BEAKED WHALE AND HARBOR PORPOISE MONITORING AND REPORTING REQUIREMENTS

In support of the 2012 Final Rule for SURTASS LFA Sonar

FINAL REPORT

19 July 2017

Executive Summary

The Final Rule authorizing the use of SURTASS LFA sonar under the Marine Mammal Protection Act (MMPA) included a requirement to convene a Scientific Advisory Group (SAG) to analyze monitoring/research that could increase the understanding of the potential effects of low-frequency active sonar transmissions on beaked whales and harbor porpoises (Federal Register 77 (161):50321; 50 CFR §218.235(h)). Following the SAG's submission of findings, the Navy had a reporting requirement to either (1) draft an action plan outlining their strategy for implementing the SAG's recommendations; or (2) describe in writing why none of the SAG's recommendations are feasible and meet with NMFS to discuss any other potential options ((50 CFR §218.236(e)). This report meets that reporting requirement.

The Navy convened the independent SAG, whose purpose was to investigate and assess different types of research and monitoring methods that could increase the understanding of the potential effects to beaked whales and harbor porpoises from exposure to SURTASS LFA sonar transmissions. The SAG was composed of six scientists who are affiliated with two universities, one Federal agency (NMFS), and three private research and consultancy firms. The SAG prepared and submitted a report, *Potential Effects of SURTASS LFA Sonar on Beaked Whales and Harbor Porpoises*, which described their monitoring and research recommendations (available at http://www.surtass-lfa-eis.com/Download/index.htm).

The SAG report was submitted to the Executive Oversight Group (EOG) for discussion and consideration in August 2013. The EOG was comprised of representatives from the U.S. Navy (Chair, OPNAV N2/N6F24; Office of the Deputy Assistant Secretary of the Navy for the Environment; Office of Naval Research; and Navy Living Marine Resources Program) and the NMFS Office of Protected Resources (OPR) (Permits, Conservation, and Education Division). Representatives of the Marine Mammal Commission also attended EOG meetings as observers. The EOG for SURTASS LFA sonar met twice in 2014 to review and further discuss the research recommendations put forth by the SAG, the feasibility of implementing any of the research efforts, and existing budgetary constraints. In addition to the research and monitoring efforts recommended by the SAG, additional promising research/monitoring suggestions were recommended for consideration by the EOG. The EOG provided insights into the most efficacious recommendations given existing budgetary constraints.

This report includes background on the impetus for studying potential behavioral responses to SURTASS LFA sonar, a summary of the SAG's assessment of research questions related to harbor porpoise and beaked whales, and the EOG consideration of research or monitoring priorities. Since the SAG report was completed in August 2013 and the EOG meetings occurred in 2014, a final recommendations section provides updated insights into some of the research recommendations, given progress (or lack thereof) in funded research, as well as a current assessment of the budgetary environment.

One study the EOG highly recommended, and Navy was able to fund, was a study to determine the extent of the geographic overlap between potential SURTASS LFA sonar operations and the distributional range of harbor porpoises. A desktop analysis of the sound field resulting from the use of SURTASS LFA sonar, including the geographic restriction that the sound field not exceed 180 dB re: 1 µPa (rms) at a distance less than 12 nautical miles (nmi) (22 kilometers (km)) from any coastline, including offshore islands ((50 CFR §218.234(f)(i)), was overlaid with the best available information on the spatial distribution of harbor porpoises. The resulting compilation provides useful information that bounds the extent of the potential impacts of SURTASS LFA sonar on harbor porpoises, a species with a known coastal distribution. The results of this study are available in a separate report.

Background

The impetus for investigating the potential effects of SURTASS LFA sonar on beaked whales and harbor porpoise is the result of observations of these taxa behaviorally responding in a more significant manner than other species, and evidence of the strandings of beaked whales associated with noise exposure, almost exclusively with mid-frequency sonar exercises. Since the 2012 Final Rule, several studies have investigated the behavioral response of beaked whales and harbor porpoise to a variety of acoustic stimuli.

