2 August 2017

Naval Facilities Engineering Command, Atlantic
Attn: AFTT EIS Project Managers, Code EV22KP
6506 Hampton Boulevard
Norfolk, VA 23508-1278

Dear Sir or Madam:

The Marine Mammal Commission (the Commission), in consultation with its Committee of Scientific Advisors on Marine Mammals, has reviewed the U.S. Navy's (the Navy) Draft Environmental Impact Statement/Overseas Environmental Impact Statement (DEIS) for training and research, development, test, and evaluation (testing) activities conducted within the Atlantic Fleet Training and Testing (AFTT) study area (Phase III; 82 Fed. Reg. 29855). The DEIS addresses the impacts on marine mammals from conducting training and testing activities in the AFTT study area and is associated with the letter of authorization (LOA) application that the Navy will submit to the National Marine Fisheries Service (NMFS). The Navy previously analyzed the various impacts, first under the Tactical Training Theater Assessment and Planning DEISs (TAP I) and second under Phase II DEISs.

Background

The Navy's AFTT study area is in the western Atlantic Ocean and encompasses the waters along the east coast of North America, the Gulf of Mexico, portions of the Caribbean Sea, Navy pierside locations and port transit channels, waters near civilian ports, and in bays, harbors, and inland waters (i.e., lower Chesapeake Bay). The activities would involve the use of low-, mid-, high- and very high-frequency active sonar, weapons systems, explosive and non-explosive practice munitions and ordnance, high-explosive underwater detonations (including ship shock trials), expended materials, vibratory and impact hammers, airguns, electromagnetic devices, high-energy lasers, vessels, underwater vehicles, and aircraft. Under the No Action Alternative, the Navy would not conduct training or testing activities[1]. Alternative 1, the Preferred Alternative, includes a representative number of training and testing activities; whereas, Alternative 2 includes the maximum number of training and testing activities. In addition to a few time-area closures, mitigation measures would include visual monitoring[2] to implement delay and shut-down procedures.

[1] The Commission appreciates that the Navy included this alternative consistent with DEISs for the Navy's Surveillance Towed Array Sensor System Low Frequency Active (SURTASS) sonar and the Commission's previous recommendations.
[2] Passive acoustic monitoring would be required only for sinking exercises, explosive sonobuoys, and explosive torpedoes.

Density estimates

The Commission had recommended in previous letters regarding Navy Phase II activities that the Navy incorporate more refined data in its extrapolated density estimates, primarily with regard to pinnipeds. For Phase III activities the Navy used density data from both Roberts et al. (2016) and Mannocci et al. (2017)—the latter provided densities for a large region of the western North Atlantic sparsely surveyed for cetaceans. Specifically, Mannocci et al. (2017) utilized generalized additive models with various environmental covariates[3] and reduced the extent of extrapolation beyond the covariate ranges based on methods by Miller et al. (2013)[4]. The Commission is pleased that the Navy has incorporated more refined density estimation methods in its Phase III documents and hopes such methods are used for the other Navy study areas as well.

The Commission also had recommended that the Navy account for uncertainty in its extrapolated[5] density estimates for Phase II activities. For AFTT Phase III activities, the Navy incorporated uncertainty for both the density and group size estimates[6] that seeded its animat modeling. The Commission again appreciates that the Navy incorporated uncertainty both in the density and group size estimates and expects that comparable methods will be used for the other Navy study areas. The Commission notes that 30 iterations or Monte Carlo simulations is low for general bootstrapping methods but understands that increasing the number of iterations in turn increases the computational time needed to run the models. Accordingly, the Commission suggests that, if the computation time is not overly burdensome, the Navy consider increasing the iterations from 30 to at least 200 for activities that have yet to be modeled for Phase III and for all activities in Phase IV.

