whale response to vessel traffic reported by McKenna et al. (2015). Palacios et al. (2019) showed how blue whale foraging behavior was influenced by modeled oceanographic variables likely associated with concentrating krill prey. The northward movement of blue whale foraging during marine heatwaves was also noted. Calambokidis et al. (2019) documented differences in blue whale day-night behaviors with more blue whale transit movements at night and at shallower depths.

4.2 Bryde's Whale

Although not new research, both Smultea et al. (2012) and Kerosky et al. (2012) documented increasing seasonal Bryde's whale occurrence within Southern California during warm water periods. The last NMFS West Coast marine mammal survey in the summer of 2018 documented eight Bryde's whale sightings (Henry et al. 2020).

4.3 Fin Whale

Keen et al. (2019a,b) documented fin whale diel occurrence within the California Bight with fin whales having a strong diel dive pattern behavior including remaining near the surface more at night. Calambokidis et al. (2019) documented differences in fin whale day-night behaviors with more fin whale transit movements at night and at shallower depths. Romagosa et al. (2021) confirmed that as suspected fin whale 40 Hz calls tend to be associated with prey biomass and these calls are most likely foraging in context.

4.4 Gray Whale

Silber et al. (2021) stated that gray whales are at ship strike risk throughout their migration routes in the North Pacific. In terms of the SOCAL portion of the HSTT Study Area, the highest risk is associated with the southern commercial shipping routes to/from the ports of Los Angeles/Long Beach and San Diego, as well as coastal routes to/from the Panama Canal.

4.5 Humpback Whale

Calambokidis et al. (2019) documented differences in humpback whale day-night behaviors with more humpback whale occurrence at night and at shallower depths.

4.6 Minke Whale

No significant new literature regarding minke whales in the SOCAL portion of the HSTT Study Area was found by the Navy for this review.

4.7 Sei Whale

Segre et al. (2021) reported on sei whale feeding behavior that includes lung and surface skimming modes. The authors postulate these modes might be an adaptation for different prey in terms of inter-species competition. Sei whales were only sited off Central and Northern California during NMFS' most recent U.S. West Coast marine mammal survey in the summer of 2017 (Henry et al. 2021).

4.8 Sperm Whale

From a Navy-funded underwater glider with passive acoustic instruments conducted off Southern California, Mellinger (2021) and Mellinger et al. (2021) reported sperm whale sounds only episodically over deep (>2000 m) waters and briefly on the shelf. This corroborates previous visual and other passive acoustic detections showing only intermittent sperm whale occurrence in the SOCAL portion of the HSTT Study Area.

5 Type of Incidental Taking Authorization Requested

There are no changes to previous NMFS authorizations for takes with the exception of a slight increase in injury or mortality takes to large whales as specified below (NMFS 2018, NMFS 2020a-c). Specifically, the Navy requests modifications to regulations and two Letters of Authorization (one LOA for training activities and one for testing activities) for the injury or mortality take of select marine mammals incidental to proposed activities in the HSTT Study Area for the remaining authorization period through 2025.

5.1 Incidental Take Request from Vessel Strikes

5.1.1 Current Authorization

Vessel strike to marine mammals is not associated with any specific training or testing activity but rather an incidental result of Navy vessel movement within the Study Area. The two Navy ship strikes in 2021 involved vessels not engaged in training or testing activities at the time of the strike.

In the 2018 HSTT Final Rule (2018) and carried forward unchanged for the 2020 7-year extension and LOAs (NMFS 2020a-c), the Navy originally requested authorization for take of no more than three (3) cetaceans, by injury or mortality, resulting from vessel strike incidental to the Navy training and testing activities combined within any portion of the Study Area over the course of the five years of the HSTT regulations. NMFS authorized that no more than three whales could be taken by serious injury or mortality over the five-year (and subsequent 7-year) period of the Rule (NMFS 2018, NMFS 2020a), and that those three whales may include no more than two of any of the following stocks: gray whale (Eastern North Pacific) stock), fin whale (CA/OR/WA stock), humpback whale (Central North Pacific stock); and no more than one of any of the following stocks: blue whale (Eastern North Pacific stock), humpback whale (CA/OR/WA, Mexico DPS), and sperm whale (Hawaii stock). Given the original NMFS authorization for ship strike was three marine mammals over 7-years, and the 2021 Navy ship strikes account for two of the three, the Navy is still within its authorized ship strike incidental take level. Prior to the 2021 Navy ship strikes in the SOCAL portion of HSTT, the previous ship strikes were in 2009. There were zero Navy ship strikes within HSTT for the 11-and-a-half year period from July 2009 to April 2021.

5.1.2 Revised Ship Strike Take Request

As a cautionary acknowledgment that some probability of ship strike, although low, could still occur over the remaining HSTT authorization period through December 2025, the Navy is electing to request additional takes from vessel strike within its authorization of training and testing in HSTT. This is predicated on a revised summary of the probability of future ship strikes in the approximately 4-years remaining in the HSTT authorizations following the unexpected Navy ship strikes in the Califorina portion of HSTT during 2021. A detailed analysis of the revised strike data is provided in Section 6.2.

The Navy in this LOA applicaton, therefore, is requesting an additional two (2) takes of large whales from ship strike for the remaining HSTT authorization period through December 2025. In terms of the full 7-year period from 2018-2025, total ship strike request would be amended from three to five large whales.

6 Take Estimates for Marine Mammals

6.1 Background on Marine Mammal Vessel Strikes

6.1.1 Rcegional Vessel Strikes

Ship strikes and entanglements in fishing gear represent significant sources of injury and mortality to large whales along the U.S. West Coast (Keen et al. 2019, Rookwood et al. 2017, Rookwood and Jahncke 2019, Szesciorka et al. 2019, Carretta et al. 2020, 2021b, Ingman et al. 2021). Since NMFS' 2018 Final Rule, there have been numerous ship strike related papers exploring various dynamics of whale-ship interactions within Central and Southern California (Abrahms et al. 2019, Crum et al. 2019, Gende et al 2019, Keen et al. 2019, Leaper et al. 2019, Redfern et al. 2019, Rookwood and Jahncke 2019, Sèbe et al. 2019, Blondin et al. 2020, Barkaszi et al. 2021, Cusato et al. 2021, Hausner et al. 2021, Rookwood et al. 2017, 2020b, 2021, Silber et al. 2021, Zobell et al. 2021).

Carretta et al. (2021b) reported a total of 1,985 human-related injury (n=1,273) and mortality (n=712) records for all marine mammals along the U.S. West Coast between 2015 and 2019. It should be noted that these values are factored into NMFS' stock assessment reports for Potential Biological Removal (PBR). For large whales between 2015-2019, there were a total of 287 records of human-caused injuries and mortalities, 47 whales were initially reported as dead and the remaining 240 were assessed for non-serious injury (NSI) and serious injury (SI), or just stated as NSI/SI (Carretta et al. 2021b). The 47 large whale records involving dead animals were represented by vessel strikes (n=26), fishery-related entanglements (n=16), entanglement in marine debris (n=1), illegal hunts (n=1), and one record of shooting. Of the 240 large whales evaluated for NSI/SI, fishery-related entanglements (n=222) were the most common cause of injury, followed by vessel strikes (n=12) and entanglement in marine debris (n=4). Large whale injury and mortality cases involved humpback whales (n=173), gray whales (n=70), unidentified large whales (n=19), blue whales (n=13), fin whales (n=10), and minke whale (n=2).

Leading cause of injury and mortality to large whale species from 2015 to 2019 include:

- Blue whales (n=13) - fishery interactions (9), vessel strike (4) (Jun-Oct; none in HSTT SOCAL study area)
- Fin whales (n=10) - ship strike (7) (May-Oct with most in May (n=4); none in HSTT SOCAL study area), fisheries interaction (3)
- Gray whales (n=70) - fishery interaction & marine debris (55)(2 in HSTT SOCAL study area); vessel strike (15) (Jan-Sep with most between Jan-May (n=10); 2 in HSTT SOCAL study area)
- Humpback whales (n=173) - fisheries interactions & marine debris (162), vessel strikes (11) (Mar-Oct with most between Mar-Jul (n=8); 1 in HSTT SOCAL study area)
- There were no reports of injury and mortality to sei whales or sperm whales

The following literature review focuses on papers related to potential ship strike published after NMFS' HSTT Final Rule in December 2018. They are presented chronologically by year and author:

Rockwood et al. (2017) specifically focused on commercial ship strikes and not naval vessel strikes which is a critical difference. The highest level of risk was in shipping lane approaches to San Francisco and Los Angeles/Long Beach. NMFS acknowledges the limitation in strike data in the HSTT BO: "However, the annual rates of large whale serious injury and mortality from vessel collisions in the [Stock Assessment Reports] SARs do provide a good representation of the relative susceptibility of large whale species to

vessel strike in the action area." Finally, the last two U.S. Navy HSTT Southern California whale strikes in 2009 did not coincide with any of the areas that Rockwood, et al. (2017) determined to have mortality above the 90th percentile.

Abrams et al. (2019), while including all of the Southern California Bight (HSTT SOCAL Study Area), is focused on Santa Barbara shipping lanes north of and outside of the HSTT Study Area. Blue whale habitat suitability was greatest in September for the western part of HSTT SOCAL, and around the northern Channel Islands, outside of HSTT. Data used for the analysis only included the years 1994–2008, which may not include current blue whale distribution due to current oceanographic conditions.

Crum et al. (2019) analyzed a modeling framework using encounter theory to estimate the risk of lethal commercial ship strike to North Atlantic right whales. Seasonal mortality rates of right whales decreased by 22% on average after a speed rule was implemented, indicating that the rule is effective at reducing lethal collisions. The rule's effect on risk was greatest where right whales were abundant and vessel traffic was heavy, but varied considerably across time and space.

Gende et al. (2019) developed a model demonstrating that (1) the opportunities for detecting a surfacing whale are often limited and temporary, (2) the cumulative probability of detecting one of the available 'cues' of a whale's presence (and direction of travel) decreases with increased ship-to-whale distances, and (3) following detection, time delays occur related to avoidance operations. These delays were attributed to the mariner evaluating competing risks (e.g., risk of whale collision vs. risk to human life, the ship, or other aspects of the marine environment), deciding upon an appropriate avoidance action, and achieving a new operational state by the ship once a maneuver is commanded. The authors identify several options for enhancing whale avoidance including training lookouts to focus search efforts on a 'Cone of Concern,' defined here as the area forward of the ship where whales are at risk of collision based on the whale and ship's transit/swimming speed and direction of travel. Their data was based on 2016-2017 observations from cruise ships transiting Glacier Bay National Park in Alaska. It should be pointed out that for the Navy ship strikes discussed in Section 5.1.1.4, the whales struck the Navy ship hulls from abaft (behind) the ship's beam in one instance, and in the other instance, after the ship had changed course.

Keen et al. (2019b) compared vessel traffic patterns in the Southern California Bight, San Francisco, and the Pacific Northwest, and found fin whales had a higher risk of nighttime ship strikes, with the nighttime risk being double daytime risk. The authors concluded that the shipping lanes contained 14% of all traffic volume and contributed 13% of all strike risk similar to conclusions reached by Rockwood et al. (2017). However, the authors also point out that a California Current Ecosystem (CCE) wide shipping speed reductions would not be practicable. Instead, they proposed 24-hour speed restrictions around and within shipping lanes would be more effective and feasible than nighttime only speed restrictions elsewhere. Keen et al. (2019b) reported high fin whale habitat suitability throughout the Southern California Bight, in particular inshore in winter and in southern portions of the Bight which include HSTT SOCAL study area.

Leaper (2019) estimated that a global 10% reduction in shipping speeds could result in a reduction of greenhouse gases by 14%, underwater sound associated with shipping by approximately 40%, and ship strike risk by around 50% by 2050. The ship strike risk reduction done by the author is highly variable based solely on the relationship between ship speed and risk, qualitative in its findings, and speculative.

Redfern et al. (2019) compared risk of ship strike to baleen whales around the Santa Barbara channel based on eight years of shipping data (2008-2015). Species evaluated include blue whales, fin whales, and humpback whales using available spatial habitat models and satellite tagging results. Spatial habitat modeling data included the years 1991, 1993, 1996, 2001, 2005, 2008, and 2009. The authors defined

collision risk based on the co-occurrence of whales and ships for various management scenarios focused on adding shipping routes, expanding existing area to be avoided, and reducing shipping speed associated with these areas. Encounter rate theory was used to predict relative mortality resulting from ship strikes by estimating (a) the encounter rate; (b) the number of encounters that result in a collision; and (c) the probability that a collision is lethal (Martin et al. 2016, Rockwood et al. 2017, Crum et al. 2019). The authors concluded that expanding the existing areas to be avoided and speed reductions within shipping lanes and their approaches would be the most effective solutions. Ship speeds declined in the Bight from 2008 to 2015 because California air pollution regulations and economic factors made slow-steaming strategies more favorable, therefore reduction in risk from slowing ships was greatest in 2008 and lowest in 2015.

Rockwood and Jahncke (2019) estimated that humpback whale mortality from January to April in Southern California alone was 6.5 whales (1.63/month), based upon updated abundance estimates for humpback whales off Southern California. When added to the estimated mortality from July to November, the total estimated annual humpback mortality from vessel strikes in California alone was 23.4 deaths (16.9 + 6.5). This study neither included information for January to April for fin or blue whales, nor estimated humpback mortality in Central or Northern California. Thus, even this updated study may underestimate whale mortality. The author’s focus was exclusively on shipping approaches to San Francisco Bay (Northern California) and Los Angeles/Long Beach (Southern California) based on Rockwood et al. 2017 with new local fine scale analysis. The paper postulated potential mortality from models, not actual reported strikes. The model is used to predict whale mortality based on factors listed in Rockwood et al. 2017. In the model results, cargo vessels, especially container ships, accounted/predicted for more than half of the mortality for all whale species in both Northern and Southern California, with oil tankers accounting for the second highest mortality. Blue whales are more migratory and not expected in numbers in Southern California during the winter months. Fin whales are year-round residents. The author’s recommendation concludes with commercial industry-wide shipping speed reduction recommendations given the model is biased on mortality as a function of speed. In summary, Rockwood and Jahncke (2019) only addresses commercial shipping strike risk associated with major California commercial ports. The paper is not applicable to how the Navy trains and tests in HSTT SOCAL study area.

Sèbe et al. (2019) assesses previous publications on whale ship strike risk methodology and proposed a systematic approach to addressing the issue called the Formal Safety Assessment: 1) identification of hazards, 2) assessment of risks, 3) risk control options, 4) cost-benefit assessment and 5) recommendations for decision-making. The author provided a case study based on data from Rockwood et al. (2017). No new data analysis is presented in the paper. Caveats to Sèbe et al. (2019) are similar to those mentioned for Rockwell et al (2017, 2019): older marine mammal data that may not be reflective of current or future distribution and focus on limited navigation within shipping approaches by commercial ships. The paper is not applicable to how the Navy trains and tests in HSTT SOCAL study area.

Szesciorka et al. (2019) concluded that while whales have some cues to avoid ships, this is true only at close range, under certain oceanographic conditions and if the whale is not otherwise distracted by feeding, breeding, or other behaviors. The paper is based on single blue whale reaction observed in the Santa Barbara Channel, north of and outside of the HSTT SOCAL Study Area. The blue whale was tagged as part of the U.S. Navy-funded Southern California Behavioral Response Study (SOCAL BRS 2010-2015) and exposed to simulated mid-frequency active sonar (MFAS) when a closest point of approach of 93 m from a passing commercial container ship was noted. The whale was only tagged for a couple of hours before tag detachment. As other published papers report from the SOCAL BRS and as cited in the HSTT FEIS, there can be significant individual variation in response to anthropogenic sources, which in this case would include vessel transit.