Beaked whales appear to exhibit behavioral reactions that indicate they may be remarkably sensitive to noise exposure. Moretti et al. (2014) examined historical records of mid-frequency sonar operations and the vocal behavior of Blainville's beaked whales. They were able to describe the probability of the beginning of a Group Vocal Period as a function of the received level of operational mid-frequency sonars. These data were used to create a behavioral dose-response function for Blainville's beaked whales that has a structure similar to the LFA risk continuum, but with a 50 percent probability of response at 150 dB re 1µPa and a shallower slope (steepness parameter). Cuvier's beaked whale responses to mid-frequency sonar have also been described (DeRuiter et al., 2013). One whale exposed to low-level simulated sonar at close ranges (RL 89 to 127 dB) responded strongly, ceasing echolocation and fluking, extended its dive duration and swam away rapidly. However, another whale incidentally exposed to distant operational mid-frequency sonars at low levels (78 to 106 dB) did not show a response. This variation in responses again illustrates the importance of context in interpreting these results.

Miller et al. (2015) presented a single northern bottlenose whale with a 1 to 2 kHz sonar signal. The initial received level at the animal was 98 dB re 1 µPa, and at this level the whale approached the sound source. When the level reached 130 dB re 1µPa, the whale turned 180° away and began the longest and deepest dive ever recorded for this species (94 min and 7,674 ft [2,339 m]). This one data point suggests that this species may also show marked responses to anthropogenic noise, as do many of the beaked whales.

Similar to beaked whales, harbor porpoises have demonstrated behavioral reactions that indicate they may be more sensitive than most species, based primarily on their reactions to exposures from pile-driving operations. Though pile-driving produces broadband noise (energy occurs across a wide frequency range), the majority of energy occurs at low frequencies (below 1,000 Hz). To study factors affecting their behavioral sensitivities, harbor porpoise were exposed to 1 to 2 and 6 to 7 kHz simulated sonar signals that were composed of upsweeps and downsweeps, with and without harmonics (Kastelein et al., 2012). The 1 to 2 kHz signal with harmonics had sound energy at frequencies of 7 to 11 kHz (the harmonics) in addition to sound energy at the fundamental frequencies of 1 to 2 kHz. For 1 to 2 and 6 to 7 kHz simulated sonar signals, there was no difference in the sound level needed to cause a startle response between the upsweeps and downsweeps. However, the animals were much more sensitive to the 1 to 2 kHz signals with harmonics (50 percent response level = 99 dB re 1µPa) than without (50 percent response level = 133 dB re 1 µPa). The response level for 6 to 7 kHz signals without harmonics was 101 dB re 1 µPa. These findings highlight the importance of signal structure on behavioral response.

Harbor porpoise exposed to 1.33 to 1.43 kHz sonar signals with a 1.25-sec duration responded with a brief change in swimming direction or speed (Kastelein, 2013). The 50 percent response threshold

ranged from RLs of 124 to 140 dB. The signal type that produced the least response (i.e., highest response threshold) was a FM downsweep without harmonics.

The Navy did conduct research to quantify the responses of selected baleen whale species engaged in biologically important behaviors to the SURTASS LFA sonar system. The Low-Frequency Sound Scientific Research Program (LFS SRP) occurred in 1997 to 1998 to inform the first environmental impact statement (EIS) of the potential effects of the SURTASS LFA sonar system. A general summary of the program follows, but the reader is referred to the Navy's 2001 Final Environmental Impact Statement/Overseas Environmental Impact Statement (FEIS/OEIS) for more details (DoN, 2001). The three phases of the LFS SRP included (1) blue and fin whales feeding in the Southern California Bight in September and October 1997, (2) gray whales migrating south along the central California coast in January 1998, and (3) humpback whales singing (reproductive vocalizations) off the coast of the island of Hawai'i in February to March 1998. The LFS SRP was designed to characterize the responses of species most likely to be sensitive to SURTASS LFA signals, from which extrapolations to less sensitive species would be most protective. The LFS SRP produced new information about responses to the SURTASS LFA sonar sounds at RLs from 120 to 155 dB re 1 µPa (rms) (SPL). The LFS SRP team explicitly focused on situations that promoted high RLs (maximum 160 dB re 1 µPa [rms] [SPL]), but were seldom able to achieve RLs in the high region of this exposure range due to the natural movements of the whales and maneuvering constraints of the LF source vessel.