Probability of strike

The Navy estimated the probabilities of expended munitions and non-explosive materials (e.g., missiles, bombs, other projectiles, sonobuoys, anchors, etc.) striking a marine mammal based on simple probability calculations (Appendix F of its DEIS). In doing so, the Navy compared the aggregated footprint of six specific marine mammal species with the footprint of all objects that might strike them. Both of those were based only on densities of marine mammals in the action area and expected amount of materials to be expended within a year in those areas. That method, as the Commission had commented on for the Navy's Phase II DEISs, is coarse and unrealistic.

To provide a more reliable estimate of possible takes from munitions and other expended materials, the Navy should incorporate spatial and temporal considerations in its calculations. For example, the Navy's model for determining takes of marine mammals from sound-producing activities accounts for the movement of sound sources and marine mammals. Using that model to estimate the probability of strike, the Navy could change the data collected by the animat dosimeters from a received sound level to a close approach distance, which would result in more realistic strike probabilities. The probability of direct strike is invariably quite low. However, if the Navy intends to

---

[3] Namely, biomass and production of epipelagic micronekton and zooplankton.
[4] Which use spatial modeling techniques to quantify uncertainty and to incorporate data smoothing in areas with complex boundaries.
[5] Specifically, those estimates that originated from other areas or regions that were applied directly to the various action areas.
[6] Using means and standard deviations that varied based on a compound Poisson-gamma distribution for densities and an inverse Gaussian distribution for group sizes.

estimate the numbers of marine mammals that could be struck by a munition or other expended material, it should do so in a more realistic and accurate manner. Therefore, the Commission again recommends that the Navy use its spatially and temporally dynamic simulation models (e.g., randomly-generated munition trajectories and animat simulations) rather than simple probability calculations to estimate strike probabilities and number of takes from expended munitions and non-explosive materials.

Criteria and thresholds

As the Commission has articulated in letters related to NMFS's Technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing: Underwater acoustic thresholds for onset of permanent and temporary threshold shifts (PTS and TTS, respectively; NMFS 2016), the Commission supports the weighting functions and associated thresholds as stipulated in Finneran (2016), which are the same as were used for Navy Phase III activities (Department of the Navy 2017). However, one new study on marine mammal hearing has published since Finneran (2016) was finalized. Branstetter et al. (2017) measured behavioral audiograms of eight captive killer whales, two of which had apparent age-related hearing loss. The six other audiograms could supplement the current composite audiogram[7] for mid-frequency cetaceans (MF). The addition of those audiograms could affect the composite audiograms, weighting functions, and/or weighted thresholds for MF and the other functional hearing groups[8]. As such, the Commission recommends that the Navy review Branstetter et al. (2017) and determine whether inclusion of the killer whale audiogram data would alter the composite audiograms, weighting functions, and/or weighted thresholds for the various functional hearing groups and if so, whether those modifications are sufficient to warrant revision of the current weighting functions and associated thresholds as stipulated in Department of the Navy (2017).

To further define its behavior thresholds for non-impulsive sources[9], the Navy developed multiple[10] Bayesian biphasic dose response functions[11] (Bayesian BRFs) for Phase III activities. The Bayesian BRFs were a generalization of the monophasic functions previously developed[12] and applied to behavioral response data[13] (see Department of the Navy 2017 for specifics). The biphasic portions of the functions are intended to describe both level- and context-based responses as proposed in Ellison et al. (2011). At higher amplitudes, a level-based response relates the received sound level to the probability of a behavioral response; whereas, at lower amplitudes, sound can cue the presence, proximity, and approach of a sound source and stimulate a context-based response

[7] Composite audiograms were based only on behavioral data, not auditory evoked potential data (Finneran 2016, NMFS 2016, Department of the Navy 2017).
[8] Specifically, those changes could affect the composite audiograms, weighting functions, and thus weighted thresholds at the various frequencies for MF and low-frequency cetaceans. The weighting functions (due to a possible change in ΔT) and resulting weighted thresholds at the various frequencies for high-frequency cetaceans, phocids, and otariids could be affected as well. The absolute weighted thresholds should not change.
[9] Acoustic sources (i.e., sonars and other transducers).
[10] For odontocetes, mysticetes, beaked whales, and pinnipeds. The Navy used the 120-dB re 1 μPa unweighted, step-function threshold for harbor porpoises as it had done for Phase II activities.
[11] Comprising two truncated cumulative normal distribution functions with separate mean and standard deviation values, as well as upper and lower bounds. The model was fitted to data using the Markov Chain Monte Carlo algorithm.
[12] By Antunes et al. (2014) and Miller et al. (2014).
[13] From both wild and captive animals.

based on factors other than received sound level[14]. The Bayesian BRFs are reasonable and a much needed improvement on the Navy's two dose response functions (BRFs)[15] that it had used both for TAP I and Phase II activities.