Blondin et al. (2020) estimated blue whale ship strike risk in the Southern California Bight by combining predicted daily whale distributions with continuous vessel movement data for 4-years (2011, 2013, 2015, 2017). The focus of the study was more oriented to the northern Southern California Bight associated with the commercial vessel traffic separation zone through Santa Barbara Channel approaching the Port of Los Angeles/Long Beach. This area is north of and outside of HSTT SOCAL. The authors found that vessel traffic activity across years (2011, 2013, 2015, 2017) was variable and whale spatial probability was also variable based on inter-annual fluctuations in environmental conditions. Similar to previous monitoring efforts in Southern California, blue whales are typically in higher concentrations north of HSTT SOCAL from July-November (Mate et al. 2018), and Blondin et al. (2021) also picked up on this seasonal variability in their analysis. Oceanographic conditions favorable for krill development and concentration (i.e., cool water periods) would lead to increased blue whale occurrence and higher strike risk as evidenced during the higher number of blue whale strikes in 2007 (Berman-Kowalewski et al. 2010). Finally, the coarse level of data analyzed by the authors does not account for short-term patchy prey conditions influencing blue whale occurrence and may result in overestimation of average risk.

Cimino et al. (2020) predicted krill abundance in the central CCE along the U.S. West Coast, an area north and outside of HSTT SOCAL. The authors found that krill abundance in spring and summer "relates to geomorphic features, coastal upwelling during the preceding winter, and spring mesoscale oceanographic conditions." Their model predicted the occurrence of two krill species (the pelagic offshore *Euphausia pacifica* and the larger more coastal *Thysanoessa spinifera*) in the Central California Current Ecosystem from 2002 to 2018. Blue whales tend to prefer *T. spinifera* over *E. pacifica* (Fiedler et al. 1998). Both krill species responded negatively to warm water conditions and positively to cold water conditions. Predator abundance, such as marine mammals including blue whales which feed almost exclusively on krill, co-occurred with modeled high krill species abundance. Similar results along more of the California coast were obtained by Fiechter et al. (2020). The limitation to Fiechter et al.'s analysis is that data was analyzed for the 2000-2010 time period and may not be representative of current oceanographic conditions under climate change impacts such as successive marine heat waves.

Redfern et al. (2020) revised their 2019 assessments of ship strike risk off California using interannual variability of risk across multiple years for blue whale, fin whale and humpback whale. The authors showed higher concentrations of both blue and fin whales along the Central California coast as compared to within HSTT SOCAL study area. Magnitude of ship strike risk was influenced by ship traffic scenario. In addition, interannual species variability (1991, 1993, 1996, 2001, 2005, 2008, and 2009) also influenced the magnitude of ship strike risk, but did not change whether nearshore or offshore scenarios had higher risk. The author's conclusions were similar to Redfern et al. (2019). Figure 2 from Redfern et al. (2020) illustrates mean blue whale, fin whale and humpback whale ship strike risk for California based on data through 2009. Results from more recent NMFS surveys in 2014 and 2018 may or may not change this assessment in the future.

Rockwood et al. (2020b) calculated expected blue whale and humpback whale mortality for hypothetical compliance scenarios by imposing speed caps within and adjacent to vessel traffic lanes leading to the Port of San Francisco in Central California, 400 miles north of HSTT SOCAL. Rookwood et al. (2020a) had already demonstrated this area off Central California had concentrated krill prey with associated higher distributions of blue whales and humpback whales. Rookwood et al. (2020b) used better temporal resolution density data than previous modeling efforts reported by Rookwood et al. (2017). Biological data analysis for Rookwood et al. (2020b) was based on regional monthly krill and whale surveys from 2004-2017. Rockwood et al.'s (2020b) overall modeling conclusions were that lower commercial ship speeds within the vessel traffic lanes could potentially reduce whale mortality from ship strike. The

authors did acknowledge that local changes in whale abundance can have strong effects on both inter-annual and long-term patterns of ship-strike mortality.

Bernknopf et al. (2021) examined the socioeconomic benefits of using remotely-sensed information instead of in situ observations for determining blue whale occurrence in the Eastern North Pacific Ocean. Their analysis used blue whale spatial distribution through 1991-2009 projects as representative of 2017 densities (Becker et al. 2012) combined with automatic identification system (AIS) derived measures of civilian commercial vessel traffic to predict blue whale ship strike risk, called the Reference case by the authors. The authors then compared estimated blue whale strike risk in a second analysis that, instead of using empirically measured blue whale observations converted into spatial habitat maps, used satellite tracking and environmental data to identify the spatial and temporal distribution of blue whales, called the Counterfactual Case by the authors (Hazen et al. 2017). Estimated mean fatal strikes to blue whales for the Reference Case based on empirical density data from 1991-2009 ranged from 0.0490 to 2.5877 (max. values >1.000 between June to October) (see Table 2 in Bernknopf et al. 2021). Estimated mean fatal strikes to blue whales for the Counterfactual Case based on environmental estimates of blue whale density in 2017 ranged from 0.0286 to 2.1556 (max. values >1.000 between August to October). An important caveat to this research is that the two approaches result in different strike risks due to using different blue whale density estimates.

Barkaszi et al. (2021) designed a model to estimate risks to large whales from shipping associated with offshore wind development along the U.S. Atlantic Coast. A key caveat for the model is that it is based on civilian vessel types associated with wind energy construction (ex., tugs, service craft, etc.) with relatively fixed, direct routes to offshore wind sites. Therefore, while lower vessel speeds can reduce mortality, prediction and implementation of reduced speed zones are a far more complex challenge (Barkaszi et al. 2021). Vessel speed has less effect on strike risk over a fixed distance with fixed target density when there are no behavioral components considered (Yin et al. 2019). Vessel speed has a significant effect on strike risk only when behavioral components are considered, thus the ability for the user to input animal or vessel aversion is an important variable that can provide insights to the encounter risk based on vessel speeds.

Cusato (2021) discusses the merits of vessel traffic separation changes or mandatory commercial ship speed reductions in the Santa Barbara Channel to reduce the risk of ship strikes to large whales. The author compares it to similar restrictions on the U.S. East Coast for North Atlantic right whales. The paper is a policy discussion rather than an analysis of current biological distribution of large whales and associated risk. Cusato (2021) focuses on reducing risk from commercial ships in the current vessel traffic separation scheme within the Santa Barbara channel. Speed restrictions in the Channel would need to be implemented through either federal regulations or federal statute. The author also correctly points out legitimate concerns that operating large vessel at slow speeds in certain conditions could pose a safety risk because large vessels are more difficult to control and steer at slower speeds.

Hausner et al. (2021) examined tradeoffs of blue whale ship strikes and speed reduction mitigation over a 17-year period from 2002 to 2018 in the Southern California Bight under two management scenarios verses a 'fixed strategy' that implements speed reductions for a fixed time period each year. The two management strategies were (1) a 'daily strategy' implementing speed reductions in response to whale habitat conditions on a daily basis, and a (2) a 'seasonal strategy' implementing speed reductions in response to whale habitat conditions on a seasonal basis. The period of the author's data analysis also covers the abnormal marine heat wave along the U.S. West Coast (2014-2016). The study's focus was exclusively with the traffic separation lanes leading from the Santa Barbara channel to the Ports of Los Angeles/Long Beach, a narrow corridor north of and outside of HSTT SOCAL. The daily and seasonal management strategies were more effective in reducing blue whale strike risk in the Santa Barbara channel than the fixed strategy. The daily management strategy had the highest protective effect. This apparent difference in strategies also applied during and after the 2014-2016 marine heat wave where the daily strategy added even extra protection. The authors acknowledge that interannual variation on blue whale presence in the shipping lanes added some variability to their analysis. In addition, their study only considered blue whales sighted within the Traffic Separation Scheme, as opposed to the broader region where vessels transit through or blue whale could occur.

Ransome et al. (2021) documented 40 vessel strikes to large whales in the Eastern Tropical Pacific Ocean between 1905 and 2017 off the coasts ten Central and South American countries (Mexico to Columbia). The authors concluded that vessel strikes to large whales are more prolific in this region than previously reported. For instance, the author's findings of 40 vessel strikes was over three times greater than previous reporting and still is likely under reporting total whale strikes. The majority of whale strikes occurred from the 1950's onward with the growth of modern shipping and whale watching. Humpback whales were the most commonly struck species (45%) although 30% of the species were not identified in their data.

Rockwood et al. (2021), similar to Rockwood et al. (2020b), calculated potential whale strike mortalities using AIS vessel data and whale density data to estimate mortality under several management scenarios within the commercial shipping lanes passing through Santa Barbara Channel and San Pedro Channel to and from the Ports of Los Angeles/Long Beach. While, the Santa Barbara Channel is approximately 100 miles north of HSTT SOCAL, Rockwood et al.'s study area also included the southern vessel traffic approach to Los Angeles/Long Beach which did extend into the northeast coastal portion of HSTT SOCAL. Recent whale surveys were not available for this effort, so the authors used long-term average blue, fin, and humpback whale densities from Becker et al. (2016). The author's model also predicted a higher level of whale ship strikes from commercial ships than Rockwood et al. (2017), although the author's acknowledged for the 2020 publication they included more vessel classes than the 2017 publication.

Silber et al. (2021) examined the risk to gray whales from commercial shipping in the North Pacific. Ship strike risk was highest for gray whales including the Western North Pacific Distinct Population Segment (WNP DPS) along most of the migratory routes. Highest risk to the WNP grey whale DPS was outside of the HSTT SOCAL in the western Bering Sea, along the east coast of the Kamchatka peninsula (Russia), and coastlines of Japan. For both Eastern North Pacific and WNP DPSs of gray whales, the greatest ship strike risk along the U.S. West Coast was from Washington to Central California.

6.1.2 NAVY POLICY ON VESSEL STRIKES

It is Navy policy to report all marine mammal strikes by Navy vessels. The information is collected by Office of the Chief of Naval Operations Environmental Readiness and provided to NMFS. Only Navy and the U.S. Coast Guard reliably report in this manner. Therefore, it should be noted that Navy vessel strikes reported in the scientific literature and NMFS databases are the result of the Navy's commitment to reporting all strikes to NMFS rather than a greater frequency of collisions relative to other ship types (e.g. commercial cargo vessels). Vessel strike to marine mammals is not associated with any specific training or testing activity but rather an incidental result of vessel movement within the Study Area. Between 2007 and 2009, the Navy developed and distributed additional training, mitigation, and reporting tools to Navy operators to improve marine mammal protection and to ensure compliance with upcoming permit requirements. In 2007, the Navy implemented the Marine Species Awareness Training, which is designed to improve the effectiveness of visual observations for marine resources, including marine mammals and sea turtles. In subsequent years, the Navy issued refined policy guidance regarding marine mammal incidents (e.g., ship strikes) in order to collect the most accurate and detailed data possible in response to a possible incident. For over a decade, the Navy has implemented the Protective Measures Assessment Protocol software tool, which provides operators with notification of the required mitigation and a visual display of the planned training or testing activity location overlaid with relevant environmental data. Similar mitigation, reporting, and monitoring requirements have been in place since 2009 and are expected to continue into the future. Therefore, the conditions affecting the potential for ship strikes are the most consistent across this time frame. The level of Navy vessel use and the manner in which the Navy trains and tests is not expected to change through the remaining HSTT authorization period.

6.2 REVISED ESTIMATED TAKE OF MARINE MAMMALS BY VESSEL STRIKE

6.2.1 PRIOR PROBABILITY CALCULATION

The Navy provided a Poisson probability for determining the statistical likelihood of Navy ship strikes for HSTT in the 2017 HSTT LOA application. The analysis was specific to Navy warships greater than 65 feet with destroyers being the smallest ship class considered. Since the probability of a Navy vessel strike to whales is influenced by the amount of time at sea for Navy vessels within the HSTT Study Area and the number of actual ship strikes, the Navy used historic at-sea days in HSTT from 2009–2016, estimated potential at-sea days for the period from 2019 to 2023, and the two ship strikes that occurred in 2009. In consultation with NMFS MMPA staff at the time, it was agreed that the probability of when large whale takes are likely to occur would be when the probability is at or above 10% level. This equated to a maximum of three (3) large whale takes based on the Poisson distribution results over a 5-year time period under the MMPA. With the subsequent 2020 Navy request and NMFS approval for an extension of the 5-year permit period to 7-year permit period (NMFS 2020a), the Navy re-examined the strike probabilities for a 7-year year period. In a January 2020 Supplemental Information Report , *"(t)he Navy concluded there is no statistically significant change in strike probabilities [for 5-years verse 7-years]. Therefore, the Navy is not requesting any additional vessel strike takes from what is authorized in the NMFS MMPA regulations and LOA issued on December 21, 2018".*

6.2.2 REVISED PROBABILITY CALCULATION 2022-2025

For this LOA application, the Navy is revisiting the original 2018 Poisson probability calculation series in light of the two U.S. Navy ship strikes in 2021. In discussions with statistical experts, the Navy was advised that using additional data such as the 2021 strikes to estimate potential risk in the remaining years of the current HSTT authorizations from 2022 to 2025 was statistically valid. Therefore, the Navy is revising the Poisson calculations to include all of the available data from 2009 to present, which corresponds to the entire period in which Navy started seeking MMPA permits for its actions in HSTT.

The Navy is using four (4) whale strikes from the period 2009 to 2021 in HSTT to predict the probabilities of future whale strikes over the remaining period of the HSTT MMPA permit from 2022 to 2025. The estimates of at sea ship days used in 2018 and the reassessment for 2020 are also used in this current calculation. The calculation process mirrors what was done for the 2018/2020 consultations, but uses the new strike rate for the period 2009-2021[1].

Results

Step 1: Calculate strike rate from 2009-2021. 4 strikes during 2009-2021 / 57,757 ship days at sea = 0.000069 strikes per day

Step 2: Calculate predicted strike rate over a four-year period from 2022-2025 remaining in permit. 18,464 ship days at sea x 0.000069 strikes per day = 1.2788 strikes over 4-years.

Step 3: Use Poisson distribution to calculate probability of getting "n" strikes when it is "expected" there could be 1.2788 strikes over the 4-year period remaining in HSTT permit between 2022 and 2025. Probabilities are:

Scenario (n)	*Probability (%)*
Probability of zero strikes (n=0)	27.8%
Probability of one strike (n=1)	35.6%
Probability of two strikes (n=2)	22.7%
Probability of three strikes (n=3)	9.7%

In abundance of caution, Navy recognizes there is some probability of ship strike, although low, that could occur between 2022-2025. Therefore, the Navy is electing to request a small number of takes to select large whale stocks from vessel strikes for HSTT (Section 5.2). The Navy is asking for an additional two takes based on the probability results above.

[1] The probabilities of a specific number of strikes (n=0, 1, 2, etc.) over a period of time can be derived from a Poisson distribution. A Poisson distribution is often used to describe random occurrences when the probability of an occurrence is small, e.g., count data such as cetacean sighting data, or in this case strike data, often described as a Poisson or over-dispersed Poisson distribution. The formula for a Poisson distribution is:

$$P(n|\mu) = \frac{e^{-\mu} \bullet \mu^{n}}{n!}$$

$P(n|\mu)$ is the probability of observing n events in some time interval, when the expected number of events in that time interval is μ.

7 Anticipated Impact of the Activity

From June 2009 through May 2021, there were no U.S. Navy ship strikes in the HSTT study area, a period of nearly 12 years. There were two Navy ship strikes to whales in 2009, with both whales identified as fin whales based on carcass photos. The locations of the two 2009 strikes were south-southwest of San Clemente Island, in the general vicinity of the two 2021 strikes. The primary driver for this LOA applicaton and associated analysis are these two Navy whale strikes of unknown species in 2021 which occurred in Year 3 of the 7-year HSTT authorizations.

The last strike by a U.S. Navy vessel in SOCAL occurred more than 12-years ago (May 2009), indicating that strike of large whales by Navy vessels is still an infrequent occurrence over any given permit time span. This is especially relevant given the likely large whale population increases off the U.S. West Coast during this past decade (Table 1-1). The Navy determined that implementing procedural mitigation for vessel movements beyond what is detailed in 2018 HSTT applications and NMFS authorizations would be incompatible with the ship safety, impractical to implement, and would negatively impact the effectiveness of the military readiness activity. The Navy must continue to have the flexibility to train and test in necessary locations and at speeds at the discretion of the ships' Commanding Officer when necessary to meet military readiness objectives, as well as for safety and logistical considerations.