Responses of baleen whales during the LFS SRP were limited to short-term disruptions that returned to normal behavior once exposure ended. Over the 19-day period of the first phase, there were no immediately obvious responses from either blue or fin whales as noted during observations made from any of the research vessels during playback of LFA sounds (Croll et al., 2001). In the second phase of LFS SRP research, migrating gray whales showed responses similar to those observed in earlier research (Malme et al., 1983, 1984) when the source was moored in the migration corridor (2 km [1.1 nmi] from shore). However, when the source was placed offshore (4 km [2.2 nmi] from shore) of the migration corridor, the avoidance response was not evident. In the third phase of the LFS SRP, some singing humpback whales showed some apparent avoidance responses and cessation of song during specific LFA sound transmissions at RLs ranging from 120 to 150 dB re 1 µPa (rms) (SPL). However, an equal number of singing whales exposed to the same levels showed no cessation of song during the same LFA sound transmissions. Of the whales that did stop singing, there was little response to subsequent LFA sound transmissions; most joined with other whales or resumed singing within less than an hour of the possible response. Those that did not stop singing sang longer songs during the period of LFA transmissions, and returned to baseline after transmissions stopped (Clark et al., 2001; Fristrup et al., 2003; Miller et al., 2000).

As the LFS SRP results demonstrate, the potential for behavioral response to an anthropogenic source is highly dependent on context, including characteristics of the sound signals and their pattern of transmission, the environmental factors affecting sound movement, and the behavioral state of the animal during exposure. Since the LFS SRP exposed LF-specialist cetaceans engaged in biologically important behaviors to real-world SURTASS LFA sonar operations, the SRP results remain the best available science for assessing potential behavioral impacts associated with exposure to SURTASS LFA sonar. Furthermore, it is even more protective for non-LF specialists since it focused on species believed to be most sensitive to SURTASS LFA sonar. Harbor porpoises and beaked whales are not known to have good hearing sensitivities to low-frequency sound. However, given their known sensitivity to other

anthropogenic activities, research recommendations that might inform the potential for response to SURTASS LFA sonar were considered.

SAG Assessment of Potential Research Questions

Using the best available information, the SAG concluded that the potential for adverse effects from SURTASS LFA sonar on beaked whales and harbor porpoises appears limited. However, to verify this conclusion, the SAG recommended several research studies, in a phased approach, to address the most relevant questions. As outlined in the SAG report, the broad questions and their applicability to laboratory or field studies included the following:

- At what sound levels would SURTASS LFA sounds be audible? (laboratory)
- Under what exposure conditions would SURTASS LFA signals be expected to induce observable behavioral responses in individuals or groups of the focal species? (field and laboratory)
- Is there general avoidance of areas in which SURTASS LFA source is operating? (field)
- What sound levels would be expected to induce temporary threshold shift (TTS), and how would this information be used to determine behavioral sound exposure criteria? (laboratory)

The SAG identified specific research studies in terms of their feasibility, whether current methods exist or would need to be developed to conduct the study, and a broad scoring of the likely cost, as well as an overall assessment of the value of each study considering these factors.

Research recommendations of the SAG for the harbor porpoise focused on laboratory studies to address the questions: (1) at what levels would SURTASS LFA signals be audible and (2) at what levels would signals be expected to induce observable behavioral responses. The SAG's highest priority research recommendation for the harbor porpoise was for additional behavioral audiogram measurements at lower frequencies (down to 100 Hz) with multiple research subjects, if possible (please see Final Recommendations where the feasibility of low-frequency audiogram measurements is discussed). Such a study would be designed to characterize the low-frequency hearing sensitivity of harbor porpoises. Their second highest research recommendation was for laboratory-based observations of individual, short-term behavioral responses in known exposure contexts. The exposure scenarios would target conditions that may result in brief changes in speed and direction of movements as well as respiratory patterns. The feasibility of this research is also discussed in the Final Recommendations section.