However, the Navy then decided to implement various cut-off distances beyond which it considered the potential for significant behavioral responses to be unlikely (Table C.4 in Department of the Navy 2017). The Navy indicated it was likely that the context of the exposure is more important than the amplitude at large distances[16]—that is, the context-based response dominates the level-based response. The Commission agrees and notes that, although an important contextual factor is the distance between the animal and the sound source, those factors already have been included in the Bayesian BRFs. Including additional cut-off distances contradicts the underlying data of those functions and negates the intent of the functions themselves. The actual cut-off distances used by the Navy also appear to be unsubstantiated. For example, the Navy indicated there are limited data on pinniped behavioral responses in general, and a total lack of data beyond 3 km from the source. However, the Navy set the cut-off distance at 5 and 10 km depending on the source. For harbor porpoises, the Navy indicated that no data were available on the response distances to sonar or other transducers, so it based the cut-off distances on responses to pile-driving activities. The Commission disagrees with that choice, given that pile-driving activities are an impulsive rather than non-impulsive source.

More concerning is the fact that, depending on the activity and species, the cut-off distances could effectively eliminate a large portion of the estimated numbers of takes. For sonar bin MF1 (the most powerful mid-frequency active sonars), the estimated numbers of takes would be reduced to zero for odontocetes beginning where the probability of response is 29 percent, for pinnipeds where the probability of response is 27 percent, and for harbor porpoises where the probability of response is 100 percent (Table 3.7-11 in the DEIS). For harbor porpoises, the cut-off distances for MF1 sources would equate to a received level of up to 136 dB re 1 μPa, which is considerably greater the 120-dB re 1 μPa threshold. On a related note, takes for mysticetes would be eliminated for MF1 sources at a received level of 148 dB re 1 μPa equating to a probability of response of 14 percent. That percentage may seem inconsequential but that received level is greater than where actual context-based behavioral responses were observed for feeding blue whales (see Figure 3 in Goldbogen et al. 2013[17]). For all of these reasons, the Commission recommends that the Navy refrain from using cut-off distances in conjunction with the Bayesian BRFs and re-estimate the numbers of marine mammal takes based solely on the Bayesian BRFs. Use of cut-off distances could be perceived as an attempt to reduce the numbers of takes, which is discussed in a subsequent section of this letter.

For behavior thresholds for explosives, the Navy assumed a threshold 5 dB less than the TTS thresholds for each functional hearing group. That value was derived from observed onset

[14] e.g., the animal's previous experience, separation distance between sound source and animal, and behavioral state including feeding, traveling, etc.
[15] One for odontocetes and pinnpeds and one for mysticetes.
[16] For example, the Navy indicated that the range to the basement level of 120 dB re 1 μPa for the BRFs from TAP I and Phase II sometimes extended to more than 150 km during activities involving the most powerful sonar sources (e.g., AN/SQS-53).
[17] Data that were used to derive the Bayesian BRFs.