The Navy reacted as quickly as possible after the 2021 SOCAL ship strikes to reinforce, for all ships at-sea at the time, the importance of marine species awareness and avoidance to the best extent practical given safety of navigation and operational needs. The Navy will also continue to refine and improve its annual whale awareness messages for HSTT with best available science and reiteration of established Navy Standard Operating Procedure, mitigations, and environmental awareness training.

Based on each species' life history information, expected behavioral patterns in the Study Area, and the application of robust mitigation procedures, combined with the historically infrequent number of Navy ship strikes, HSTT training and testing activities are anticipated to have a negligible impact on marine mammal populations within the Study Area.

8 Anticipated Impacts on Subsistence Uses

<There are no changes to the Navy's previous submissions on this topic>

9 Anticipated Impacts on Habitat

<There are no changes to the Navy's previous submissions on this topic>

10 Anticipated Effects of Habitat Impacts on Marine Mammals

<There are no changes to the Navy's previous submissions on this topic>

11 Mitigation Measures

There is no change to Navy Standard Operating Procedures (SOP) and mitigation measures except as noted below. The Navy already has an extensive set of mitigations developed in 2013 and has continually improved education and training on those mitigations to lessen the risk of Navy ship strike to the maximum extent practicable. The Navy can also respond when there are elevated risk periods as evidenced by the HSTT SOCAL Fleet marine mammal awareness message released in July 2021 following the second Navy ship strike. The Navy has also developed new technology for integration into ship navigation simulators in which to train officers and bridge watchstanders on surface ship navigation basics, tactics, and safety including obstacle avoidance such as other vessels and boats, marine mammals, and in water objects.

11.1 Standard Operating Procedures

In response to the two Navy ship strikes in the spring and summer of 2021, U.S. Third Fleet directed a marine mammal awareness and safety stand down on 15 Jul 2021 to all units assigned to U.S. Third Fleet who would be underway in Southern California through October 2021. U.S. Third Fleet, under U.S. Pacific Fleet, is the Navy's operational control authority within waters of Southern California in the HSTT study area. All units were required to complete marine mammal awareness training by 30 Jul 2021, even if this was already accomplished earlier by an overall training plan. As a result of this directive, 28 surface ships, 3 carrier air wings, and 4 submarines reported completing a re-review of the Navy's Marine Species Awareness Training and the review of the U.S. Third Fleet Marine Mammal Awareness Refresher briefing. This represents approximately 50% of the ships homeported in San Diego with the remaining ships either deployed outside of the Southern California area, in maintenance status within San Diego Bay or elsewhere, or with no planned at-sea time through Oct 2021. Correspondingly for the testing community, Naval Sea Systems Command (NAVSEA) on 29 July 2021 directed all NAVSEA Program Offices and field activities who were, or planned to be, conducting at sea testing within HSTT SOCAL through October 2021 to ensure all watchstanders compete marine mammal awareness training by 16 August 2021, even if already accomplished as part of an overall testing plan in the past.

11.2 Mitigation Measures

No changes to procedural or geographic mitigation measures agreed to in the 2018 HSTT consultation and subsequent rule making are proposed.

However, Navy policy regarding lookouts has changed from a policy of one lookout required if a ship was underway and not engaged in sonar training or testing. In 2018, the Navy's navigation instruction was updated to increase lookout requirements on surface ships, to ensure 360 degree view anytime a ship is underway. This instruction was further revised in October 2021 to more specifically mandate lookout manning by Navy ship class. The 2018 and October 2021 updates now require three lookouts on Navy cruisers and destroyers while underway. Cruisers and destroyers are the only types of ships that have had a whale strike in the Pacific.

11.3 ENVIRONMENTAL AWARENESS AND EDUCATION

The Navy will continue to implement procedural mitigation to provide environmental awareness and education to the appropriate personnel to aid visual observation, environmental compliance, and reporting responsibilities. Between 2001 and 2010 prior to and immediately after these new initiatives to provide better awareness training to the Fleet, the Navy reported 11 whale strike in HSTT (an average of 1.1 per year). Between 2011 and 2020, after successive rounds of awareness training and revisions, there were zero whale strikes in HSTT. It is likely that the implementation of the Marine Species Awareness Training starting in 2007, and the additional U.S. Navy Afloat Environmental Compliance Training Series modules starting in 2014, could have contributed to this reduction in strikes. This indicates that the environmental awareness and education program may be helping to improve the effectiveness of mitigation implementation. The Navy continues to make improvements to the Marine Species Awareness Training with five updated versions being promulgated between 2007 and 2021. Starting in 2019, as part of another mitigation measure agreed to during the HSTT consultations with NMFS, the Navy instituted two new annual large whale awareness messages to the Fleet specific to HSTT SOCAL study area, a spring-summer message for blue whales and a fall-winter message for gray whales. Additional information about fin whales is also provided in these two SOCAL-related Navy messages. These messages describe likely whale occurrence within SOCAL and further stress adherence to promulgated avoidance measures and reporting procedures. From June 2019 to November 2021, a total of six Fleet messages have been released for the SOCAL portion of the HSTT Study Area.

12 Arctic Plan of Cooperation

<There are no changes to the Navy's previous submissions on this topic>

13 Monitoring and Reporting

The Navy has been conducting research and monitoring in the HSTT study area for over 20 years following development of a formal marine species monitoring program in support of the MMPA authorizations for the Hawaii and Southern California range complexes in 2009. This robust program has resulted in hundreds of technical reports and publications on marine mammals that have informed Navy and NMFS analysis in environmental planning documents, Rules and Biological Opinions. The reports are made available to the public on the Navy's marine species monitoring websitehttps://www.navymarinespeciesmonitoring.us/ and the data on the Ocean Biogeographic Information System Spatial Ecological Analysis of Megavertebrate Populations (OBIS-SEAMAP) https://www.seamap.env.duke.edu/ and Animal Telemetry Network https://atn.ioos.us/

The Navy commits to continue monitoring the occurrence, exposure, response and consequences of marine species to Navy training and testing and to further research the effectiveness of implemented mitigation measures. Taken together, mitigation and monitoring comprise the Navy's integrated approach for reducing environmental impacts from the Proposed Action in HSTT. The Navy's overall monitoring approach will seek to leverage and build on existing research efforts whenever possible.

Consistent with the cooperating agency agreement with NMFS, monitoring measures presented here, as well as mitigations discussed in Chapter 11 (Mitigation Measures), focus on the requirements for protection and management of marine resources. A well-designed monitoring program can provide important feedback for validating assumptions made in analyses and allow for adaptive management of marine resources. Monitoring is required for compliance with final rules issued under the MMPA, and details of the monitoring program under the Proposed Action have already been developed in coordination with NMFS through the regulatory process for previous Navy at-sea training and testing actions. No changes are anticipated to the monitoring program or reporting that has been conducted to date. However, discussions with resource agencies during the consultation and permitting processes under the Proposed Action may result in changes to the mitigation as described in this document.

Within the SOCAL portion of HSTT, the Navy has been primariy focused on beaked whale monitoring since 2018 through two separate ongoing projects that are expected to continue until 2025. These projects use passive acoustic devices, visual surveys, satellite tagging, genetic analysis, photoID, and response to anthropogenic sounds to refine population status of beaked whales in SOCAL. There is also one concurrent project with fin whales using visual surveys, satellite tagging, and photoID to gather additional data on fin whale populations in Southern California. Finally, the Navy continues to fund marine mammal sighting data collected during California Cooperative Oceanic Fisheries Investigations (CALCOFI) https://calcofi.org/ These data are collected on a much more frequent basis than NMFS' West Coast visual survey which typically occur once every five years in the summer. CALCOFI survey occur quarterly ever year to include winter and spring seasons NMFS does not survey. Sufficient marine mammal sightings have been accumulated since the Navy started funding in 2004 for the data to be incorporated into ongoing NMFS spatial habitat models including new models for select species. The Navy also annually funds continued NMFS spatial habitat model improvements as new data and techniques become available. These models benefit the Navy and other Federal partners such as the Bureau of Ocean Energy Management (BOEM) and NMFS, for use in future regional marine mammal density derivation.

14 Suggested Means of Coordination

The U.S. Navy is one of the world's leading organizations in assessing the effects of human activities the marine environment including marine mammals. Navy scientists work cooperatively with other government researchers and scientists, universities, industry, and non-governmental conservation organizations in collecting, evaluating, and modeling information on marine resources. They also develop approaches to ensure that these resources are minimally impacted by existing and future Navy operations.

There are three pillars to the Navy's monitoring and research program: the Research and Development programs under the Navy's Chief of Naval Operations, Environmental Planning and Conservation (OPNAV N4I54), the Office of Naval Research, and the Fleet/Systems Commands compliance monitoring program. The goal of the Navy's Research and Development program is to enable collection and publication of scientifically valid research as well as development of techniques and tools for Navy, academic, and commercial use. Research and Development programs are funded and developed by OPNAV N4I54 and the Office of Naval Research, Code 322 Marine Mammals and Biological Oceanography Program. Primary focus of these programs since the 1990s is on understanding the effects of sound on marine mammals, including physiological, behavioral and ecological effects. The third pillar of the Navy's marine species research and monitoring programs is the Fleet Systems Command compliance program that started in 2009 with the first MMPA permits. Coordination is frequent between the three programs with members of each program sitting on advisory or steering commitees of the others' to facilitate collaboration, transition, and feedback loops to all three.

The Office of Naval Research's current Marine Mammals and Biology Program objectives include, but are not limited to (1) monitoring and detection research, (2) integrated ecosystem research including sensor and tag development (3) effects of sound on marine life (such as hearing, behavioral response studies, physiology [diving and stress], Population Consequences of Acoustic Disturbance), and (4) models and databases for environmental compliance.

To manage some of the Navy's marine mammal research programmatic elements, OPNAV N4I54 developed in 2011 a new Living Marine Resources Research and Development (LMR R&D) Program. The goal of the LMR R&D Program is to identify and fill knowledge gaps and to demonstrate, validate, and integrate new processes and technologies to minimize potential effects to marine mammals and other marine resources. The LMR has an Advisory Committee comprised of Navy biologists and staff from the Fleets, Systems Commands, and service providers, providing a nexus for feedback and collaboration for the three pillars of the Navy's Research and Monitoring programs.

Below are representative Navy research-funded projects from ONR and LMR currently either starting or ongoing within the SOCAL portion HSTT in 2022:

ONR

- Dynamics of environmental deoxyribonucleic acid (eDNA); Oregon State University; 2018-2022
- Environmental eDNA metabarcoding for estimating haplotype diversity and population differentiation of social odontocetes; Oregon State University; 2021-2023
- Passive and active acoustic tracking mooring; Scripps Institution of Oceanography; 2019-2022 (DURIP)
- Fine-scale foraging behavior of marine mammals in relation to oceanography, prey and mid-frequency active sonar; Scripps Institution of Oceanography; 2020-2024
- Deep sea acoustic and optical predator-prey observations; Scripps Institution of Oceanography; 2022-2023 (Defense University Research Instrumentation Program)
- Planning for a pilot global eDNA marine collection and analysis program (GEMCAP); Scripps Institution of Oceanography; 2021-2023
- Investigating bone-conduction as a pathway for mysticete hearing; San Diego State University; 2018-2022
- Vital rates of Cuvier's beaked whales: A Multi-regional comparative assessment; Foundation for Marine Ecology and Telemetry Research; 2021-2023
- Low-power mass-storage upgrade for high-frequency acoustic recording packages (HARPs); Scripps Institution of Oceanography; 2019-2022 (Defense University Research Instrumentation Program)
- Body condition as a predictor of behavioral responses of cetaceans to sonar; University of St. Andrews: 2019-2022
- Behavioral Response Studies For Potential Consequence of Disturbance (BRS4PCOD): Integrating the results of behavioral response studies into models of the population consequences of disturbance; University of Washington; 2019-2022
- Using context to improve marine mammal classification; San Diego State University; 2017-2022
- Machine learning detection of cetacean tonal calls without human annotations; San Diego State University; 2021-2023
- Demographics and diving behavior of Cuvier's beaked whales at Guadalupe Island, Mexico: A comparative study to better understand sonar impacts at the Southern Californi Offshore Anti-submrine warfare Range (SOAR); Foundation for Marine Ecology and Telemetry Research; 2018-2022
- Cuvier's beaked whales at Guadalupe Island, Mexico: A comprehensive assessment of demographics and behavior in an undisturbed area; Foundation for Marine Ecology and Telemetry Research; 2020-2024
- Relationship between blue, fin, and beaked whales and their prey in Southern California; Norges Teknisk-Naturvitenskapelige Universitet (NTNU); 2021-2023
- Behavioral and physiological response studies (BPRS) with social delphinid cetaceans using operational and simulated military mid-frequency active sonar; Southall Environmental Associates; 2019-2023
- Improving estimates of Cuvier's beaked whale sonar response by linking satellite tag and range acoustic data; University of St. Andrews: 2021-2022
- Improving estimates of Cuvier's beaked whale sonar response by linking satellite tag and range acoustic data; Naval Undersea Warfare Center; 2021-2022

LMR

- Cuvier's beaked whale and fin whale behavior during military sonar operations: Using medium-term tag technology to develop empirical risk functions; Marine Ecology and Telemetry Research; 2016-2022
- The Effects of Underwater Explosions on Fish; University of Washington, NIWC Pacific, Environmental BioAcoustics; 2016-2022
- Measuring the effect of range on the behavioral response of marine mammals through the use of Navy sonar and small source playbacks; Marine Ecology and Telemetry Research; 2017-2022
- Standardizing Methods and Nomenclature for Automated Detection of Navy Sonar; NIWC Pacific, NUWC Newport, Cornell University; 2018-2022
- Multi-spaced measurement of underwater fields from explosive sources; University of Washington; 2018-2023
- Use of "Chirp" Stimuli for non-invasive, low-frequency measurement of marine mammal auditory evoked potentials; NIWC Pacific; 2019-2021
- Improved Tag Attachment System for Remotely-Deployed Medium-Term Cetacean Tags; Marine Ecology and Telemetry Research; 2019-2024
- ACCURATE: ACoustic CUe RATEs for passive acoustics density estimation; University of St. Andrews; 2019-2024
- MSM4PCoD' Marine Species Monitoring for the Population Consequences of Disturbance; Sea Mammal Research Unit; 2019-2024
- Capability enhancements for Tethys, a passive acoustic metadata workbench; San Diego State University; 2015-2023
- Standardizing auditory evoked potential hearing thresholds with behavioral hearing thresholds; National Marine Mammal Foundation; 2020-2023
- Combining global OBS and CTBTO recordings to estimate abundance and density of fin and blue whales; University of St. Andrews; 2021-2025
- Loudness perception in killer whales (*Orcinus orca*); effects of temporal and frequency summation; National Marine Mammal Foundation; 2021-2024
- Minimum sound pressure levels required for TTS during simulated continuously active sonar; National Marine Mammal Foundation; 2021-2024
- Dolphin conditioned hearing attenuation; NIWC Pacific; 2021-2022

OTHER NON-NAVY PARTNERS

The Navy also collaborates regularly with BOEM, NMFS, and other federal agencies on projects with mutual goals along the U.S. West Coast. An example is the Navy's participation in the joint NMFS/BOEM/Navy program "Pacific Marine Assessment Program for Protected Species" (PACMAPPS).
https://www.fisheries.noaa.gov/west-coast/science-data/pacmapps-pacific-marine-assessment-program-protected-species
PACMAPPS conducts visual and acoustic surveys for cetacean abundance within the Pacific Ocean. The most recent survey along the U.S. West Coast including the SOCAL portion of HSTT was in 2017. In conjuction with but outside of the contribution to PACMAPPS, the Navy provides additional annually funding supporting cetacean spatial habitat model improvements, new density data inclusion, and GIS files for use in future compliance documents.

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Appendix A

U.S. Navy Additional Scientific Literature Review 2020-2021

The following contains results from Navy literature reviews for 2020 and 2021. The major focus of these annual reviews is on acoustic and other sound related stressors, as well as marine species hearing and responses to sound.