The SAG also considered experimental field studies focusing on the harbor porpoise. Based on the lack of tagging technology and the difficulty and cost of passive acoustic field methods in LFA mission areas, research options were assessed as not recommended, not feasible, or not applicable.

Similarly, for beaked whale species, the SAG considered laboratory and experimental field studies. Since beaked whales have not been maintained successfully in captivity to date, laboratory studies are not presently feasible. Two experimental field studies were recommended, with a limited controlled exposure experiment (CEE) study using passive acoustic monitoring (PAM) assets on an instrumented Navy range ranking highest. The second recommended study was to conduct CEEs with tagged or focal follow methods to measure individual responses. The SAG recommended the PAM study with a single LFA element in an experimental context as a starting point, with the tagging/focal follow study to integrate the existing methods for measuring behavior.

In summary, the SAG concluded that given the present knowledge of hearing in beaked whales and harbor porpoises and how SURTASS LFA sonar is operated, the potential effects are expected to be limited, with the detection of the SURTASS LFA signals at ranges of no more than several kilometers.

However, because of the elevated responsiveness to various human activities compared to other marine mammals, there is the potential for behavioral responses. The known distribution of beaked whales in offshore waters, compared to the coastal distribution of harbor porpoise, increases the potential for beaked whales to be exposed to SURTASS LFA sonar signals.

EOG Consideration of Research or Monitoring Priorities

The SAG report was provided to the EOG for discussion and consideration. The goal of the EOG was to develop a plan of action recommending monitoring and research efforts the Navy could implement to study the potential effects of SURTASS LFA sonar on beaked whales and harbor porpoises. The EOG met twice to discuss the SAG recommendations and prioritize the research plans.

Regarding harbor porpoises, it was decided that a desktop study to determine the extent of potential exposure of harbor porpoise habitat by SURTASS LFA sonar transmissions should be conducted before other additional research is considered. Therefore, to further inform the research needs related to harbor porpoise, it was recommended that this study be conducted, which the Navy was able to fund. It was recommended that the results of the desktop study on harbor porpoise be used to prioritize the overall research recommendations (i.e., should research focus more on harbor porpoise or beaked whales). Of the remaining recommendations related to harbor porpoise, the EOG considered the recommendations of the SAG for behavioral audiograms and observations of captive animals' behavioral responses (see Final Recommendations for feasibility of low-frequency audiogram measurements). It was discussed that the harbor porpoise would be an appropriate representative species for other porpoise species in terms of auditory abilities, but that given the great differences in life history, distribution, and morphology among porpoise species, it would not be appropriate to extrapolate behavioral response results from the harbor porpoise to other species. It was also discussed that extrapolating observations of behavioral responses in laboratory settings to free-ranging animals in the field should be done with extreme caution, especially considering what is now known about the importance of context in predicting behavioral responses (Ellison et al., 2012). Both recommendations also have technical difficulties because of the issues with presenting low-frequency stimuli in laboratory scenarios. The long wavelength of low-frequency signals requires extremely large tank facilities to discourage near-field and reverberation effects. Future review of the potential for field studies with harbor porpoises should be done as the technology develops for tagging of harbor porpoises.