behavioral responses by captive bottlenose dolphins during non-impulsive TTS testing[18] (Schlundt et al. 2000). The justification for that threshold itself is a bit questionable, however, more concerning is the fact that the Navy continues to believe that marine mammals do not exhibit behavioral responses to single detonations (Department of the Navy 2017)[19]. The Navy has asserted that the most likely behavioral response would be a brief alerting or orienting response and significant behavioral reactions would not be expected to occur due to no further detonations following the initial detonation. Although there are no data to substantiate that assumption, the Navy notes that the same reasoning was used in previous ship shock trial final rules in 1998, 2001, and 2008. Without such data, there is no reason to continue to ascribe validity to assumptions made 10 to 20 years ago. Larger single detonations (such as explosive torpedo testing or ship shock trials[20]) would be expected to elicit 'significant behavioral responses'[21] as described in Department of the Navy (2017) and used by the Navy to differentiate behavioral response severity. The Navy provided no justification why it believes that an animal would exhibit a significant behavioral response to two 5-lb charges detonated within a few minutes of each other but would not exhibit a similar response for a single detonation of 50 lbs, let alone detonations of more than 500 and up to 58,000 lbs. Therefore, the Commission recommends that the Navy include behavior takes of marine mammals during *all* explosive activities, including those that involve single detonations.

Further on the topic of explosive thresholds, the Commission notes that the constants and exponents[22] for the impulse metrics regarding both onset mortality and onset slight lung injury for Phase III activities have been amended from those used in TAP I and Phase II activities. The Navy did not stipulate why the constants and exponents have changed while the underlying data[23] remain the same. The modifications yield smaller zones[24] in some instances and larger zones in other instances[25]. These results are counterintuitive since the Navy presumably amended the impulse metrics to account for lung compression with depth, thus the zones would be expected to be smaller rather than larger the deeper the animal dives. The Commission recommends that the Navy (1) specify why the constants and exponents for onset mortality and onset slight lung injury thresholds[26] for Phase III have been amended, (2) ensure that the modified equations are correct, and (3) specify whether any additional assumptions were made.

More importantly, the Navy only used the onset mortality and onset slight lung injury criteria to determine the range to effects[27]. It used the 50 percent mortality and 50 percent slight lung injury criteria to estimate the numbers of marine mammal takes[28]. That approach is inconsistent with the manner in which the Navy estimated the numbers of takes for PTS, TTS, and behavior for explosive activities. All of those takes have been and continue to be based on onset, not 50-percent values.

---

[18] Based on 1-sec tones.
[19] Including certain gunnery exercises that have several detonations of small munitions occurring within a few seconds.
[20] With net explosive weights of 500 to 650 lbs (Bin E11) and 7,250 to 58,000 lbs (Bins E16 and 17), respectively.
[21] Including the animals (1) altering their migration path, speed and heading, diving behavior; (2) stopping or altering feeding, breeding, nursing, resting, or vocalization behavior; (3) avoiding the area near the source; or (4) displaying aggression or annoyance (e.g., tail slapping).
[22] The constants have increased and the exponents have decreased from 1/2 to 1/6.
[23] Based on Richmond et al. (1973), Yelverton et al. (1973), Yelverton and Richmond (1981), and Goertner (1982).
[24] When animals occur at a depth between the surface and 8 m, yielding greater absolute thresholds.
[25] When animals occur at depths deeper than 8 m, yielding lesser absolute thresholds.
[26] Equations 11 and 12 in Department of the Navy (2017).
[27] To inform the mitigation zones.
[28] A similar approach was taken for gastrointestinal (GI) tract injuries.

More relevant to this point, multiple common dolphins were killed during one of the Navy's underwater detonation events in March 2011 (Danil and St. Leger 2011). Although the effectiveness of the Navy's mitigation measures[29] has yet to be determined, those circumstances make it clear that the Navy's mitigation measures are not fully effective, especially for explosive activities. Thus, it would be prudent for the Navy to estimate injuries and mortalities based on onset rather than a 50-percent incidence of occurrence. The Navy did indicate that it is reasonable to assume for impact analysis—thus its take estimation process—that extensive lung hemorrhage[30] is a level of injury that would result in wild animal mortality (Department of the Navy 2017). It is unclear why the Navy did not follow through with that premise. The Commission recommends that the Navy use onset mortality, onset slight lung injury, and onset GI tract injury thresholds to estimate both the numbers of marine mammal takes *and* the respective ranges to effect.