Annual Science Review 2021

INTRODUCTION

The scientific community continues to generate new data in an effort to expand and improve our understanding of the marine environment. Since the publication of the Atlantic Fleet Training and Testing (AFTT) and Hawaii-Southern California Training and Testing (HSTT) 2018 Final EIS/OEISs and Record of Decisions (ROD), and the publication of the 2020 Supplemental Information Reports (SIRs), the Navy has reviewed new scientific research relevant to the analysis of acoustic and explosive impacts to living marine resources. Although the Navy continues to incorporate relevant best available science into ongoing at-sea compliance efforts (e.g., Phase 3 Gulf of Alaska Training), this document specifically presents scientific information updated since the analysis conducted in the AFTT and HSTT 2018 Final EIS/OEISs, RODs, and 2019 and 2020 SIRs. While there are additional research papers pertaining to living marine resources, the studies outlined below were chosen because of their relevance to the analysis of acoustic and explosive impacts. In the sections that follow, the Navy presents a review of new research and evaluates how the results apply to the Navy's assessment of marine resources.

ACOUSTIC STRESSORS

This chapter contains a summary of scientific information pertaining to acoustic stressors that were analyzed in the 2018 AFTT and HSTT Final EIS/OEIS and 2019 and 2020 SIRs. New best available science was found concerning aircraft noise. This chapter also presents the Navy's determination of whether this new information supports the analysis contained in the 2018 Final EIS/OEISs.

AIRCRAFT NOISE

Kuehne et al. (2020) measured in-air and underwater sound from low-altitude EA-18G Growler flights in the immediate vicinity of Ault Field at Naval Air Station Whidbey Island (NASWI). Data were collected by two in-air recorders and one hydrophone placed just off the runway at a depth of 30 meters. The underwater 10-flight average sound measurement was 134 ± 3 dB re 1 µPa rms in the highest 1-second window. The results showed that the peak frequency range of the Growler overflight noise both in air and underwater was between 50 and 1,000 Hertz (Hz), which is typically a frequency range with high background noise underwater, particularly in areas with large amounts of vessel traffic (Erbe et al., 2012). The study did not include behavioral observations of wildlife, and the authors' conclusions about potential impacts to wildlife were unsupported by data from the study. In a separate effort, Kuehne and Olden (2020) relied on volunteers to identify military aircraft noise in recordings taken on land on the Olympic Peninsula. This study also did not examine impacts to or responses by wildlife to aircraft.

CONCLUSIONS

Two publications presented new information regarding in-air and underwater sound measurements from Navy aircraft. The findings do not change the analysis and conclusions in the 2018 AFTT and HSTT Final EIS/OEISs.

MARINE MAMMALS

This chapter contains a summary of scientific information pertaining to marine mammal acoustic stressors analyzed in the 2018 AFTT and HSTT Final EIS/OEIS and 2019 and 2020 SIRs. New best available science was found concerning auditory masking, temporary threshold shift (TTS) and permanent threshold shift (PTS), behavioral reactions, physiological stress, stranding, and population consequences of disturbance (PCOD) and cumulative impacts. This chapter also presents the Navy's determination of whether this new information supports the analysis contained in the 2018 Final EIS/OEISs.

HEARING, VOCALIZATION, AND MASKING

Branstetter et al. (2021) measured underwater, masked hearing thresholds for frequencies between 0.5 and 80 kHz in two killer whales. Critical ratios computed from the threshold measurements ranged from 16 to 32 dB. For communication signals in the 1.5 – 15 kHz range, killer whales would require the signal to be up to 26 dB above background Gaussian noise to be detected. The authors note that ambient background noise in the marine environment is not Gaussian, the tones used in this study do not contain as much frequency information as biologically relevant signals, and the temporal and spectral characteristics of actual signals and noise may result in some degree of release from masking. These results are consistent with critical ratio measurements from other odontocete species, despite differences in hearing ability and head size.

Fournet et al. (2021) measured call amplitudes from male bearded seals in the Beaufort Sea under different ambient noise conditions. The results showed that estimated source levels of seal calls increased with ambient noise up to approximately 100-105 dB rms, above which no further Lombard effect was observed. This suggests that masking of bearded seal mating calls may occur, resulting in reduced communication range, which could reduce the ability of bearded seals to detect one another, mate, and reproduce.

Mercado (2021) aimed to characterize how units within humpback whale songs were systematically varied using a large dataset of recordings from off the coast of Kona, Hawaii. The data showed that narrowband, reverberant units repeated at regular time intervals and dominated most song sessions, while broadband units were less predictable and occupied frequency bands that did not overlap with the narrowband units. The persistent production of narrowband units at regular time intervals resulted in consistent reverberation, which could either function to increase the range at which the song can be detected, or listen for fluctuations in echoes to indicate the presence of whale-sized targets.

Rey-Baquero et al. (2021) collected theodolite and passive acoustic data on humpback whales in a pristine environment along the Colombian Pacific for two months. When acoustic data (n=34 files) were analyzed for unit duration and inter-unit interval before and after boats passed, song unit lengths were shorter and more variable when boats were present. The second aim of this study was to model the whales' communication space during ambient noise or one to two boats traveling slowly. The most common peak frequency of this stock's song (350 Hz) was used in the model, and, along with a whale's location along the coast, informed calculations of transmission loss. However, the source level of "typical whale-watching boats" (145 dB re 1 uPa at 1 m; (Erbe et al., 2012)) and humpback whales (153 dB re 1 uPa at 1 m; (Au et al., 2006)) were taken from previous studies. Authors found that the infrequent addition of ecotour boat noise could temporarily reduce the "very audible area" (> 10 dB SNR) in their song's commonly used peak frequency (350 Hz) by 63%.

Ruscher et al. (2021) measured aerial behavioral hearing thresholds in a Hawaiian monk seal (*Neomonachus schauinslandi*). The results showed a hearing range between 0.1 and 33 kHz with relatively poor sensitivity compared to Phocinae seals. The most sensitive thresholds were 40 dB re 20 µPa measured at 800 Hz and 3.2 kHz. The resulting audiogram was most similar to the northern elephant seal, which is the only other species of Monachinae seal with audiogram data (Reichmuth et al., 2013). This study suggested that hearing sensitivity of Monachinae seals is substantially reduced compared to other species within their functional hearing group (phocid carnivores in air,

PCA); so the use of the PCA weighting function to predict auditory impacts is likely conservative for Hawaiian monk seals.

Sills et al. (2021) measured underwater auditory detection thresholds in a male Hawaiian monk seal, and the range of most sensitive hearing was between 0.2 and 33 kHz. Peak hearing sensitivity of 73 dB re 1 µPa was observed at 1.6 kHz. The audiogram for this individual was similar but narrower and elevated compared to the hearing group (phocid carnivores in water, PCW) composite audiogram used to assess impacts to this species. Underwater vocalizations were also measured, and 6 call types were identified, which had peak energy between 55 and 400 Hz. The number of calls produced per minute fluctuated seasonally, and peaked in the breeding season with the highest call rates recorded in December.

A study by von Benda-Beckmann et al. (2021) modeled the effect of pulsed and continuous 1-2 kHz active sonar on sperm whale echolocation clicks, and found that the presence of upper harmonics in the sonar signal increased masking of clicks produced in the search phase of foraging compared to buzz clicks produced during prey capture. Different levels of sonar caused intermittent to continuous masking (120 to 160 dB re 1 μPa^2, respectively), but varied based on click level, whale orientation, and prey target strength. Continuous active sonar resulted in a greater percentage of time that echolocation clicks were masked compared to pulsed active sonar.

HEARING LOSS (TTS AND PTS)

Houser (2021) reviews existing literature on the relationship between auditory threshold shift and tissue destruction in mammals. According to small terrestrial mammal literature, temporary threshold shifts (TTSs) of approximately 30-50 dB measured 24 hours after sound exposure induced progressive tissue damage despite the return of normal hearing thresholds. Although large TTSs allow for full recovery of hearing, pathological tissue destruction may occur; however, smaller-magnitude TTSs are unlikely to result in tissue damage. The author concludes that the current criteria of 40 dB of TTS measured within minutes of the noise exposure as the onset of injury is likely to encompass recoverable auditory threshold shift without tissue damage. This publication supports the use of current definitions of auditory injury in marine mammals.

Kastelein et al. (2021a) underwater, behavioral hearing thresholds at 0.5, 0.71, and 1 kHz in one harbor porpoise before and after exposure to one-sixth-octave band noise centered at 0.5 kHz. Maximum TTS was 8.9 dB (mean = 7.6 dB) at the 0.5 kHz hearing test frequency after a 205-dB SEL exposure. For the 0.71 and 1 kHz hearing test frequencies, no mean TTS > 6 dB was observed. However, at 0.71 kHz, maximum TTS was 6.5 dB (mean = 5.8 dB) was observed after a 205-dB SEL exposure. At 1 kHz, a maximum of 6.3 dB of TTS (mean = 5.7 dB) occurred after 206-dB SEL exposures. All shifts < 5 dB recovered within 12 minutes and shifts > 6 dB recovered within 60 minutes. *These results are consistent with Navy Phase 3 Criteria and Thresholds (C&T).*

Kastelein et al. (2021b) measured behavioral, underwater hearing thresholds at 2, 2.8, and 4.2 kHz in two sea lions before and after exposure to band-limited noise centered at 2 kHz. Sea lion hearing was also tested at 4.2, 5.6, 8 kHz before and after exposure to noise centered at 4 kHz. Maximum TTS was 24.1 dB (22.4 dB mean) at the 5.6 kHz test frequency after a 205-dB SEL exposure centered at 4 kHz. Threshold shifts greater than or equal to 6 dB occurred at 187, 181, and 187 dB SEL for 4.2, 5.6, and 8 kHz test frequencies respectively. After exposure to the 2-kHz noise, maximum TTS of 11.1 dB (10.5 dB mean) occurred for 203 dB SEL at the 2 kHz test frequency. Threshold shifts greater than or equal to 6 dB occurred at SELs of 192, 186, and 198 dB for test frequencies 2, 2.8, and 4.2 kHz respectively. These data suggest that ½ octave above the exposure frequency is the most sensitive to noise exposure. TTS between 6 and 10 dB recovered within 60 minutes, 10-15 dB of TTS recovered within 120 min, and TTS up to 24.1 dB recovered after 240 min.   *These results are not consistent with Navy Phase 3 C&T, and suggest that the onset of TTS for otariids in water is lower than Phase 3 exposure functions.*

Kastelein et al. (2020a) measured underwater, behavioral hearing thresholds in one harbor porpoise before and after exposure to playbacks of one-sixth-octave band noise centered at 1.5 kHz, and a 6.5 kHz continuous wave. Following exposure to the 1.5 kHz noise band at 201 dB SEL, a maximum of a 7.8 dB, 9.8 dB, and 7 dB TTS was

observed for 1.5, 2.1, and 3 kHz hearing frequencies respectively. After exposure to the 6.5 kHz continuous wave at 184 dB SEL, a maximum of a 7.5, 16.7, and 11.8 dB TTS was observed for 6.5, 9.2, and 13 kHz hearing frequencies respectively. For the 6.5 kHz exposure, a mean TTS > 6 dB was observed for the 178 and 180 dB SELs when the hearing test frequency was 9.2 kHz, and for the 180 dB SEL when the hearing test frequency was 13 kHz. *Use of Navy criteria would have over-estimated effects for both the 1.5 and 6.5 exposure frequencies.*

Kastelein et al. (2020b) measured underwater, behavioral hearing thresholds in two harbor seals before and after exposure to playbacks of one-sixth-octave band noise centered at 0.5, 1, and 2 kHz. Hearing tests were conducted at the center frequency, ½ octave above, and 1 octave above center frequency. No TTS > 6 dB was observed for any hearing frequency after 204, 210, or 211 dB SEL exposures to the 0.5 kHz noise band. For the 1 kHz exposure frequency, max TTS of 7.4 dB (6.1 mean) was observed after a 207 dB SEL exposure at a hearing frequency of 1.4 kHz. For this exposure frequency, no other test condition produced TTS > 6 dB; although, a 5.9 dB shift (at 1.4 kHz) occurred at 206 dB SEL. For the 2 kHz noise band, after a 201 dB SEL exposure, max TTS of 12 dB was measured one octave above the center frequency (4 kHz). For this exposure frequency, TTS > 6 dB was observed at SELs > 201, 198, and 192 dB for hearing frequencies 2, 2.8, and 4 kHz respectively. All shifts recovered within 1 hour. *Use of Navy criteria would have over-estimated effects (i.e., predicted PTS).*

Kastelein et al. (2020c) measured underwater, behavioral hearing thresholds in one harbor porpoise before and after exposure to playbacks of one-sixth-octave band noise centered at 88.4 kHz. Maximum TTS of 13.6 dB was observed at 197 dB SEL for the 100 kHz hearing test frequency. No TTS > 6 dB was observed for any SEL at the 88.4 kHz test frequency. For 125 kHz, shifts > 6 dB were observed for 191, 194, and 197 dB SEL exposures, with a mean TTS of 5.4, 6.1, and 5.9 dB, respectively. *Use of Navy criteria would have over-estimated effects.*

Kastelein et al. (2020d) measured underwater, behavioral hearing thresholds in one harbor porpoise before and after exposure to airgun impulses (“shots”). Exposure conditions varied with regards to number of airguns, number of shots, light cues, and position of the dolphin relative to the airguns. Hearing test frequencies were 2, 4, and 8 kHz, and no TTS > 6 dB was observed. *Use of Navy criteria would have over-estimated effects.*

Kastelein et al. (2020e) measured underwater, behavioral hearing thresholds in two harbor seals before and after exposure to playbacks of one-sixth-octave band noise centered at 40 kHz. For the 50 kHz hearing test frequency, a maximum TTS of 30.7 dB was observed 12-16 minutes after the 189 dB SEL, and a mean TTS > 6 dB was observed for all SELs 177 dB and above. The 30-dB shift recovered after 3 days. No TTS > 6 dB was observed for any SEL at the 63 kHz test frequency for either seal. At 40 kHz, mean TTS of 9.2 dB was observed after a 189-dB SEL. *These results are consistent with Navy Phase 3 C&T.*

Sills et al. (2020) exposed one bearded seal to multiple impulsive underwater noise exposures (seismic air gun “shots”). Hearing tests were conducted at 100 Hz and 400 Hz after exposures to 2, 4, and 10 shots. After a 4-shot (191 dB SEL) exposure, max TTS of 9.4 dB was observed, but no other TTS > 6 dB was demonstrated, despite four 10-shot (194-195 dB SEL) exposures. It is possible that TTS recovered during the measurements, as quantified by a mean “first miss” of 7.5 dB for the 10-shot exposures (mean TTS was 2.2 dB). *Use of Phase 3 Navy criteria would have over-estimated hearing effects.* Behavioral responses were also scored and averaged across three observers. For most exposures, seal exhibited mild/detectable responses, and all scores indicated that the seal did not move more than half his body and consistently participated in the study.

BEHAVIORAL REACTIONS

In a study by Benti et al. (2021), vocalizations from Northeast Atlantic herring-feeding killer whales and Northeast Pacific mammal-eating killer whales were played back to humpback whales in Norwegian waters while their behavior was monitored through animal-borne tags and visual observations. In 5 of 6 cases the humpback whales approached the fish-eating killer whales, suggesting some attraction. The response to the mammal-eating killer whales varied with the behavioral context of the humpback whales. The results suggested that the calls of the fish-eating killer whales may have acted like a dinner-bell and initiated approach and foraging behavior in the humpback whales,

while the unfamiliar sounds of the mammal-eating killer whales may have been perceived as a threat in offshore waters, but led to mixed behavior during inshore herring foraging by humpback whales. These results indicated that the humpback whales were able to discriminate between the different call types and respond with different behavioral strategies.