Regarding laboratory studies of beaked whales, the EOG agreed that the laboratory studies outlined in the SAG report were not feasible. However, the EOG recommended considering anatomical modeling, using finite element models of beaked whale heads, ears, and hearing mechanisms, as a possible laboratory study to be considered (e.g., Cranford/Krysl lab, Ketten/Mountain lab). Current research has lower frequency limits of 2 to 3 kHz, but it was recommended that extending those frequencies to 100 Hz should be feasible and cost effective and they recommended this study as the highest priority, though additional considerations are presented in the Final Recommendations section. In addition, the discussion of the low-frequency limit of auditory brainstem response (ABR) and auditory evoked potential (AEP) studies included a summary of currently funded research by the Navy to extend the limit from 3 to 5 kHz to 100 to 200 Hz. This topic should be revisited in the future with technological developments and, if possible, consider making additional portable ABR/AEP equipment available to stranding response networks that would allow for LF measurements beyond the current limit of 3 to 5 kHz. Extending the LF capability of ABR/AEP studies would also benefit the understanding of the hearing

ability of harbor porpoises. Navy-funded research to extend the lower limit of AEP measurements is further discussed in the Final Recommendations section.

Regarding field studies of beaked whales, in addition to those recommended by the SAG, the EOG suggested exploring existing data acquired by high-frequency acoustic recording package (HARP) sensors for spatial and temporal overlap with SURTASS LFA sonar transmissions. If overlap exists, the HARP data could be screened for LFA signals to compare the vocal behavior of beaked whales before, during, and after exposures. If overlap didn't exist, then targeted deployments of HARP sensors in LFA mission areas could be considered. NOAA has conducted HARP deployments in the western North Pacific Ocean in which SURTASS LFA sonar operates, but funding would be required to coordinate known times/places with beaked whale recordings with previous SURTASS LFA operations, the exact time and place of which are classified. However, this study was ranked highest by the EOG since it would be the least costly (data already collected) and could leverage existing funded analyses from other Navy projects.

The EOG also rankly highly the SAG-recommended field study of a CEE with beaked whales. However, the EOG suggested caution with the use of a scaled or surrogate source, noting that the results of the ongoing mid-frequency sonar behavioral response studies are showing that context is a significant parameter influencing response, particularly at lower received levels. These studies have found that scaled or surrogate sources yield results that require careful consideration when extrapolating to full-scale operations or operations with different sound sources, which may be particularly complex with a long-distance source such as SURTASS LFA sonar. The proximity of the vessel, its movement relative to that of the animal, the behavior of the animal during exposure, and the environmental conditions are just a few of the factors that have been found to affect an animal's response, in addition to the sound received level (Friedlaender et al., 2016). For the Phase III At-sea Testing and Training EISs, the Navy acknowledges that at moderate to low received levels, contextual factors mediate behavioral responses such that there is a very poor correlation between probability of reaction and received sound pressure level (DoN, 2017). The Navy has divided its dose-response behavioral curves into two parts, one at low to moderate received levels that correspond to context-based responses and the other at moderate to high received levels that correspond to level-based responses. Within the region of context-based response, factors other than sound level, such as proximity and motion of the sound source, are likely to be more important factors in predicting a significant behavioral response. The biphasic dose-response behavioral response function (BRF) for beaked whales has a 50% probability of response at 144 dB re 1 µPa (Figure 1, DoN, 2017).