Mitigation measures

The Navy's proposed mitigation zones are similar to the zones[31] previously used during Phase II activities and are intended, based on the Phase III DEIS, to avoid the potential for marine mammals to be exposed to levels of sound that could result in injury (i.e., PTS). However, the Phase III proposed mitigation zones would not protect various functional hearing groups[32] from PTS. For example, the mitigation zone for an explosive sonobuoy is 549 m but the PTS zones range from 2,205–3,324 m for HF and 308–1,095 m for LF. Similarly, the mitigation zone for an explosive torpedo is 1,920 m but the PTS zones range from 13,105–14,627 m for HF, 3,133–3,705 m for LF, and 3,072–3,232 for PW. This is further complicated by platforms firing munitions (e.g., for missiles and rockets) at a target that is 28 to 140 km away from the firing platform. An aircraft would clear the target area well before it positions itself at the launch location and launches the missile or rocket. Ships, on the other hand, do not clear the target area before launching the missile or rocket. In either case, marine mammals could be present in the target area at the time of the launch unbeknownst to the Navy.

In addition, the Navy indicated that lookouts would not be 100 percent effective at detecting all species of marine mammals for every activity because of the inherent limitations of observing marine species and because the likelihood of sighting individual animals is largely dependent on observation conditions (e.g., time of day, sea state, mitigation zone size, observation platform). The Commission agrees and has made numerous recommendations to the Navy in previous letters related to the effectiveness of visual monitoring. Since 2010, the Navy has been collaborating with researchers at the University of St. Andrews to study Navy lookout effectiveness. The Navy does not appear to have mentioned that study in its DEIS for Phase III. For its Phase II DEISs, the Navy noted that data that had been collected were not statistically significant. The Commission understands that point but continues to consider the basic information provided by the studies to be useful. In one instance, the marine mammal observers (MMOs) sighted at least three marine mammals at distances of less than 914 m (i.e., within the mitigation zone for mid-frequency active

[29] Which is discussed further herein.
[30] i.e., onset mortality; see Table 4-1 in Department of the Navy (2017).
[31] The Commission appreciates the Navy providing the estimated mean, minimum, and maximum distances for all impact criteria (i.e., behavior, TTS, PTS, onset slight lung injury, onset slight gastrointestinal injury, and onset mortality) for the various proposed activity types and for all functional hearing groups of marine mammals. That approach is consistent with the Commission's recommendations on Phase II activities.
[32] Primarily high- and low-frequency cetaceans (HF and LF, respectively) and phocids (PW).

sonar for cetaceans), which were not sighted by Navy lookouts (Department of the Navy 2012). In other instances, MMOs sighted a group of approximately three dolphins at a distance of 732 m (Department of the Navy 2014a), a group of approximately 20 dolphins at a distance of 759 m (Department of the Navy 2014c), a group of approximately 9 pilot whales at a distance of 383 m (Department of the Navy 2014b), and a small unidentified marine mammal at 733 m (Department of the Navy 2014b)—none of which were documented as having been sighted by the Navy lookouts. Further, MMOs have reported marine mammal sightings not observed by Navy lookouts to the Officer of the Deck, presumably to implement mitigation measures (Department of the Navy 2010). Neither the details regarding those reports nor the raw sightings data were provided to confirm this.

The Commission is not aware of any additional data that have been made available since 2014 but understands that any data that have been collected since then would not be sufficient to conduct a statistical analysis. The Commission recognizes that the study will be very informative once completed but notes that in the interim, the preliminary data do provide an adequate basis for taking a precautionary approach. Accordingly, the Commission continues to believe that rather than simply reducing the size of the zones it plans to monitor, the Navy should supplement its visual monitoring efforts with other monitoring measures. The Navy did propose to supplement visual monitoring with passive acoustic monitoring during three explosive activity types but not during the remaining explosive activities or during low-, mid- and high-frequency active sonar activities. The Navy uses visual, passive acoustic, and active acoustic monitoring (via HF/M3) during SURTASS LFA sonar activities to augment its mitigation efforts over large areas. The Navy indicated in its Phase III DEIS that it is not able to use HF/M3 during training and testing activities due to limitations regarding space, personnel, and the resources needed to design, build, install, and maintain the devices. The Navy however did not specify the limitations for using passive acoustic capabilities (devices and other assets) that prevent it from being able to monitor more than the three activity types. As an example of surmounting presumed difficulties, the Commission suggests that sonobuoys could be deployed with the target in the various target areas prior to the activity for the Navy to better determine whether the target area is clear and remains clear until the munition is launched.