Boisseau et al. (2021) exposed foraging minke whales in Icelandic waters to an acoustic deterrent device that emitted 15 kHz pure tones with a source level of 198 dB rms. Pulse length and the number of pulses in a block were randomized but average pulse length was 752 ms with a 10% duty cycle. The source was deployed from a Zodiac boat 500 m away from an animal for the first two exposures, and 1000 m away in the remaining 8 exposures (max received level of 150 dB RMS at a minimum distance of 338 m). Video-range tracking was used to track animals before, during, and after the exposures and dive duration (sec), swim speed (km/h), reoxygenation rate (blows/min), and path predictability were also examined. During the exposure, animal speed and dive duration increased, measures of path predictability increased indicating straighter paths, and reoxygenation rate decreased. Path predictability had a strong relationship with received level whereas speed and dive duration did not, which suggested those two metrics were more influenced by the presence of the exposure signal than the received sound level.

Curé et al. (2021) conducted controlled exposure experiments using both pulsed (PAS, 5% duty cycle) and continuous active sonar (CAS, 95% duty cycle) to measure and score tagged sperm whale behavioral responses. No sonar control exposures resulted in significantly fewer and less severe behavioral responses than sonar exposures. No significant differences were observed between sonar types, but the presence of killer whales or pilot whales did significantly increase the number of responses. The probability of observing low and medium severity responses increased with cumulative sound exposure level (SEL, dB re 1 μPa^2 s), reaching a probability of 0.5 at approximately 173 dB SEL for low severity responses. Medium severity responses reached a probability of approximately 0.35 at cumulative SELs between 179 and 189 dB. This study suggested that both PAS and CAS exposure resulted in a greater number of behavioral changes in sperm whales as compared to the vessel (control) alone, and the types of behavioral responses might differ across sonar types.

Czapanskiy et al. (2021) modeled energetic costs associated with behavioral response to mid-frequency active sonar using datasets from eleven cetaceans' feeding rates, prey characteristics, avoidance behavior, and metabolic rates. Authors found that the short-term energetic cost was influenced more by lost foraging opportunities than increased locomotor effort during avoidance. Additionally, the model found that mysticetes incurred more energetic cost that odontocetes, even during mild behavioral responses to sonar.

Durbach et al. (2021) analyzed acoustic tracks from minke whales detected on the Pacific Missile Range Facility (PMRF) in Hawaii in three years before, during, and after major Navy training exercises. These tracks were fit using a continuous-time correlated random walk at 5-minute interpolated locations. During sonar periods, fast movement became more northerly and more directed (less turning), with less movement south and east in the direction of the training activity, and this more northerly movement continued after sonar cessation. Specifically, whales to the north of the training activity were more likely to head north, while whales that were west of the activity were more likely to head west. Headings did not appear to change for slow, undirected movement during sonar. In addition, fast movement was more likely to occur during sonar than during any other period (70% during vs 35-41% in the other periods). Finally, whales were more likely to stop calling when in the fast state although not necessarily more during sonar than in other periods; in contrast, slow moving whales were more likely to stop calling during sonar than other periods. These results demonstrated that minke whales moved faster and movements were more directed during periods of active sonar. Minke whales also avoided the locations of the ships producing the sonar, and were more likely to cease calling during sonar.

Fernandez-Betelu et al. (2021) used passive acoustic data recorded over a 10-year time period to assess the effects of impulsive noise produced during offshore activities on coastal bottlenose dolphin occurrence. Offshore activities included seismic surveys and pile driving from wind farm construction. Echolocation detections of dolphins were compared across years with and without offshore activity and also across days with and without impulsive noise. The effect of distance from the noise-producing activities on dolphin detections was also investigated by placing

recorders (CPODs) at locations expected to be the most (impact areas) and least (reference areas) impacted by noise. No consistent relationship was found between annual dolphin occurrence and impulsive noise, but significantly more detections were observed on days with impulsive noise. The results showed that dolphins were not displaced by impulsive noise levels up to 141 dB re 1 µPa and as close as 20 km from the impact area. These results suggest that the increase in dolphin detections during far-field noise was likely due to an increase in the number and/or amplitude of echolocation vocalizations.

Hastie et al. (2021) studied how the number and severity of avoidance events may be an outcome of marine mammal cognition and risk assessment. Five captive grey seals were given the option to forage in a high- or low-density prey patch while continuously exposed to silence, pile driving or tidal turbine playbacks (source levels = 148 dB re 1 µPa at 1 m) for one hour. One prey patch was closer to the speaker, so had a higher received level in experimental exposures. Overall, seals avoided both anthropogenic noise playback conditions with higher received levels when the prey density was limited, but would forage successfully and for as long as control conditions when the prey density was higher, demonstrating a classic cognitive approach utilized with predation risk and profit balancing.

Heide-Jorgensen et al. (2021) conducted the first controlled exposure experiment to investigate the effect of airgun pulses on a well-studied population of tagged narwhals in an Arctic fjord. Eleven narwhals were exposed to seismic vessels with or without airgun noise at various distances (airgun source levels = 231 and 241 dB re 1 µPa at 1m). Even though small and large airgun sources reached ambient noise levels around 3 and 10 km, respectively, narwhals still changed their swimming direction away from the source and towards shore when seismic vessels were in line of sight over 11 km away. Swimming speed was context-dependent; whales usually increased speed in the presence of vessels but would reduce speed ("freeze") in response to closely approaching airgun pulses. Other behaviors, like feeding, also ceased when the ship and airgun noise was less than 10 km away, although received SELs were below 130 dB re 1 μPa^2 s for either airgun at this distance. Due to study research methods and criteria, even these long-distance reactions of narwhals may be conservatively estimating narwhals' range to behavioral response.

In a study by (Holt et al., 2021a), DTAGs (miniature sound and movement recording tags) were attached with suction cups to Southern Resident Killer Whales in the Salish Sea to investigate the relationship between probability of prey capture and vessel and sound variables. The predicted probability of prey capture was lower when vessels increased their speed. Received noise level did not significantly affect the probability of prey capture. The rate of descent during dives was slower when echosounders were on. The observed effects of echosounders suggest that whales prolonged their foraging efforts to successfully hunt, which could be caused by acoustic masking or increased attention to vessels. The rate of descent increased with increasing broadband noise levels and decreasing vessel distance. Decrease prey abundance also decreased the probability of predicted prey capture.

Holt et al. (2021b) attached DTAGs to twenty-three southern resident killer whales in the San Juan Islands over three field seasons in order to investigate the effects of vessel distance on underwater foraging behavior. When vessels were less than 366 m away, whales (n=13) decreased the number of dives associated with prey capture and the amount of time spent in these dives. Additionally, female killer whales were more likely to stop foraging, socializing and prey-sharing and instead start traveling when vessels approached at this distance. At the same distance from vessels, male orcas were more likely to transition from close prey capture to socializing and prey-sharing, but would not stop general foraging behavior, such as searching for prey at deeper depths. Female orcas may therefore be at greater risk than males during close vessel interactions.

Kates Varghese et al. (2021) analyzed the effect of two separate surveys using a 12 kHz multi-beam echosounder (i.e., downward directed, unlike ASW sonar) over the Southern California Antisubmarine Warfare Range (SOAR) hydrophone array on Cuvier's beaked whale foraging. The authors conducted a spatial analysis, building off a temporal analysis of a previously presented dataset (Varghese et al., 2020). There were differences in spatial use of the SOAR for foraging between the two survey years. While no change in overall foraging effort was detected before, during, and after the surveys each year, some localized spatial shifts in foraging hot spots were detected during and after the survey in the second year. Because of the known heterogeneity of prey patches on SOAR, lack of evidence

of avoidance of the sound source, and no observed change in overall foraging effort, the authors suggest that the observed spatial shifts were most likely due to prey dynamics.

In a study by Laborie et al. (2021), Unmanned Aerial Vehicles (UAVs) were flown at three altitudes (25, 20, and 15m) over Weddell seals, including adult males and females and females with pups. There was generally little response; 88% of the time the animals showed mild vigilance or no responses, and mothers rarely ended nursing. Agitation or escape responses only occurred in 12% of observations. The strongest response was in females with pups when wind speeds were lowest and therefore ambient noise levels were at their lowest. The probability of response increased with lower altitude flights, so at altitudes over 25 m a low level of impact to Weddell seal behavior would be expected.

PHYSIOLOGICAL RESPONSES AND STRESS

Elmegaard et al. (2021) exposed two captive harbor porpoises to sonar sweeps (6-9 kHz, 500 msec duration, 50-100 msec rise time, varying RL) and pulsed sounds (50 msec duration, peak frequency 40 kHz, half power bandwidth of ~5 kHz, rise time < 5 msec, varying RL) to investigate startle reflex and changes in heart rate. The sonar exposures did not elicit startle responses; the initial two to three exposures induced bradycardia, with subsequent habituation. This habituation was conserved after a three-year pause in exposures. The authors suggest that the initial bradycardia allows "a prolonged breath-hold to assess the nature of a novel stimuli or flee in crypsis if needed;" in naïve wild cetaceans, the reduced peripheral perfusion caused by this response may reduce N_2 diffusion from supersaturated tissues during dive ascents, increasing risk of decompression sickness. Startle responses to the pulse exposures were directly correlated to RL. The 50% motor-startle probability threshold was around 130 dB re 1 µPa (rms50). This is ~85 dB above hearing threshold and is similar to that observed in bottlenose dolphins (~90 dB over hearing threshold) (Gotz et al., 2020). No significant change in heart rate was observed. The authors suggest that the parasympathetic cardiac dive response may override any transient sympathetic response, or that diving mammals may not have the cardiac startle response seen in terrestrial mammals in order to maintain volitional cardiovascular control at depth.

Fahlman et al. (2021) reviews decompression theory and the mechanisms dolphins have evolved to prevent high N2 levels and gas emboli (i.e., bends-like symptoms) in normal conditions. However, in times of high stress, the selective gas exchange hypothesis states that this mechanism can break down. In addition, circulating microparticles may be useful biomarkers for decompression stress in cetaceans.

Yang et al. (2021) measured cortisol concentrations in blood samples of two captive bottlenose dolphins and found significantly higher levels after exposure to high sound level (140 dB re 1 µPa) impulsive noise playbacks, compared to control and low sound levels (0 and 120 dB re 1 µPa, respectively). Six cytokine gene transcriptions were also measured in blood samples and two (IL-10 and IFN-γ) showed significant changes at high sound level exposure, compared to control and low sound levels. Results suggest that repeated exposures or sustained stress response to impulsive sounds may increase an affected individual's susceptibility to pathogens, affect growth and reproduction, etc. In addition, no avoidance behavior was observed during the trials, indicating that stress-induced physiological changes could be present despite the absence of behavioral changes.

STRANDING

Danil et al. (2021) document the findings of NOAA's investigation of the strandings of three coastal bottlenose dolphins in 2015 at Silver Strand Training Complex in NOAA Technical Memorandum NMFS-SWFSC-641. On 21 October 2015, two dolphins were found stranded dead near each other on the beach. Because a Navy major training exercise was underway, these strandings met the criteria of an Uncommon Stranding Event in accordance with the Southern California Stranding Response Plan in the Navy's Phase 2 Letter of Authorization under the Marine Mammal Protection Act (MMPA) for HSTT. A third decomposed dolphin was found in the same area ten days later. Examination of the dolphins resulted in findings indicative of severe acute trauma, including lower jaw subcutaneous hemorrhage, emphysema, and cervical blubber hemorrhage. Additional signs of injury to the cerebrum and heart,

or lipids in the lungs were also discovered. No hemorrhage was found near the ears. At least two of the dolphins showed signs of feeding before stranding, and all were in robust condition. There were no external signs of strike or entanglement. These observations and lack of others did not clearly determine the cause of the acute trauma. Based on previous case studies, the investigators determined that underwater detonation, peracute underwater entrapment (i.e., fisheries interaction), or sonar were the most plausible causes. No anti-submarine (ASW) sonar or explosive use was associated with the Navy Major Training Exercise; however, unit level training with MF1 sonar occurred on OCT 19 (for 35 min.) and OCT 20 (62 min. in total), with sonar use as close as 6 NM to the stranding location. No known squid or bait fishing efforts occurred in the vicinity preceding the strandings.

POPULATION CONSEQUENCES OF DISTURBANCE AND CUMULATIVE STRESSORS

Migrating humpback whale mother-calf pairs' responses to seismic surveys were modeled by Dunlop et al. (2021) using both a forwards and backward approach. While a typical forwards approach can determine if a stressor would have population-level consequences, authors demonstrated that working backwards through a population consequences of disturbance (PCoD) model can be used to assess the "worst case" scenario for an interaction of a target species and stressor. Assumptions for the extreme scenario were likely exaggerated (e.g., in area for > 48 hours, exposed to > 3 air gun events) but lack data to inform humpback nursing behavior and calf survivability during acoustic stressors. The results demonstrated that migrating whales would not likely experience enough of a delay as a result of disturbance to result in population consequences, but whales disturbed in breeding or resting areas would be more vulnerable to consequences of disturbance.

Greenfield et al. (2020) demonstrated that bottlenose dolphins who had been injured from boat strike or entanglement experienced a decline in their social network's preferred associations, and as a result were more vulnerable to predation and less fecund.

Hin et al. (2021) used a previously published energy budget model for pilot whales (Hin et al., 2019) to examine how lost foraging days affect individuals in a population at carrying capacity. In this model, depletion of prey is dependent on whale density, and prey density limits the energy available for growth, reproduction and survival. The authors assumed extreme disturbance events for this study: consecutive days of no foraging affecting all individuals in a population. The undisturbed whale population was regulated through the effect of prey availability on calf survival and pregnancy rates and on age at first reproduction of females. During a disturbance event, population decline was generally attributed to loss of lactating females and calves due to reduced body condition. The subsequent increase in prey density and per capita prey availability, however, resulted in improved body condition in the population overall and decreased age at first calf. As disturbance duration was increased (~40 days of no foraging), the population would enter extreme decline towards extinction.

Murray et al. (2021) conducted a cumulative effects assessment on Northern and Southern resident killer whales, which involved both a Pathways of Effects conceptual model and a Population Viability Analysis quantitative simulation model. Authors found that both populations were highly sensitive to prey abundance, and were also impacted by the interaction of low prey abundance with vessel strike, vessel noise, and polychlorinated biphenyls contaminants. However, more research is needed to validate the mechanisms of vessel disturbance and environmental containments.

Pirotta et al. (2021) integrated different sources of data (e.g., controlled exposure data, activity monitoring, telemetry tracking, and prey sampling) into a bioenergetic model, which was used to predict effects from sonar on a blue whale's daily energy intake. Approximately half of the simulated whales had no change in daily net energy intake because they either had no response or were not exposed. However, the other half experienced a decrease in net energy intake. A portion (11%) of those simulated whales had negative net energy even after brief (e.g., 6-30 min) or weak (e.g., 160-180 dB re 1 µPa source level) events, which indicated that they would not be able to cover that day's energetic cost. This dichotomy in results was due to the variation in activity budgets, lunging rates and ranging patterns between tagged whales. This evidence suggests that context can influence the predicted costs of

disturbance even more than body size or prey density distribution on a daily scale (although prey availability and abundance affected behavioral patterns).

CONCLUSIONS

New information regarding marine mammal vocalizations and masking supported the analysis and conclusions in the 2018 AFTT and HSTT Final EIS/OEISs. Of the nine new publications summarized in the Hearing Loss section, one supports the current definition of auditory injury in marine mammals, and eight measured hearing loss (TTS/PTS) in marine mammals due to noise exposure. Two of those empirical studies exposed marine mammals to impulsive sounds, and the other six exposed them to tonal sounds. Two papers demonstrated that Navy's analysis for phocid carnivores in water and an air (PCW and PCA) likely overestimated impacts for Hawaiian monk seals. With the exception of one study (Kastelein et al., 2021b), all of the data either supported the use of the Navy's Phase 3 auditory criteria and thresholds, or showed that the auditory criteria would have over-estimated the observed effects. Kastelein et al. (2021b) demonstrated that auditory effects on otariid carnivores in water (OCW) might have been under-estimated in the HSTT Final EIS/OEISs.