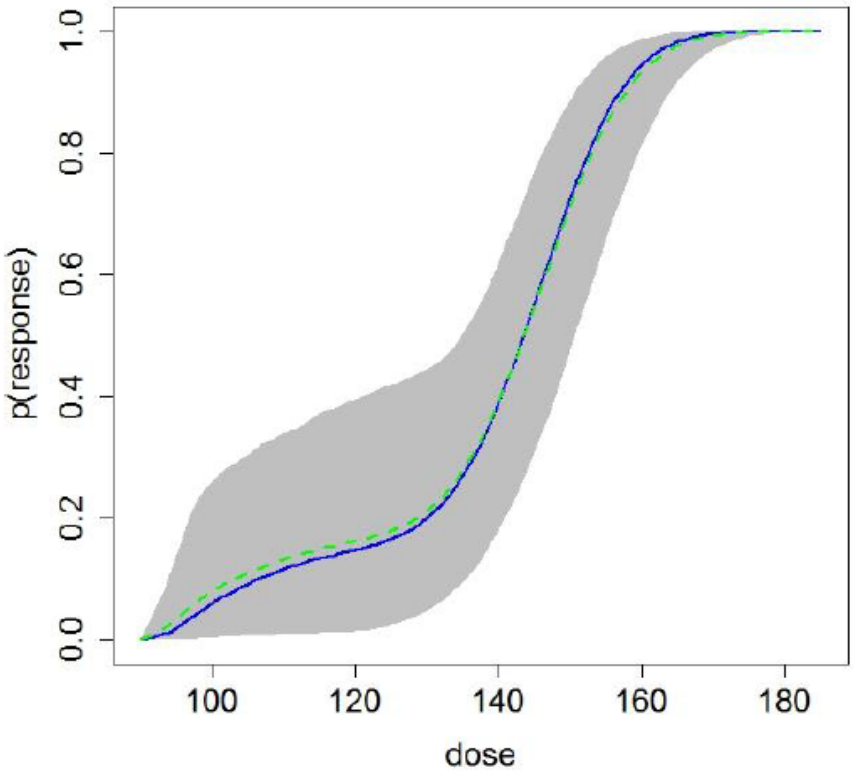

Figure 1. The Bayesian biphasic dose-response BRF for beaked whales. The blue solid line represents the Bayesian posterior median values; the green dashed line represents the biphasic fit of the BRF; the gray represents the variance (DoN, 2017).

It was also suggested by the EOG that the SURTASS LFA team should increase their integration with the Navy's Marine Species Monitoring Program (http://www.marinespeciesmonitoring.us/). A representative from N2/N6F24 does sit on the LMR review board and coordinates with ONR, LMR, and OPNAV N45 on research needs and priorities across platforms, but continued discussions and increased collaboration will occur.

Final Recommendations

In summary, after consideration of the SAG recommendations and the inputs provided by the EOG, the research monitoring studies were ranked as follows. In addition to the topic, the approximate cost of the research effort is also listed.

The category of research recommendations that were ranked highest included those estimated to cost less than $100K:

1. Desktop study of potential overlap of harbor porpoise habitat by SURTASS LFA sonar transmissions. Navy funded.
2. Review existing HARP data to determine spatiotemporal overlap with SURTASS LFA missions. NMFS contacted Erin Oleson (NOAA) about deployments in the western and central North Pacific and John Hildebrand (Scripps) about deployments in the eastern North Pacific. Since the

EOG, Baumann-Pickering et al. (2014) presented the results of over eleven cumulative years of HARP deployments in the North Pacific, which may overlap with SURTASS LFA missions. It would be fairly straightforward and require minimal cost to determine the spatiotemporal overlap of HARP deployments and LFA missions. If it was determined that overlap existed, the cost for data analysis would depend on the amount of overlap.

The second-highest ranked group of recommendations consisted of studies that are estimated to cost in the $100K-$500K range, but for which methodologies exist and implementation would extend existing studies:

1. Targeted deployment of one HARP sensor in the western North Pacific for one year; approximate estimated cost of $250K. The objective of this study would be to document beaked whale vocal behavior before, during, and after LFA sonar transmissions. Careful consideration of lessons learned from previous deployments would be needed to increase the probability of a successful project.

2. Anatomical modeling of LF sound reception by beaked whales; approximate estimated cost of $150K-$200K. Since the EOG meetings in 2014, Cranford and Krysl (2015) presented a synthetic audiogram for a fin whale, predicted based predominantly on bone conduction of sound through the head to the ear. NMFS (2016) noted that the predicted audiogram does not match the typical U-shaped audiogram expected with normal hearing in mammals in that there is "hump" at low frequencies and shallow roll-off of sensitivity at high frequencies. Given these difficulties, additional funding would be required to determine the source of the abnormal results.

The final group of recommendations is studies that require additional methodological developments and/or would cost greater than $500K.