The Navy did indicate that it was continuing to improve its capabilities for using range instrumentation to aid in the passive acoustic detection of marine mammals. For example, at the Southern California Offshore Range, the Pacific Missile Range Facility off Kauai, and the Atlantic Undersea Test and Evaluation Center in the Bahamas, the Navy has capabilities to monitor instrumented ranges in real time or through data recorded by hydrophones. The Commission has supported the use of the instrumented ranges to fulfill mitigation implementation (see the Commission's 16 May 2017 letter). Similar capabilities should be available at the Navy's instrumented Undersea Warfare Training Range (USWTR) off Jacksonville, which is expected to be in use in the next several years.

Given that the effectiveness of Navy lookouts conducting visual monitoring has yet to be determined, the Commission believes that passive or active acoustic monitoring should be used to supplement visual monitoring, especially for activities that could injure or kill marine mammals. Therefore, the Commission again recommends that NMFS require the Navy to use passive and active acoustic monitoring, whenever practicable, to supplement visual monitoring during the implementation of its mitigation measures for all activities that could cause injury or mortality

beyond those explosive activities for which passive acoustic monitoring already was proposed—this includes use of the instrumented USWTR in the coming years.

Level A harassment and mortality takes

The Navy used various post-model analyses for estimating the numbers of marine mammal takes during acoustic and explosive activities that are similar to methods used in its Phase II DEISs. Those analyses effectively reduced the model-estimated numbers of Level A harassment (i.e., PTS and injury) and mortality takes. The analyses were based on (1) animal avoidance, (2) mitigation effectiveness, and (3) cut-off distances. The Commission has discussed the first two aspects at length in letters written for Phase II activities. That information is not repeated herein but should be reviewed in conjunction with this letter (see the Commission's most recent 15 September 2014 letter). The Commission has a few additional comments on those analyses.

For avoidance, the Navy assumed that animals present beyond the range to onset PTS for the first three to four pings are assumed to avoid any additional exposures at levels that could cause PTS. That equated to approximately 5 percent of the total pings or 5 percent of the overall time active; therefore, 95 percent of marine mammals predicted to experience PTS due to sonar and other transducers were instead assumed to experience TTS. That assumption has no scientific basis. Given that sound sources are moving, it may not be until later in an exercise that the animal is close enough to experience PTS and it is those few close pings that contribute to the potential to experience PTS. An animal being beyond the PTS zone initially has no bearing on whether it will come within close range later during an exercise since both sources and animals are moving. In addition, Navy vessels may move faster than the ability of the animals to evacuate the area. The Navy should have been able to query the dosimeters of the animats to verify whether its 5-percent assumption was valid.

Regarding mitigation effectiveness, the Commission notes that the specific mitigation effectiveness scores for the various activities were provided for the Phase II activities. The Navy included more detail regarding how the scores were determined (including species sightability, observation area extent, visibility factors, and whether sound sources were under positive control) but did not specify what the actual scores were for those four factors or the mitigation scores as a whole. In addition, the Navy apparently did not include model-estimated numbers of takes. That lack of information makes it difficult for the Commission and the public to assess the appropriateness of the mitigation scores or their effect on the overall numbers of marine mammal takes. Most importantly, however, the Navy has yet to determine the effectiveness of its mitigation measures, and it is premature to include any related assumptions to reduce the numbers of marine mammal takes.