New science continues to expand the understanding of contextual factors, in addition to received level, that may influence marine mammal behavioral responses to both anthropogenic and natural sounds. New literature on behavioral reactions suggested that prey dynamics or perceived foraging opportunities influenced potential responses to anthropogenic activity (grey seals - Hastie et al., 2021; Cuvier's beaked whales - Varghese et al., 2021) or natural sounds (humpback whales - Benti et al., 2021), and females were more susceptible to foraging disruption (Southern resident killer whales - Holt et al., 2021b). Additionally, perception of predation risk also influenced behavioral responses (humpack whales - Benti et al., 2021; sperm whales - Curé et al., 2021).

Several studies examined behavioral responses to military sonars and other non-impulsive sound sources. Potential for behavioral response was shown to be correlated to cumulative sound exposure level for both continuous and pulsed sonars (sperm whales - Curé et al., 2021). Some aspects of observed responses were correlated to received level (directional movement), whereas others (swim speed and dive duration) were related to presence of the signal only (minke - Boisseau et al., 2021). Durbach et al. (2021) showed minke whale avoidance and reduced vocalization during actual military sonar training. In two different studies, vessels with echosounders were shown to either prolong (Southern Resident killer whales - Holt et al., 2021a) or have no effect (Cuvier's beaked whales - Varghese et al., 2021) on foraging effort.

Two studies provided additional information on marine mammal behavioral responses to impulsive sounds, although these were based on exposures to seismic air guns or construction, which are unlike most naval activities. A variety of responses were observed, ranging from increased vocalizations without displacement (coastal bottlenose dolphin - Fernandez-Betelu et al., 2021) to avoidance or "freezing" behavior if in close proximity to the seismic source (narwhal - Heide-Jorgensen et al., 2021), showing that responses notably differ between species.

Several studies provided more insight into physiological responses to sound exposures. New information showed that a physiological stress response can occur in the absence of observable behavioral reactions (Yang et al., 2021). Elmegaard et al. (2021) suggested that reduced heart rate during initial exposures of naïve animals to sounds may increase risk of decompression sickness, although the subject in that study quickly habituated to the stimulus, which persisted over three years.

Finally, researchers continued to refine and conduct case studies with population consequences of disturbance (PCoD) models. Studies that showed 1) migrating humpback whales were less likely than breeding or resting whales to incur PCoD, 2) injured individuals or those with poor body condition were more vulnerable to cumulative stressors, and 3) disturbances that reduced or interacted with feeding opportunities resulted in more severe PCoD.

Although this section presents additional information on impacts to marine mammals by acoustic stressors, this new information, together with the existing body of science considered in the in the 2018 AFTT and HSTT Final EIS/OEISs

and subsequent SIRs, does not change the conclusions in the 2018 AFTT and HSTT Final EIS/OEISs. However, one exception (Kastelein et al., 2021b) could change Navy's analysis regarding OCW hearing impacts, which might result in increased auditory impacts for OCW as compared to impacts quantified in the 2018 HSTT FEIS/OEISs. There are no otariids present in AFTT study area. The data from this publication is currently being evaluated in the development of the Navy's Phase 4 criteria and thresholds.

METHODOLOGY FOR ASSESSING ACOUSTIC IMPACTS

This chapter contains a summary of scientific information pertaining to methodology for assessing acoustic stressors that are relevant to the analysis presented in the 2018 AFTT and HSTT Final EIS/OEIS and 2019 and 2021 SIRs. This chapter also presents the Navy's determination of whether this new information supports the analysis contained in the 2018 Final EIS/OEISs.

Guan and Brookens (2021) reviewed how psychoacoustics research has been applied in marine mammal auditory impact assessment in the United States. The paper highlights that behavioral response thresholds for both acoustic and explosive sources require further development, and that data on noise-induced threshold shift (TTS and PTS) is still lacking for some groups such as mysticetes (LF cetaceans). The authors also point out that quantifying population level and cumulative effects remains challenging, and recommend further research on the relationship between sound exposure and stress.

CONCLUSIONS

The review paper presented in this section does not change the analysis and conclusions in the 2018 AFTT and HSTT Final EIS/OEISs.

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INTRODUCTION

The scientific community continues to generate new data in an effort to expand and improve our understanding of the marine environment. Since the publication of the AFTT and HSTT 2018 Final EIS/OEISs and Record of Decisions (ROD), and the publication of the 2019 Supplemental Information Reports (SIRs), the Navy has reviewed new scientific research relevant to the analysis of acoustic and explosive impacts, the majority of which were published after the Final EIS/OEIS and SIRs were issued. Most of these new publications are peer-reviewed journal articles on topics including, but not limited to: the effects of vessel noise, impulsive noise, construction noise, and sonar on marine species; disturbance models for marine mammals; auditory impacts to marine mammals; behavioral responses of fishes; marine bird hearing; sea turtle vocalizations; mitigation technology advancements; and acoustic impact assessment methodologies. Although many of these studies are incorporated into the Navy's at-sea impact analysis through other region specific projects (e.g., the Northwest Training and Testing Draft SEIS/OEIS), this document presents scientific information updated since the analysis conducted in the AFTT and HSTT 2018 Final EIS/OEISs, RODs, and 2019 SIRs. While there are additional research papers pertaining to marine resources, the studies outlined below were chosen because of their relevance to the analysis of acoustic and explosive impacts on marine resources. In the sections that follow, the Navy presents a review of new research and evaluates how the results apply to the Navy's assessment of marine resources.

ACOUSTIC STRESSORS

This chapter contains a summary of scientific information pertaining to acoustic stressors that were analyzed in the 2018 AFTT and HSTT Final EIS/OEIS and 2019 SIR. New best available science was found concerning vessel noise and aircraft noise. This chapter also presents the Navy's determination if this new information supports the analysis contained in the 2018 Final EIS/OEISs.

VESSEL NOISE

Wladichuk et al. (2019) measured source levels from 20 small vessels of different vessel types (i.e., mono-hull, catamaran, RHIB, landing craft, sailboat, and small outboard) that followed controlled transit protocols when passing by an underwater recorder. This study aimed to quantify source levels from a sample of small vessels to investigate how source levels correlated with vessel type, speed, and propulsion type. Overall, the authors found a positive trend in source level relative to vessel speed and that smaller vessels have more energy in higher frequencies relative to published source levels for large vessels. The authors also computed source levels for the different vessel types in frequency bands with biological relevance for southern resident killer whales (SRKW) and found that landing crafts and catamarans produced the highest source levels. Landing crafts at slow speeds produced the highest source levels in the SRKW echolocation frequency band.

MacGillivray et al. (2019) used bottom moored acoustic recorders and AIS data collected before, during, and after a voluntary 60-day trial slow down period in the Haro Strait to quantify the effect of reduced speed on vessel source levels. The slow down resulted in a reduction in source levels for containerships (11.5 dB), cruise vessels (10.5 dB), vehicle carriers (9.3 dB), tankers (6.1 dB), and bulkers (5.9 dB). Source level measurements were analyzed in frequency bands with biological significance for SRKW (broadband 10-100,000 Hz, communication masking 500-15,000 Hz, and echolocation masking 15,000-100,000 Hz). Vessels that participated in the slow down had a significant reduction in source levels compared to measurements from outside of the trial period. The smallest mean reductions (3.1–10.8 dB) occurred in the SRKW communication masking band (0.5–15 kHz) and greatest mean reductions (5.1–17.8 dB) occurred in the SRKW echolocation band (>15 kHz). The authors conclude that reducing speed is an effective method for reducing radiated vessel noise and is expected to result in a net reduction in ambient noise levels in SRKW critical habitat.

AIRCRAFT NOISE

Erbe et al. (2018) measured underwater commercial aircraft overflight noise in the Canning River (Western Australia) and in the ocean adjacent to a runway in Denpasar (Indonesia). These recording locations have different environmental conditions and capture sound levels from commercial airplanes during different stages of the flight pattern which impacts underwater sound levels. In addition, the authors indicated that the variability in sound levels was also due to different types of commercial airplanes, heights, angles, speeds, and sound propagation conditions. In general, findings indicate that most energy from aircraft noise measured in-water is under 1,000 Hz with a peak around 100 Hz. The authors conclude that underwater sound from aircraft overflight noise is often overlooked, understudied, and can impact marine species, particularly those with high hearing sensitivity for lower frequencies.

CONCLUSIONS

These publications present new information regarding measurements and biological analyses of underwater noise levels from small and large vessels and commercial aircraft. The findings from these studies do not change the analysis and conclusions in the 2018 AFTT and HSTT Final EIS/OEISs.

MARINE MAMMALS

This chapter contains a summary of scientific information pertaining to marine mammal acoustic stressors analyzed in the 2018 AFTT and HSTT Final EIS/OEIS and 2019 SIRs. New best available science was found concerning auditory masking, temporary threshold shift (TTS) and permanent threshold shift (PTS), behavioral reactions, physiological stress, stranding, and population consequences of disturbance (PCOD) and cumulative impacts. This chapter also presents the Navy's determination if this new information supports the analysis contained in the 2018 Final EIS/OEISs.

MASKING

Accomando et al. (2020) found that bottlenose dolphins (*Tursiops truncatus*) exhibit direction-dependent hearing sensitivity for 2, 10, 20, and 30 kHz sounds, for which directional dependence increases with sound frequency. The frequencies used in this study are in the range used by odontocetes for communication, and the results suggest that the relative angle between the sound and the dolphin hearing it affects the detection threshold. This paper affirms the dependence of hearing sensitivity on source location relative to the dolphin, and the authors suggest that directional hearing sensitivity could contribute to spatial release from masking, even for lower-frequency communication sounds.

Byl et al. (2019) used psychophysical methods to test the horizontal underwater sound-localization acuity of harbor seals (*Phoca vitulina*) for two noise bands (8–16 kHz and 14–16 kHz). The results showed that minimum audible angles (MAAs) were between 5.1 and 17.5°. These results are consistent with previous literature that shows better sound localization for stimuli with more spectral information. This study provides evidence that seals likely have well-developed directional hearing for sounds in this frequency range, and therefore may also undergo a spatial release from masking for noise.

Dunlop (2019) modeled communication space of humpback whales (*Megaptera novaeangliae*) and found that the 4 km of modeled communication space in wind-dominated noise was reduced to 3 km in vessel-dominated noise at the same received level. They also found that, at 105 dB re 1 µPa of noise, communication space decreased to 2 km for low-frequency signals and 1 km for high-frequency signals. In addition, humpback whales changed their acoustic and social behavior when vessels were present; their communication area was reduced by half in average vessel-dominated noise, but the physical presence of vessels was the major contributing factor to decreased social interaction.

Guazzo et al. (2020) detected, localized, and tracked humpback song units using bottom mounted hydrophones at the U.S Navy's Pacific Missile Range Facility to investigate the Lombard Effect in humpback whales due to naturally occurring increases in background noise levels. Call source levels and background noise levels were measured in the 150-1,000 Hz range which covers the humpback song detection band. Transmission loss was estimated using the sonar equation and calls were required to be within a 10 km radius of the center hydrophone of a subarray. Results indicated that humpback whales had a maximum response of increasing their call source level by 0.68 dB per 1 dB increase in background noise levels when noise was 91 dB. The average response was an increase in source level by 0.53 dB per 1 dB increase in background noise levels over the full range of noise encountered (80-105 dB). Overall, humpback whales responded to increasing ambient noise levels by increasing the source level of their calls which helps contextualize the impact of anthropogenic noise on calling.

Helble et al. (2020) localized and tracked minke whale (*Balaenoptera acutorostrata*) calls that were recorded off the coast of Kauai, HI at the U.S. Navy's Pacific Missile Range Facility to investigate the Lombard effect in minke whale calls due to naturally varying noise levels in the dominant frequency band of minke whale calls (1,250–1,600 Hz). Results indicate that minke whales had a maximum response of increasing their call source level by 0.34 dB per 1 dB increase in background noise levels when noise was 82 dB. The average response was an increase in source level by 0.24 dB per 1 dB increase in background noise levels over the full range of noise encountered (65-90 dB). Since the sensors used in this study are mounted on the sea floor, the noise level at the sea floor was measured and was used as a proxy for the noise level near the surface where minke whales are expected to occur. It is likely that the noise levels experienced by minke whales are greater near the surface, and the observable Lombard effect in this study is likely an upper-bound response. The authors conclude that minke whales may not be able to compensate for all instances of natural increases in background noise levels which helps contextualize the effect on call source levels due to increases in noise levels from anthropogenic sources.

Kloepper and Branstetter (2019) showed that individual bottlenose dolphins have different strategies for avoiding conspecific sonar jamming (i.e., echolocating at the same time). One dolphin subject responded to jamming signals by omitting clicks (i.e., utilized a temporal response) and the second subject increased peak frequency and lowered center frequency, increasing click bandwidth (i.e., utilized a spectral response). Both temporal and spectral jamming avoidance strategies have previously been documented in bats. These results show that dolphins can adapt their sonar in response to challenging acoustic environments.

Popov et al. (2020) measured auditory-evoked potentials (AEPs) in a single bottlenose dolphin and observed a 32-dB masking effect when there was no separation between signal and noise, and both were presented directly in front. Spatial release from masking (SRM) occurred when the masker was moved 30 degrees or more off-axis; but smaller angular separations between signal and noise were not tested. This study only measured SRM with a single frequency, 64 kHz. The release from masking was smaller than expected: masking was reduced by ~16–24 dB but did not return to baseline even when the masker was 90 degrees to the left or right of center. While these results are pertinent, some of the brain structures that produce the AEP receive information from both ears, which might reduce the ability of this method to fully describe spatial release from masking.

HEARING LOSS (TTS AND PTS)

Kastelein et al. (2020b) exposed two harbor seals to 32 kHz, continuous, band-limited noise for 1 hour resulting in a cumulative sound exposure level (SEL) between 128–188 dB re 1 μPa^2s, and measured less than 6 dB of threshold shift at 32 kHz which recovered within 1 hour. At a post-exposure test frequency of 45 kHz (a half-octave above the exposure frequency), the maximum TTS observed in this study occurred after a ~188 and ~191 dB re 1 μPa^2s exposure, which resulted in approximately 34 and 45 dB of TTS, respectively. Recovery occurred over 4 days for both TTSs. Recovery was gradual for the 34-dB shift, but recovery from the 45-dB shift was not observed until between 4- and 24-hours post-exposure. No TTS was observed at a test frequency of 63 kHz for any sound exposure level. Overall, these studies combined with previous work showed that for harbor seals, times to recovery are consistent

for similar-magnitude TTS, regardless of the type of sound exposure (impulsive, continuous noise band, or sinusoidal). However, recovery patterns may be less gradual for higher-magnitude TTS (above 45 dB).

A series of three publications by Kastelein and colleagues describe TTS in harbor porpoises (*Phocoena phocoena*) due to one-sixth octave noise bands at 16 kHz (Kastelein et al., 2019d), 32 kHz (Kastelein et al., 2019c), and 63 kHz (Kastelein et al., 2020a). These publications show that if the fatiguing sound is above ~6.5 kHz, harbor porpoises become less susceptible to TTS as frequency increases. The main finding of these papers contrasted with previous work by the same research group, which showed that if the fatiguing sound is below ~6.5 kHz, susceptibility to TTS generally increases with frequency. In these studies, harbor porpoises recovered quickly from the majority of exposures (within 60 minutes), and the highest SEL exposures recovered within 120 minutes. In general, harbor porpoises in these studies showed the greatest magnitude of TTS at the hearing test frequency one half octave above the exposure frequency when exposed to higher SELs, and the greatest magnitude of TTS at the center frequency of the fatiguing sound when exposed to lower SELs. One of the subjects in Kastelein et al. (2020a) showed the highest magnitude of TTS at the center frequency of the 63-kHz fatiguing sound, but the authors propose that SELs were not high enough for the greatest TTS to be produced one half octave higher. These studies contribute new data for incorporation into predictive TTS functions for this hearing group (very high frequency cetaceans, VHF), and generally support that TTS susceptibility in odontocetes is frequency dependent.