1. CEE for beaked whales with an appropriate LF source. There are many complexities associated with this recommendation, even more so considering the results of the ongoing mid-frequency sonar BRS studies demonstrating the importance of real-world exposures for characterizing behavioral responses. It is possible that existing LF sources already in use on Navy ranges could be surrogates for SURTASS LFA sonar, but such extrapolations would need to be considered carefully. SURTASS LFA sonar is currently authorized for use in the western and central North Pacific and Indian oceans, regions in which CEEs have not been conducted, making experiments with the LFA system itself particularly difficult. Given the cost and complexities associated with this recommendation, it was ranked as a lower priority. This recommendation should also be revisit with future development of tagging technologies for harbor porpoises.

2. LF behavioral audiograms for harbor porpoise or LF ABR/AEP audiograms for beaked whales. Since the EOG concluded, the Navy funded a study led by Finneran (http://greenfleet.dodlive.mil/files/2017/05/LMRFactSheet_Project9.pdf) to correlate AEP measurements of hearing sensitivity with perceived loudness (Muslow et al., 2015). Part of this study included attempts to extend the LF range of AEP measurements, which may be transferable to studies of hearing sensitivity of harbor porpoise or beaked whales. There are difficulties with the transmission of LF sounds, in achieving the required power with manageable laboratory systems and creating a far-field sound field consistent across the measurement experiment. The final results of the study have not been published yet, but the study found that AEPs were only successful down to frequencies of 10 kHz for bottlenose dolphins (where 10 kHz

is the upper range of what is considered mid-frequency) and 1 kHz for California sea lions (the upper range of what is considered low-frequency). In addition, the correlation of equal latency contours only applied over a limited frequency range, providing limited benefit beyond the frequency range of auditory thresholds. Therefore, it is currently not feasible to conduct ABR/AEPs at frequencies within the range of SURTASS LFA sonar (100 to 500 Hz).

The ranking of research and monitoring recommendations has helped inform Navy and NMFS decision makers of the scientific priority, feasibility, and cost of possible experiments to increase understanding of potential effects of SURTASS LFA sonar on harbor porpoises and beaked whales. Discussions amongst Navy decision makers from OPNAV N2/N6F24, Office of the Deputy Assistant Secretary of the Navy for the Environment, Office of Naval Research, and Navy Living Marine Resources Program will continue to leverage research among various programs. N2/N6F24 has put in funding requests for FY17 and beyond, but there are significant budgetary constraints throughout the Federal agency. Ongoing discussions between Navy and NMFS will continue to evaluate the most efficient and cost effective way forward for Navy environmental compliance research efforts.

Literature Cited

Baumann-Pickering, S., Roch, M. A., Brownell Jr, R. L., Simonis, A. E., McDonald, M. A., Solsona-Berga, A., Oleson, E.M., Wiggins, S.M., & Hildebrand, J. A. (2014). Spatio-temporal patterns of beaked whale echolocation signals in the North Pacific. *PloS one, 9*(1). doi: 10.1371/journal.pone.0086072.g001

Clark, C. W., Tyack, P., & Ellison, W. T. (1999, Revised 2001). Overseas Environmental Impact Statement and Environmental Impact Statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) Sonar Technical Report 1: Responses of Four Species of Whales to Sounds of SURTASS LFA Sonar Transmissions. Cornell University, Woods Hole Oceanographic Institution, Marine Acoustics, Inc. for the Department of the Navy.

Cranford, T. W., & Krysl, P. (2015). Fin whale sound reception mechanisms: Skull vibration enables low-frequency hearing. *PLoS ONE, 10*(1), e0116222. doi: 10.1371/journal.pone.0116222

Croll, D., Clark, C., Calambokidis, J., Ellison, W., & Tershy, B. (2001b). Effect of anthropogenic low-frequency noise on the foraging ecology of Balaenoptera whales. *Animal Conservation, 4*(1), 13-27.

Department of the Navy (DoN). (2001). *Final overseas environmental impact statement and environmental impact statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar*. Washington, D.C.

DoN. (2017). Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase III). Technical Report, SSC Pacific.