Although the flaws of the cut-off distances were articulated in a previous section of this letter, it seems apparent that the post-analyses as a whole would underestimate the numbers of Level A harassment and mortality takes despite the lack of a scientific basis for those reductions. Therefore, the Commission again recommends that the Navy (1) provide the total numbers of model-estimated Level A harassment (PTS and slight lung and GI injuries) and mortality takes rather than reduce the estimated numbers of takes based on the Navy's post-model analyses and (2) include the model-estimated Level A harassment and mortality takes in its LOA application to inform NMFS's negligible impact determination analyses.

Pile-driving activities

The Navy did not stipulate whether it estimated the numbers of marine mammal takes during pile-driving activities using the Navy Acoustic Effects Model (NAEMO) or NMFS's user spreadsheet. However, based on the estimated extents of the PTS zones[33], the Navy does not appear to have used NMFS's user spreadsheet. That tool would yield PTS zones[34] that range from 55 to 1,343 m for the various functional hearing groups. In addition, the PTS and TTS zones for LF and HF are estimated to be the same (Table 3.7-19 in the DEIS). Neither NAEMO (based on results for the other broadband sources) nor NMFS's user spreadsheet would yield the exact same ranges for LF and HF. Therefore, the Commission recommends that the Navy (1) specify what modeling method and underlying assumptions were used to estimate the PTS and TTS zones for pile-driving activities and (2) clarify why those zones were estimated to be the same for LF and HF.

Most, if not all, of the Commission's recommendations would apply to the Navy's LOA application as well and should be considered as such. Please contact me if you have questions concerning the Commission's recommendations or rationale.

Sincerely,

Rebecca J. Lent

Rebecca J. Lent, Ph.D.
Executive Director

cc: Jolie Harrison, NMFS

References

Antunes, R., P.H. Kvadsheim, F.P. Lam, P.L. Tyack, L. Thomas, P.J. Wensveen, and P.J. Miller. 2014. High thresholds for avoidance of sonar by free-ranging long-finned pilot whales (*Globicephala melas*). Marine Pollution Bulletin 83(1):165–180.

Branstetter, B.K., J. St. Leger, D. Acton, J. Stewart, D. Houser, J.J. Finneran, and K. Jenkins. 2017. Killer whale (*Orcinus orca*) behavioral audiograms. The Journal of the Acoustical Society of America 141:2387–2398. http://dx.doi.org/10.1121/1.4979116.

Danil, K., and J.A. St. Ledger. 2011. Seabird and dolphin mortality associated with underwater detonation exercises. Marine Technology Society Journal 45(6):63–87.

Department of the Navy. 2010. Appendix C–Cruise report, marine species monitoring and lookout effectiveness study: Submarine Commanders Course, February 2010, Hawaii Range Complex. *in* Marine mammal monitoring for the U.S. Navy's Hawaii Range Complex and Southern California Range Complex Annual Report 2010. Department of the Navy, U.S. Pacific Fleet. 31 pages.

Department of the Navy. 2012. Cruise report, marine species monitoring and lookout effectiveness study: Koa Kai, November 2011, Hawaii Range Complex. *in* Marine species monitoring for

[33] Ranging from 2 to 65 m for the various functional hearing groups.

[34] Assuming six piles would be driven per day with 35 strikes per minute for a total of 15 minutes per pile, a source level of 182 dB re 1 μPa^2-sec, and transmission loss of 16.5 (Sections 3.0.3.3.1.3 and 3.7.3.1.4 of the DEIS).

the U.S. Navy's Hawaii Range Complex 2012 Annual Report. Department of the Navy, U.S. Pacific Fleet, Honolulu, Hawaii. 12 pages.

Department of the Navy. 2014a. Final cruise report, marine species monitoring and lookout effectiveness study: Koa Kai, January 2014, Hawaii Range Complex. Department of the Navy, U.S. Pacific Fleet, Honolulu, Hawaii. 29 pages.

Department of the Navy. 2014b. Final cruise report, marine species monitoring and lookout effectiveness study: Submarine Commanders Course, August 2013, Hawaii Range Complex. Department of the Navy, U.S. Pacific Fleet, Honolulu, Hawaii. 18 pages.