Reichmuth et al. (2019) tested harbor seal hearing after exposure to a 4.1 kHz tone that increased incrementally in sound pressure level (SPL) and duration over time. No reliable TTS trend was observed until the harbor seal was exposed to 181 dB re 1 µPa (60 s), which resulted in a massive TS of over 47 dB. The harbor seal's hearing at 4.1 kHz recovered within two days, but his hearing at one-half (5.8 kHz) and one (8.2 kHz) octave above the frequency of the noise resulted in PTS (8–11 dB) for over 10 and 2 years, respectively. This study contradicts common assumptions about the relationship of TTS and PTS: there was no gradual growth of TTS with increased levels of SEL before onset of PTS. As a result, researchers might not be able to observe gradual TTS with increasing exposure levels, and it is possible for permanent hearing damage to occur without consistent measurable behavioral hearing threshold changes.

Schaffeld et al. (2020) presented a source-based simulation approach to model how accumulation of single pile-driving strikes could result in TTS for harbor porpoises. The authors used this model to compute "hazard zones" for a specified location and source, and advocate for development of this regulatory approach as opposed to the use of absolute threshold-based criteria for modeling marine mammal sound exposures.

Stober and Thomsen (2019) modeled and compared three different established exposure criteria frameworks (Germany's BSH, Denmark's MMWG, and NMFS) for auditory impacts (PTS and TTS) to harbor porpoises and harbor seals for fictitious wind-farm pile driving in a particular location with and without noise mitigation ("big bubble curtain"). The results showed that all three criteria produced similar outcomes, and that without noise mitigation, harbor porpoises were predicted to be exposed to PTS and TTS and harbor seals to TTS. For harbor porpoises, the model showed that noise mitigation eliminated the risk of PTS as a result of impact pile driving. The authors conclude that while single noise exposure criteria are most conservative and easier to enforce (BSH), the frequency weighting methods used in NMFS and accounting for animal movement (used in MMWG) are more realistic – especially when sufficient data on hearing and behavioral responses are available.

BEHAVIORAL REACTIONS

Barlow et al. (2020) tagged 19 Cuvier's beaked whales (*Ziphius cavirostris*) on the SOAR range in Southern California and found that their average dive depth was 1182 m (max 1427 m) and that their foraging dive depths increased with sea floor depths, as they forage within 200 m of the sea floor. Beaked whales were not foraging in areas where seafloor depths were > 2000 m and foraged more frequently at night. However, during the day (and when there is strong lunar illumination) they were more likely to dive deep and avoided swimming near the surface (< 50 m), likely

to avoid predation. Navy sonar presence on the SOAR range overlapped with whale presence 10.4 percent of the time, and its effect on most of the whale's dive metrics was small.

Barrett (2019) measured sea otter (*Enhydra lutris*) activity in response to potential disturbance over three years in California and found that sea otters have high metabolic rates and are at risk of increased energetic costs when disturbed. However, there was less than a 10 percent chance of disturbance when small vessels were more than 54 m away from sea otters.

Christiansen et al. (2020) flew unmanned aerial vehicles 5–30 m above 10 southern right whale (*Eubalaena australis*) mother-calf pairs and did not observe any behavioral response in the form of changes in swim speeds, respiration rates, turning angles, or inter-breath intervals. In addition, some of the animals were equipped with DTAGS to measure the sound of the unmanned aerial vehicle; the received levels in the 100–1500 Hz band were 86 ± 4 dB re 1 µPa, very similar to ambient noise levels (81 ± 7 dB) in the same frequency band.

Clarkson et al. (2020) and Kassamali-Fox et al. (2020) investigated the short-term effects of tour boats on bottlenose dolphin behavior, and through more than two years of land-based surveys off the coast of Montenegro. Clarkson et al. (2020) found that dolphins were less likely to continue diving, and would not engage in milling, socializing, or surface feeding in the presence of non-targeted tour boats (e.g., cruise ships, ferries, passenger vessels). After analyzing boat-based survey data in Panama, Kassamali-Fox et al. (2020) found that dolphins were less likely to continue socializing, were more likely to travel, and were not likely to begin foraging during their avoidance response to cetacean-targeted tour boats.

DiMarzio et al. (2019) analyzed average group vocal period (GVP) of Cuvier’s beaked whales before, during, and after Navy mid-frequency active sonar (MFAS) exposure on the SOAR range. GVP did not vary substantially between the before-sonar and after-sonar periods, indicating a much shorter recovery period than previously seen, which might be due to the shorter duration sonar events. Two sonar sources were used: surface ship hull-mounted, and helicopter-deployed dipping sonar; and three types of events were analyzed, including ship (9 events), helicopter (11 events), and combined (3 events). Beaked whales responded similarly whether the event included only helicopter-deployed dipping sonar (n=11 events) or included surface ships, but the authors use statistical analysis to conclude that the reduction in GVP was significantly greater for events involving ships. These results do not necessarily contradict Falcone et al. (2017), which demonstrated stronger responses to helicopter-dipping sonar at short ranges, because the helicopter-deployed dipping sonar source levels in this study were much lower than the hull-mounted sonar source levels.

Dunlop et al. (2020) studied humpback whale social behavior (e.g., males joining mother-calf pairs) in different acoustic conditions, and found that migrating humpback whales reacted similarly to vessels towing seismic air gun arrays, regardless of whether the air guns were active or not. Ramp-up events did not reduce the whales’ joining interactions, but this may have been due to the difference in duration of ramp-up events (30 minutes) compared to all other treatments (60 minutes).

Erbe et al. (2019) reviewed the most studied species, habitats, vessel types, and impacts on marine mammals from vessel noise. While bottlenose dolphin and humpback whales are the most studied species, enough species have been studied to show that the impacts of ship noise on marine mammals appear to be largely context- and species-dependent. There are many knowledge gaps in the literature, including a lack of research on river dolphins, deep-diving cetaceans and sirenians outside of Florida, controls between studies (e.g., vessel types, environments, and demographics), baseline behaviors, and attempts to quantify the biological significance of marine mammal responses to boat noise. More standards in study design, data analysis and reporting are needed in order to appropriately compare between studies and assess the consequences of chronic ship noise.

Fiori et al. (2019) measured humpback whale behavioral responses to tourism activities over two breeding seasons in the South Pacific, and found that the “J” approach (i.e., traveling parallel to the whales’ direction of travel, then

overtaking the whales by turning in front of the group) correlated with avoidance responses much more (68 percent) than parallel or direct approaches. Mother-calf pairs always avoided tour boats that used direct and J approaches (n=16), so tour boats generally approached mother-calf pairs in parallel. Mother humpback whales spent significantly more time diving when tour boats and swimmers were present, indicating a preference for a vertical avoidance strategy.

Frankel and Stein (2020) exposed migrating gray whales (*Eschrichtius robustus*) to sonar transmissions in the 21–25 kHz frequency band. The results showed that, compared to controls, gray whales changed their path and moved closer to the shore when the moored vessel source range was 1–2 km during sonar transmissions. Estimated received levels were approximately 148 dB re 1 μPa^2. The authors conclude that gray whales can hear up to 21 kHz. This evidence supports the Southall et al. (2019) and U.S. Department of the Navy (2017) estimated mysticete hearing range extending up to 30 kHz.

Gotz et al. (2020) tested startle responses in bottlenose dolphins and found that these responses can occur at moderate received levels and mid-frequencies, and that the relationship between rise time and startle response was more gradual than expected in an odontocete. They therefore hypothesize that the extreme responses of beaked whales to sonar could be a form of startle response, rather than an anti-predator response.

Graham et al. (2019) conducted passive acoustic monitoring of harbor porpoise echolocation clicks during a wind-farm construction project that used impulsive pile-driving. The results revealed that distance at which behavioral responses were probable decreased over the course of the construction project, suggesting habituation to pile-driving noise in the local harbor porpoise population.

Harris et al. (2019) utilized minke whale tracks at the U.S. Navy's Pacific Missile Range Facility to demonstrate changes in the spatial distribution of minke whale acoustic presence before, during and after surface ship MFAS training. The spatial distribution of probability of acoustic presence was different in the 'during' phase compared to the 'before' phase, and the probability of presence at the center of ship activity for the during phase was close to zero for both years. The 'after' phases for both years retained lower probabilities of minke whale presence, suggesting the return to baseline conditions may take more than 5 days. The results showed a clear spatial redistribution of calling minke whales during surface ship MFAS training, however a limitation of passive acoustic monitoring is that one cannot conclude if the whales moved away, went silent, or a combination of the two.

Harris et al. (2019) conducted a controlled exposure experiment on the effects of sonar on the foraging behavior of three species of lunge filter feeders (i.e., blue, fin, and humpback whales). Humpbacks decreased lunge rate more than blue or fin whales, which did not differ significantly from controls. However, data from humpbacks was collected at higher received levels (3S project, Norway, towed sonar array, 3–4 kHz, 30 minutes) than blue and fin whales (SOCAL-BRS project, California, floating sonar source, 1–2 Hz, 10 minutes). It is difficult to determine if the variation in species' behavioral response was due to received level, location, species, project, sonar source type, sonar frequency content, sonar duration, etc.

Hermannsen et al. (2019) estimated that noise in the 16 kHz frequency band resulting from small recreational vessels not equipped with AIS and therefore not included in most vessel noise impact models could be elevated up to 124 dB re 1 µPa and raise ambient levels up to 51 dB; these higher levels were associated with vessel speed and range. Using the threshold levels found by Dyndo et al. (2015) and Wisniewska et al. (2018), these authors determined that recreational vessel noise in the 16 kHz band could cause behavioral responses in harbor porpoises, and that those thresholds were exceeded by 49–85 percent of high noise events.

Isojunno et al. (2020) exposed sperm whales (*Physeter macrocephalus*) to pulsed low-frequency active sonar (LFAS) at moderate source levels and high source levels, as well as continuous LFAS at moderate levels for which the summed energy (SEL) equaled the summed energy of the high source level pulsed LFAS. Foraging behavior did not change during exposures to moderate source level LFAS, but non-foraging behavior increased during exposures to high source level LFAS and to the continuous LFAS, indicating that the energy of the sound (the sound exposure level)

was a better predictor of response than SPL. However, the time of day of the exposure was also an important covariate in determining the amount of non-foraging behavior, as were order effects (e.g., the SEL of the previous exposure).

Kastelein et al. (2019a) examined the potential masking effect of high sea state ambient noise on captive harbor porpoise perception of and response to high duty cycle playbacks of AN/SQS-53C sonar signals by observing their respiration rates. Results indicated that sonar signals were not masked by the high sea state noise and received levels at which responses were observed were similar to those observed in prior studies of harbor porpoise behavior.

Kavanagh et al. (2019) analyzed over 8,000 hours of cetacean survey data for multiple species and habitats. Sighting rates of several baleen and toothed whales found in waters off the UK were compared on regular vessel surveys versus both active and passive periods of seismic surveys. Models of sighting numbers were developed, and it was determined that baleen whale sightings were reduced by about 88% during active and inactive phases of seismic surveys, compared to regular surveys, while toothed whale sightings were reduced by 53% and 29%, respectively. These results seemed to occur regardless of geographic location of the survey; however, when only comparing active vs inactive periods of seismic surveys the geographic location did seem to effect the change in sighting rates.

Mikkelsen et al. (2019) used long-term biologgers (DTAGs) on harbor seals and grey seals (*Halichoerus grypus*) to opportunistically examine natural behaviors including reactions to vessel noise. The data showed that seals were exposed to vessel noise between 2.2 and 20.5 percent of their time in water. The authors describe seal behavior in general and highlight examples of instances where it appeared that seals deviated from their behavior in response to vessels. These disturbances included interruption of resting and foraging behaviors, which could have energetic consequences for individuals and populations. This observational study supports previous findings with regards to seal behavior and demonstrates the potential uses of multi-week, high-temporal resolution biologgers for studies of marine mammal behavior, including responses to noise, in natural contexts.

Niu et al. (2020) exposed captive bottlenose dolphins to pulsed and continuous tonal signals to investigate acoustic deterrence. For all test frequencies, the dolphins increased surfacing distance relative to transducer, surfaced more often, and reduced clicks compared to baseline. Although some acclimatization was observed during daily tests, no habituation was observed over the full duration of the studies.

Omeyer et al. (2020) tested a 50–120 kHz pinger near harbor porpoise and found a 37 percent reduction in detections at the recorder near the pinger, but only a 9 percent reduction at a recorder 100 m away, indicating a response only occurred in relatively close proximity to the pinger. While clicking returned to normal levels as soon as the pinger was shut off (implying no long term displacement), the response to the active pinger remained consistent over the 9 month study period, indicating no habituation occurred and the pingers remained an effective deterrent.

Sarnocińska et al. (2020) placed C-Pod recorders at nine stations (seven near oil and gas platforms and two reference stations 15 km away) to detect harbor porpoise clicks and buzzes within about 100 m. Recordings made when an active seismic vessel was within 20 km were analyzed to count minutes with clicks and buzzes, and these detections were compared before/during/after each survey as well as against the control station data. A dose-response effect was detected with the lowest amount of porpoise activity closest to the seismic vessel and then increasing porpoise activity out to 8–12 km, outside of which levels were similar to baseline. The lowest amount of porpoise activity occurred at SEL (single shot) = 155 dB re 1 µPa2-s, although the distance to the seismic vessel was a better model predictor of porpoise activity than sound level. Despite these smaller scale responses, a large scale response was not detected, with overall porpoise activity in the seismic area similar to that at the control stations; this may indicate that the porpoises were moving around the seismic area to avoid the ship, but not leaving the area entirely.

Schuler et al. (2019) investigated the behavior of humpback whales in response to whale-watching ships in Alaska and found that more time spent near the tour boats increased humpback respiration rates, swim speed, and non-

linear movement. In addition, while foraging and travel behavior states were likely to be maintained in the presence of tourist vessels, surface active behavior was more likely to transition to travel.

Szesciorka et al. (2019) observed the behavioral response of a tagged, female blue whale to an approaching large commercial ship in Southern California. The whale turned around mid-ascent (57.5 m deep) and descended perpendicular to an approaching ship's path. The ambient noise in the area (125–130 dB re 1 µPa) showed a rapid increase in energy at frequencies above 1 kHz with the ship's approach. At the ship's closest point of approach (100 m distance, 135 dB re 1 µPa), the whale quickly rolled left and arrived at 57.5 m depth. After the ship passed, the whale ascended to the surface again with a 3-minute delay. While this whale was exposed to MFAS (3–4 kHz) 62 minutes prior to the large ship encounter, the whale still responded to ship noise only 10 dB above ambient noise levels.

Varghese et al. (2020) analyzed group vocal periods from Cuvier’s beaked whales during multibeam echosounder (MBES, 12 kHz center frequency) activity recorded in the Southern California Antisubmarine Warfare Range. No clear evidence of behavioral response due to MBES was found, and the whales did not leave the range or cease foraging. These results are in contrast to previous work, where beaked whales reduced foraging or left the area in response to MFAS (1–10 kHz center frequency).

PHYSIOLOGICAL STRESS

Houser et al. (2020) measured the stress hormones cortisol and epinephrine in bottlenose dolphins exposed to simulated U.S. Navy mid-frequency sonar and did not find an increase from baseline or control levels. This study is the same as Houser et. al. (2013), which reports that the frequency and severity of behavioral responses obtained during the test procedure increased with increasing received SPLs. However, the predicted physiological endocrine stress response was not found to correlate with SPL, suggesting that behavioral reactions are not necessarily indicative of a physiological stress response.

STRANDING

De Soto et al. (2020) analyzed biologging data from pairs of Blainville's (*Mesoplodon densirostris*) and Cuvier's beaked whales and found deep-dive and foraging synchrony. Based on the evidence collected in this study and a larger body of biological information, the authors concluded that synchronized, diving and vocal behavior evolved to reduce the threat of killer whale predation. The data in this study provided two lines of evidence supporting predator-avoidance as an evolutionary driver of beaked whale dive behavior: 1) beaked whales ascended from deep-dives at a shallower angle than other deep-diving species, creating a larger search area for predators, and 2) beaked whales surfaced in an unpredictable direction based on behavior at depth. The authors argued that extreme predator-avoidance behavior has become maladaptive because whales would potentially exhibit adverse reactions to “predator-like" sounds such as sonar. Overall, the body of scientific literature suggests that behavioral reactions at depth may result in fewer foraging opportunities, reduced individual and/or group fitness, and possibly stranding events in beaked whales.

