Environmental Studies Program: Ongoing Study

Title	Developing an auditory weighting function for low-frequency whales
Administered by	Headquarters
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Procurement Type(s)	Interagency Agreement
Conducting Organization(s)	Office of Naval Research
Total BOEM Cost	$761,000
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PICOC Summary	
Problem	It is not possible to conduct controlled hearing test on a large baleen whale, yet we are required to know this information for analyses under the Marine Mammal Protection Act (MMPA) and Endangered Species Act (ESA). Therefore, the hearing abilities of low-frequency (LF) whales remains one of the major "unknowns" as the regulatory community has tried to deal with effects of noise on marine mammals. The result is potential over-estimation of takes and/or effects and improper application of mitigation.
Intervention	Although this question has existed for some time, this is the right place and right time to pursue this project, mainly due to partnership interest and advances in research methodologies. The SOST interagency task force for ocean noise and marine life recently identified this question as the #1 information need on marine sound issues for broad-scale interagency support. Agency members of this task force have committed to contributing funds to partner on this project.
Comparison	As it is not possible to obtain a behavioral audiogram or electrophysiological audiogram from a free-swimming baleen whale, the SOST Task force identified three potential approaches for funding that might produce results. The first, the observation of wild animals exposed to controlled sounds during migration, is being completely funded by US Navy source and will not be discussed further here. BOEM will be funding the second and third approaches. The second method is the examination of the physiology of the auditory system from whale carcasses and, using finite-element modeling, generate a digital model. Then that digital model can be subjected to sound waves to determine how the auditory system would respond - i.e., how the whale would "hear" if it was alive. This is the currently the best conceivable method for addressing this question. The third approach is to obtain AEP measurements from stranded or restrained animals. In this case, neurological responses to played-back sounds would be measured. If this project is not implemented, the best estimates for baleen whale hearing will continue to come from proxy species (e.g., odontocetes), but the accuracy of these proxies is also unknown.

Outcome	The results of this study will be used to inform future versions of the NMFS acoustic criteria and be more immediately used in BOEM marine sound analyses. Further, this project contains the validation of hearing models - models which were previously rejected by NMFS due to lack of validation. It also will advance the technology for obtaining new data from stranded whales. Accurate hearing data will allow for more accurate "take" estimates under the MMPA and ESA or BOEM- authorized activities such as G&G surveys and pile-driving. At the moment the models are likely to be overly conservative due to the lack of data and potentially result in overestimates of effects and over-application of mitigation.
Context	Depends on the method chosen. The data need is national. Information on hearing abilities from just one species of baleen whale will significantly advance the current understanding (which is almost nonexistent), so the results from one species would be extrapolated to other species.

BOEM Information Need(s): Understanding the auditory capabilities of LF whales is the biggest remaining knowledge gap in the field of marine bioacoustics as well as regulatory analyses under the MMPA and ESA. Specifically, BOEM needs to know the shape of the audiogram, as well as the lowest-amplitude sound that LF whales can detect, in order to build auditory weighting functions. These weighting functions are built into the "acoustic criteria" that NMFS requires for estimating "takes" from acoustic exposure. Therefore, this information is imperative for BOEM to assess the potential effects of its noise-producing actions (from both oil and gas and renewable energy) on these species, many of which are highly threatened, are afforded additional legal protection and are the focus of stakeholder concerns. Faced with the lack of information that we have now, regulators are forced to use information from proxy species (captive odontocetes) as stand-ins, but given the differences in life-histories, hunting strategies, and communication signals between baleen and toothed whales, these proxies are likely inadequate.

Background: Due to a lack of knowledge about their hearing capabilities, the NMFS 2016 and 2018 Acoustic Criteria used conservative assumptions in establishing the auditory weighting function for low-frequency whales, especially for the lowest frequencies (< 1 kHz). This resulted in relatively low numerical thresholds for several source types, such as low frequency impulsive sources (i.e. airguns). Low thresholds result in increased take estimates—a larger number of animals that would experience temporary or permanent threshold shift. This in turn leads to overly conservation analyses of effects and additional requirements for mitigation, the effectiveness of which is also poorly understood.

BOEM has previously funded field work (e.g., the BRAHSS study ($2.2 M), SWSS study ($9 M)) which looked at the behavioral response of certain cetacean species to manmade sounds. At-sea Controlled Exposure Experiments are inevitably high-cost, but due to high individual variability and the difficulty of obtaining large sample sizes for such highly-migratory species, these studies have yielded mixed results. The return-on- investment for these field studies has been relatively low. The methods proposed here are not field-based behavioral work, but instead rely on physiological or modeling methods (which need to be validated). As such, their potential return on investment (especially when comparing costs between methodologies), is much higher.

Results from either of the two projects funded though this interagency agreement will be compared to the existing low-frequency hearing function used in the 2016 NMFS acoustic criteria and would serve to improve the criteria. These criteria, in turn, form the foundation of all analyses under the MMPA and

ESA. For all other hearing groups except LF whales, these criteria are based on real data. The lack of meaningful, validated data for LF whales has made it extremely challenging for NMFS and others to derive meaningful regulatory "not-to-be-exceeded thresholds" for noise sources, as required under the MMPA and ESA.

Objectives: To build an audiogram for low-frequency cetacean(s).

Methods: The SOST group has published a Broad Agency Announcement that includes three research areas:

1. Validation of finite-element model outputs of whale skulls - may include:
    a. Validation of the bone conduction pathway
    b. Scanning an additional baleen whale species – e.g., a Bowhead that is obtained from subsistence harvest, or a stranded animal that can be mobilized quickly before decomposing.
2. Improve equipment and methodology for AEP methods
    a. Development of appropriate transducer - a portable speaker that can reproduce sounds < 1kHz - this remains a major technological hurdle.
    b. Testing of appropriate size and placement of subcutaneous needles – this can be started with sounds above 1 kHz, before the appropriate transducer has been developed.
    c. Note: later stages of AEP work would include testing on real, stranded animals, but the steps above are necessary first.
3. Open-ended call for proposals that aim to build an auditory weighting function for LF whales - using new ideas, methods, or technology

Critical reviews of the SOST Task force members resulted in the winnowing of the received proposals down to three candidates to be funded. For simplifying contractual reasons, two of these proposals / approaches, the whale skull modeling and the AEP approach are being funded directly by BOEM.

Specific Research Question(s): What is the shape of the audiogram for LF whales?

Current Status: Study #1 above is moving forward as scheduled without any major delays due to COVID-19. They have already scanned a gray whale skull. Study #2 above has been delayed by one year due to COVID-19. They are currently preparing for their first field season in summer 2021 and have the requisite permits in place.

Publications Completed: None.

Affiliated WWW Sites:

https://www.navfac.navy.mil/navfac_worldwide/specialty_centers/exwc/products_and_services/ev/lmr/sost.html

References:

Cranford, T. W. and P. Krysl (2015). "Fin whale sound reception mechanisms: skull vibration enables low-frequency hearing." PLoS One 10(1): e0116222.

Cranford, T. W., P. Krysl and M. Amundin (2010). "A new acoustic portal into the odontocete ear and vibrational analysis of the tympanoperiotic complex." PLoS One 5(8): e11927.

National Marine Fisheries Service. 2016. Technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (NOAA technical memorandum NMFS-OPR-55)

Johnson, A. C. (April 2018). Scientists use rocket scanner to learn how whales hear: first whole-body CT scan of a minke whale yields insights on whale communication. This is a recent article about forthcoming work from Cranford and colleagues (not published yet but will be presented at an upcoming conference).