Department of the Navy. 2014c. Final cruise report, marine species monitoring and lookout effectiveness study: Submarine Commanders Course, February 2014, Hawaii Range Complex. Department of the Navy, U.S. Pacific Fleet, Honolulu, Hawaii. 12 pages.

Department of the Navy. 2017. Technical report: Criteria and thresholds for U.S. Navy acoustic and explosive effects analysis (Phase III). SSC Pacific, San Diego, California. 194 pages.

Ellison, W.T., B.L. Southall, C.W. Clark, and A.S. Frankel. 2011. A new context-based approach to assess marine mammal behavioral responses to anthropogenic sounds. Conservation Biology 26(1):21–28.

Finneran, J.J. 2016. Auditory weighting functions and TTS/PTS exposure functions for cetaceans and marine carnivores. May 2016. SSC Pacific, San Diego, California. 73 pages.

Goertner, J.F. 1982. Prediction of underwater explosion safe ranges for sea mammals. Naval Surface Weapons Center, Dahlgren, Virginia. 31 pages.

Goldbogen, J.A., B.L. Southall, S.L. DeRuiter, J. Calambokidis, A.S. Friedlaender, E.L. Hazen, E.A. Falcone, G.S. Schorr, A. Douglas, D.J. Moretti, C. Kyburg, M.F. McKenna, and P.L. Tyack. 2013. Blue whales respond to simulated mid-frequency military sonar. Proceedings of the Royal Society B 280(1765):20130657.

Mannocci, L., J.J. Roberts, D.L. Miller, and P.N. Halpin. 2017. Extrapolating cetacean densities to quantitatively assess human impacts on populations in the high seas. Conservation Biology 31: 601–614. doi:10.1111/cobi.12856

Miller, D.L., M.L. Burt, E.A. Rexstad, and L. Thomas. 2013. Spatial models for distance sampling data: recent developments and future directions. Methods in Ecology and Evolution 4:1001–1010. doi:10.1111/2041-210X.12105

Miller, P.J., R.N. Antunes, P.J. Wensveen, F.I. Samarra, A.C. Alves, P.L. Tyack, P.H. Kvadsheim, L. Kleivane, F.P. Lam, M.A. Ainslie, and L. Thomas. 2014. Dose-response relationships for the onset of avoidance of sonar by free-ranging killer whales. The Journal of Acoustical Society of America 135(2):975–993.

NMFS. 2016. Technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing: Underwater acoustic thresholds for onset of permanent and temporary threshold shifts. Office of Protected Resources, NMFS, Silver Spring, Maryland. NOAA Technical Memorandum NMFS-OPR-55. 178 pages.

Richmond, D.R., J.T. Yelverton, and E.R. Fletcher. 1973. Far-field underwater-blast injuries produced by small charges. Lovelace Foundation for Medical Education and Research, Defense Nuclear Agency, Washington DC. 95 pages.

Roberts, J.J., B.D. Best, L. Mannocci, E. Fujioka, P.N. Halpin, D.L. Palka, L.P. Garrison, K.D. Mullin, T.V.N. Cole, C.B. Khan, W.A. McLellan, D.A. Pabst, and G.G. Lockhart. 2016. Habitat-based cetacean density models for the U.S. Atlantic and Gulf of Mexico. Scientific Reports 6:22615. doi:10.1038/srep22615.

Schlundt, C.E., J.J. Finneran, D.A. Carder, and S.H. Ridgway. 2000. Temporary shift in masked hearing thresholds of bottlenose dolphins, Tursiops truncatus, and white whales,

Delphinapterus leucas, after exposure to intense tones. The Journal of Acoustical Society of America 107(6):3496–3508.

Yelverton, J.T., and D.R. Richmond. 1981. Underwater explosion damage risk criteria for fish, birds, and mammals. Paper presented at the 102nd Meeting of the Acoustical Society of America, Miami Beach, Florida. 35 pages.

Yelverton, J.T., D.R. Richmond, E.R. Fletcher, and R.K. Jones. 1973. Safe distances from underwater explosions for mammals and birds. Lovelace Foundation for Medical Education and Research, Albuquerque, New Mexico. 64 pages.