Granger et al. (2020) conducted a preliminary meta-analysis of stranding data which suggests that disruption in magnetoreception in gray whales is linked to solar activity and live strandings. However further research is needed to determine the mechanism for increases strandings under high RF-noise. This paper largely draws out the methodology for future stranding investigations.

Moore et al. (2020) reviews the various factors that can complicate the assessment of a marine mammal carcasses cause of death, such as decomposition, buoyancy, oceanic conditions, and environmental mechanical damage.

Simonis et al. (2020) relied on substantially incomplete or inaccurate assumptions about U.S. Navy sonar use around the Mariana Islands (i.e., publicly available press releases and news reports about named Navy activities, which may or may not have involved sonar, rather than actual records of sonar use) to find that beaked whale strandings were

significantly correlated to sonar use in the Mariana Islands. The authors determined that statistically there is a 1 percent chance that three of eight beaked whale stranding events would occur by chance within 6 days of MFAS operations; therefore, there was a high probability that the Mariana strandings were associated with the use of MFAS. In response to the preliminary analysis of Simonis et al., the Navy provided additional information to the researchers indicating that the assumptions about sonar use in their analysis were incorrect or incomplete; therefore, their published findings were not valid. In discussions with NMFS following Simonis et al.'s findings, including NMFS researchers who participated in Simonis et al.'s study, the Navy agreed to examine the classified sonar record around the Mariana Islands for correlation with beaked whale strandings. The Center for Naval Analysis conducted a statistical study of correlation of beaked whale strandings around the Mariana Islands with the use of U.S. Navy sonar, and found that no statistically significant correlation exists (Center for Naval Analysis, 2020). The Center for Naval Analysis study used the complete classified record of all U.S. Navy sonar used between 2007 and 2019, including major training events, joint exercises, and unit level training/testing. Sonar sources in this record conservatively included both hull-mounted and non-hull-mounted sources, rather than solely hull-mounted sources (which have been previously associated with a limited number of beaked whale strandings). The analysis also included the complete beaked whale stranding record for the Mariana Islands through 2019. Following the methods in Simonis et al. (2020), the Center for Naval Analysis conducted a Poisson distribution analysis and found no statistically significant correlation between sonar use and beaked whale strandings when considering the complete sonar use record. The unclassified summary of the Center for Naval Analysis's study was provided to NMFS and their scientists.

POPULATION CONSEQUENCES OF DISTURBANCE AND CUMULATIVE STRESSORS

Balmer et al. (2019) performed a case study of a single adult male bottlenose dolphin, who was captured, tagged, and released. This individual exhibited long-term site fidelity to estuaries in southern Georgia, and had anemia, which the authors suggest is likely due to site-specific contaminants (polychlorinated biphenyls) in the area.

Booth (2019) and Kastelein et al. (2019b) investigated the potential consequences of fasting for harbor porpoises because their high metabolic rate may leave them especially vulnerable to disturbances that prevent them from feeding. Kastelein and colleagues used an opportunistic experimental approach whereby four stranded wild harbor porpoises were able to consume 85–100 percent of their daily food mass intake in a short time period. Similarly, using a modelled approach, Booth (2019) found that harbor porpoises are capable of recovering from lost foraging opportunities, largely because of their varied diet, high foraging rates, and high prey capture success.

Booth et al. (2020) reviewed a range of methods used to monitor populations of cetaceans and pinnipeds that are subject to disturbance and identified current knowledge gaps in the PCOD modelling process. Demographic characteristics like the ratio of calves to mature females and the proportion of immature animals in the population were assessed as response variables that may provide an early warning of population decline with three representative species (harbor porpoises, bottlenose dolphins, and Blainville's beaked whales). In addition, uncertainty, population structure, sampling scale, natural variation, and uncertainty should be considered when designing an effective monitoring program.

Derous et al. (2020) proposed that blubber thickness, which has been used to measure cetacean energy stores and health, is not appropriate for use in PCOD models because marine mammals may not use their fat stores in a similar manner to terrestrial mammals. These results may be useful in the development of future Population Consequences of Multiple Stressors (PCoMS) and PCOD models since they should attempt to qualify cetacean health in a more ecologically relevant manner.

Griffiths et al. (2020) used random forest cluster modeling for assigning species to narrow-band high frequency clicks detected by drifting recorders along the California Current. The classification model correctly assigned 97 percent of clicks to their correct cluster: Dall's porpoise (*Phocoenoides dalli*), dwarf sperm whale *(Koia sima*)*,* and pygmy sperm whale (*Kogia breviceps*). The results suggest that dwarf and pygmy sperm whale (*Kogia*) click parameters such as

peak frequency and shoulder frequency vary more than previously thought. These variations likely reflect behavioral or environmental conditions and/or biological variation in click production by *Kogia*. The authors note that this variability necessitates flexible spectral templates when classifying clicks, and this work has applications for studying species population density by passive acoustic methods.

Hin et al. (2019) looked at the impacts of disturbance on long-finned pilot whales (*Globicephala melas*) and found that the timing of the disturbance with seasonally available resources is important. If a disturbance occurred during periods of low resource availability, the population-level consequences were greater than if the disturbance occurred during periods when resource levels were high.

CONCLUSIONS

The new and relevant scientific literature reviewed in this chapter largely supports the Navy's analysis conducted in the 2018 AFTT and HSTT Final EIS/OEIS, ROD, and 2019 SIR.

For masking, three new publications suggest that the effect of masking on marine mammals is reduced by spatial separation between signal and noise, directional hearing, and behavioral strategies. New publications on TTS and PTS support the Navy's marine mammal auditory weighting functions and their use in predicting TTS and PTS. Numerous new literature on behavioral reactions provide detailed descriptions of marine mammal species' reactions to various stressors. A single new publication on physiological stress challenges the assumption that behavioral reactions are indicative of a stress response. New information about strandings highlight the difficulty in determining the underlying causes of stranding events, and a new publication erroneously associated naval sonar with stranding in the Mariana Islands (Simonis et al., 2020). Finally, new literature on PCOD and cumulative stressors suggests that while some marine mammals may be able to recover from missed feeding opportunities, the timing of disturbance and factors such as site fidelity can increase the effect of cumulative stressors.

In conclusion, there is no new and relevant scientific literature found in this review that would substantially change the Navy's analysis and conclusions in the 2018 AFTT and HSTT Final EIS/OEISs.

MITIGATION TECHNOLOGY

This chapter contains a summary of new scientific information pertaining to mitigation technology relevant to acoustic stressors analyzed in the 2018 AFTT and HSTT Final EIS/OEIS and 2019 SIR. This chapter also presents the Navy's determination if this new information supports the analysis contained in the 2018 Final EIS/OEISs.

Mingozzi et al. (2020) described the use of X-band radar instruments for marine mammal monitoring. A preliminary pilot experiment in the Mediterranean Sea indicated that X-band radar instruments, which allow for continuous observation of the sea surface within a certain range from the radar antenna, were able to detect bottlenose dolphins during optimal weather and sea state conditions. Detections by radar were generally limited by conditions such as waves, which did not allow for the correct identification of small targets, and rain, which masked the radar signal reflection and reduced the ability to detect targets. The pilot experiment used a manual approach to observe for and validate radar detections; however, future technological developments could potentially allow for automated marine mammal observation using X-band radar.

Smith et al. (2020) found that overall marine mammal detection rates increased when complementary methods (marine mammal observers, infrared cameras, and passive acoustic monitoring) were used. The study determined that a combination of techniques balances the benefits and limitations of each method, particularly in conditions such as high sea state and low visibility.

Verfuss et al. (2018) determined that based on the science of current thermal detection system technologies, the combined performance of two or more observation methods would improve detection probability for real-time

monitoring of marine mammals. The study also showed that thermal detection systems are generally thought to be most effective in detecting large, short-diving marine mammals in cold environments where there is a large temperature differential between an animal's temperature and the environment.

Current thermal detection systems have proven more effective at perceiving thermal anomalies as distance to the observer decreases. Zitterbart et al. (2020) found that certain cues, such as those caused by the displacement of relatively large amounts of water (e.g., whale breaches) were less affected by distance than other cues (e.g., whale blows) that showed a linear decay related to the effects of wind on thermal perceptibility. The study also found that the maximum thermal perceptibility distance ranged from < 1 to 10 kilometers, depending on factors such as cue type, species, and observation location. Maximum false positive rates were greater than 30 or 50 per hour, depending on observation location.

CONCLUSIONS

The new and relevant scientific literature reviewed in this chapter supports the Navy's analysis conducted in the 2018 AFTT and HSTT Final EIS/OEISs. New publications on marine mammal mitigation technology, such as thermal detection and radar systems, as well as research on the use of these technologies in combination with traditional visual observation techniques, is generally consistent with the Navy's mitigation assessments and conclusions presented in those documents.

METHODOLOGY FOR ASSESSING ACOUSTIC IMPACTS

This chapter contains a summary of scientific information pertaining to methodology for assessing acoustic stressors that are relevant to the analysis presented in the 2018 AFTT and HSTT Final EIS/OEIS and 2019 SIR. New best available science was found concerning take estimation, quantifying impulsive sound, estimating acoustic dose, and other topics. This chapter also presents the Navy's determination if this new information supports the analysis contained in the 2018 Final EIS/OEISs.

Carlson et al. (2019) summarized methods for estimating salmon take as a result of exposure to confined underwater rock blasting in a river. The general methodology described by the authors follow similarly established predictive take models that utilize sound source measurements, dose response criteria, and estimated species abundance within a given environment. In this particular case, the source level of the underwater blasts was unavailable and therefore estimates were used in place of actual measurements. In addition, species abundance was estimated during monitoring efforts. Although this method proved valuable for the applicants and allowed them to estimate fish mortality take for the proposed activity, the authors acknowledge that this specific method may only be appropriate when estimating take for similar actions and in a similar environment.

Hastie et al. (2019) recorded acoustic signals produced by air gun arrays and pile driving at different ranges from the source to describe how impulsive characteristics (rise time, pulse duration, peak pressure, and crest factor) change with distance. All metrics showed a clear relationship with source range except for crest factor, which was a poor metric of impulsivity, and impulsive characteristics underwent the most change in the 0.5–10 km range, after which they plateaued. This study provides support for the conclusion that the quotient of peak pressure and signal duration exceeds 5,000 Pa/s in the 2–3 km range, but the authors suggest that more research be conducted to determine whether the quotient of these metrics is biologically meaningful (i.e., relationship to TTS).

Lucke et al. (2020) computed received levels of single air gun impulses by a harbor porpoise from a previous masked TTS study (Lucke et al., 2009) to determine whether existing international criteria appropriately estimated the risk of producing TTS in that case. The previous study used AEP methods to determine hearing thresholds and measure TTS after single air gun impulses. The analysis presented in the paper showed that there were four instances out of nineteen where TTS was induced in the harbor porpoise at received levels below recent frequency-weighted criteria (Finneran, 2016) for high frequency cetaceans. The criteria from Southall (2007) and Finneran (2016) showed fewer

instances of exceedance than the German and New Zealand criteria. However, the results rely on data collected using AEP methodology rather than behavioral methods and used only one test subject. Furthermore, all of those instances occurred in a six-day time window at the end of a five-month long study period where the subject had been exposed to progressively higher SPLs. The exceedance instances in question were derived from data obtained from high-level exposures that occurred every other day. Considering the potential for complex interactions between timing of exposures and recovery as well as methodological limitations, this paper is interpreted cautiously.

Martin et al. (2020) addressed the problem of how to quantify whether a sound is impulsive or non-impulsive. This study compared kurtosis, crest factor, and the Harris impulse factor, and found kurtosis to be the best metric for quantifying impulsiveness. A kurtosis value greater than 40 indicates that a sound is impulsive. The authors argue that, although impulsive sounds become non-impulsive as they spread away from the source, this transition point is not relevant for assessing hearing injury because sounds remain impulsive when SPLs are above the effective quiet threshold. However, the authors also note that a majority of sounds from vessels could be classified as impulsive if weighted for the very-high frequency (VHF) hearing group. Finally, the authors conclude that an impulsiveness corrected SEL metric be developed in order to better describe the effect of anthropogenic noise on marine mammals; but this requires a better understanding of the biological relevance of kurtosis as an indicator for impulsiveness.

McQueen et al. (2020) presented a framework for assessing the effects of underwater sounds from dredging operations. Dredging produces underwater sounds that vary substantially depending on the exact type of activity, the substrate type, bathymetry, and other factors. The method presented by the authors encourages the use of site and project specific information, along with simple sound propagation models, and published marine resource-specific effects thresholds, in order to assess risk more efficiently and transparently for species of concern. This framework applies the concepts largely developed by NMFS and the Navy, and this publication serves as a roadmap for how to assess and manage risks to marine resources associated with underwater dredging.

Popper et al. (2020, In Press) briefly reviewed and provided an opinion about the state of existing research on the impacts of underwater sound on marine life. In their review, they note the need for a more focused investigation of sound impacts as it relates to the animal. Specifically, research is needed to establish species specific risk assessments in order to better develop management and mitigation measures as it is apparent that not all effects from sound exposure would necessarily result in an impact to an animal. For example, where a sound source does not appear to impact the survivability or fitness of an animal, legislation/regulations should not be created for that source. Furthermore, it is difficult to extrapolate impacts from individual sound exposures to larger population level impacts. A vast majority of current research is focused on marine mammals and ignores larger marine biomasses (fishes and invertebrates). The authors recommend that researchers and regulators work collaboratively to ensure funding is focused on the right questions to better develop meaningful mitigations and regulations.

von Benda-Beckmann et al. (2019) addressed the problem of estimating received acoustic dose from satellite tags and fixed long-term acoustic recorders, especially in behavioral response studies. Predictions currently rely on propagation modeling and low-resolution spatial data from these types of recorders, but the authors argue that these estimations of acoustic dose diminish the ability to establish dose-response curves for sonar. The authors presented a method for estimating uncertainty to produce a range of sound levels that might be received by an animal. Large uncertainties with regard to satellite-tagged animal depth limited prediction of acoustic dose. The authors propose the development of on-board processors to measure acoustic dose and recommend measuring sound speed profiles in areas of interest to sample the environment and improve modeling accuracy.

Whyte et al. (2020) used previously collected data from 24 tagged harbor seals near a pile-driving site in order to model sound exposure levels and seal density. The authors found relatively large differences in predicted TTS and PTS depending on the weighting functions and thresholds used. They also showed that estimated seal densities differed depending on how water depth and other factors were incorporated into the estimates. The authors recommend using annulus zones rather than cumulative zones for estimating single strike SEL because this resulted in more conservative values. Based on the different results produced by different modeling approaches, and

variation associated with different weighting functions, the authors caution that predicting auditory damage and impacts to population-level distributions is subject to inherent limitations.

CONCLUSIONS

The new and relevant scientific literature reviewed in this chapter present new perspectives and methods that do not necessarily support or contradict the Navy's analysis conducted in the 2018 AFTT and HSTT Final EIS/OEIS, and their associated RODs.

The possibility that vessel noise could be considered impulsive when weighted for VHF cetaceans proposed by Martin et al. (2020) would potentially change how future analyses describe the impact of vessel noise on this hearing group. However, this is based on extensive modeling, and the authors acknowledge that a better understanding of the biological relevance of kurtosis as an impulsiveness metric is required.

The difficulty in estimating received acoustic dose from satellite tagged animals highlighted by Von Benda-Beckmann et al. (2019) should be considered in future efforts to estimate uncertainty in behavioral response functions. While this research proposes better technology to address this issue, this new research does not change the Navy's analysis.

In conclusion, the new scientific literature presented in this chapter is pertinent for developing future analytical methods but does not present any necessary changes to the Navy's analysis conducted in the 2018 AFTT and HSTT Final EIS/OEISs.

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