DeRuiter, S. L., Southall, B. L., Calambokidis, J., Zimmer, W. M. X., Sadykova, D., Falcone, E. A., Friedlaender, A.S., Joseph, J.E., Moretti, D., Schorr, G.S., Thomas, L. & Tyack, P. L. (2013). First direct measurements of behavioural responses by Cuvier's beaked whales to mid-frequency active sonar. *Biology Letters, 9*, 20130223.

Ellison, W. T., Southall, B. L., Clark, C. W., & Frankel, A. S. (2012). A new context-based approach to assess marine mammal behavioral responses to anthropogenic sounds. *Conservation Biology, 26*(1), 21-28. doi: 10.1111/j.1523-1739.2011.01803.x

Friedlaender, A. S., Hazen, E. L., Goldbogen, J. A., Stimpert, A. K., Calambokidis, J., & Southall, B. L. (2016). Prey-mediated behavioral responses of feeding blue whales in controlled sound exposure experiments. *Ecological Applications, 26*(4), 1075–1085.

Fristrup, K. M., Hatch, L. T., & Clark, C. W. (2003). Variation in humpback whale (*Megaptera novaeangliae*) song length in relation to low-frequency sound broadcasts. *The Journal of the Acoustical Society of America, 113*(6), 3411-3424.

Kastelein, R. (2013). Brief behavioral response threshold levels of a harbor porpoise (*Phocoena phocoena*) to five helicopter dipping sonar signals (1.33 to 1.43 kHz). *Aquatic Mammals, 39*(2), 162-173.

Kastelein, R. A., Steen, N., Gransier, R., Wensveen, P. J., & de Jong, C. A. (2012). Threshold received sound pressure levels of single 1-2 kHz and 6-7 kHz up-sweeps and down-sweeps causing startle responses in a harbor porpoise (Phocoena phocoena). *Journal of the Acoustical Society of America, 131*(3), 2325-2333.

Malme, C. I., Miles, P. R., Clark, C. W., Tyack, P., & Bird, J. E. (1983). Investigations of the Potential Effects of Underwater Noise from Petroleum Industry Activities on Migrating Gray Whale Behavior. Anchorage, AK: Bolt, Beranek and Newman Inc. Prepared for Minerals Management Service, Dept. of the Interior.

Malme, C. I., Miles, P. R., Clark, C. W., Tyack, P. L., & Bird, J. E. (1984). Investigations of the potential effects of underwater noise from petroleum industry activities on migrating gray whale behavior. Phase II: January 1984 Migration. Anchorage, AK: Bolt, Berankek and Newman Inc. prepared for Minerals Management Service, U.S. Dept. of the Interior.

Miller, P. J. O., Biassoni, N., Samuels, A., & Tyack, P. L. (2000). Whale songs lengthen in response to sonar. *Nature, 405*(22 June 2000), 903.

Miller, P. J., P. H. Kvadsheim, F. P. Lam, P. L. Tyack, C. Cure, S. L. DeRuiter, L. Kleivane, L. D. Sivle, I. S. P. van, F. Visser, P. J. Wensveen, A. M. von Benda-Beckmann, L. M. Martin Lopez, T. Narazaki, & S. K. Hooker. (2015). First indications that northern bottlenose whales are sensitive to behavioural disturbance from anthropogenic noise. *Royal Society Open Science 2*(6), 140484.

Moretti, D., L. Thomas, T. Marques, J. Harwood, A. Dilley, B. Neales, J. Shaffer, E. McCarthy, L. New, S. Jarvis, & R. Morrissey. (2014). A risk function for behavioral disruption of Blainville's beaked whales (Mesoplodon densirostris) from mid-frequency active sonar. *PLoS ONE, 9*(1), e85064.

Muslow, J., Schlundt, C. E., Brandt, L., & Finneran, J. J. (2015). Equal latency contours for bottlenose dolphins (*Tursiops truncatus*) and California sea lions (*Zalophus californianus*). *Journal of the Acoustical Society of America, 138*(5), 2678-2691.