

STATEMENT OF WORK

Low-Frequency Hearing in Pinnipeds (NT-21-x14)

PURPOSE

The purpose of this study is to obtain data on auditory thresholds, critical ratios, and critical bandwidths for two species of pinnipeds at frequencies below 100 Hz.

BACKGROUND

Offshore energy development and mineral extraction introduce noise into the marine environment. In order to assess potential impacts from this noise on exposed marine life, it is essential to have information about the hearing sensitivities of likely affected species. Indeed, auditory thresholds inform auditory weighting functions, which are a central component of the modeling that we conduct in our environmental impact assessments. In addition, we use animal hearing data to inform the sound levels at which we expect incidental take to occur, i.e. the “level A” and “level B” thresholds under the Marine Mammal Protection Act.

Auditory thresholds are determined by exposing an animal to a pure tone at a distinct frequency and amplitude. Doing this repeatedly at different frequencies forms the points on the audiogram, also known as the hearing curve. Then, noise of a certain frequency bandwidth is added, which raises the hearing threshold, called the “masked threshold”. This continues until you reach a point where a wider bandwidth of noise no longer increases the hearing threshold, called the “critical bandwidth”. The critical bandwidth correlates with the bandwidth of the animal’s auditory filter, which provides information about the shape and function of the cochlea. The term “critical ratio” in psychoacoustics denotes the detectability of a tone embedded in white noise; this is the ratio of acoustic power between the tone and the noise that is presented experimentally as described above.

Southall et al 2007 provided the first comprehensive information about hearing in marine mammals. Recent studies have provided audiograms for several new species of pinnipeds (e.g., harbor seals, Kastelein et al 2009, Reichmuth et al 2013; spotted seals, Sills et al 2014; ringed seals, Sills et al 2015; California sea lions, Reichmuth et al 2012), but none of these studies have tested hearing at frequencies below 100 Hz. That is because it is very difficult to conduct these tests in tanks due to issues with standing waves for sounds with large wavelengths, and the fact that many underwater speakers cannot produce low-frequency sounds. Work in mammals thus far has shown that the critical bandwidth is about 1/3 of an octave, but since very little testing has been done with sounds below 100 Hz, we lack information about their auditory filters at these lowest frequencies.

This work will provide the first data on hearing below 100 Hz in two species of pinnipeds: the California sea lion; and the bearded seal, which are vulnerable to noise from offshore energy development and mineral extraction. Current investigations on bearded seals are already testing at 63 Hz and 100 Hz, but not below 63 Hz. Previous tests on California sea lions have not gone below 100 Hz. These are important datapoints to obtain because many industrial sources (e.g., airguns, marine vibroseis, pile-driving) produce significant energy in these low frequencies. This new study will enhance our understanding of hearing sensitivity and critical bandwidths at very low frequencies, which may provide insights on low-frequency hearing in other marine mammals as well. This work is important to BOEM because active acoustic sources used by all three programs target these low frequencies.

REFERENCES

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- Sills, J.M., B.L. Southall, and C. Reichmuth. 2015. Amphibious hearing in ringed seals (*Pusa hispida*): Underwater audiogram, aerial audiograms and critical ratio measurements. *The Journal of Experimental Biology* 218:2250-2259.
- Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene, Jr., D. Kastak, D.R. Ketten, J.H. Miller, P.E. Nachtigall, W.J. Richardson, J.A. Thomas, and P.L. Tyack. 2007. Marine mammal noise exposure criteria: Initial scientific recommendations. *Aquatic Mammals* 33:411-521.

OBJECTIVES

- Obtain data on the critical ratio, critical bandwidth, and auditory thresholds at 40 Hz and 50 Hz for bearded seals.
- Obtain data on the critical ratio, critical bandwidth, and auditory thresholds at four frequencies between 40-100 Hz for California sea lions.

DESCRIPTION OF WORK

Methods: A team of researchers has already trained two individual bearded seals and one California sea lion in behavioral audiogram testing. Using an in-ground tank and a highly calibrated speaker, they expose the animals to pure tones at different frequencies and measure their response (a yes/no of detection plus response latency observed through a video camera). The amplitude of the signal is measured in terms of pressure and particle motion. These tests reveal the lowest amplitude that can be detected at each frequency, i.e. the auditory threshold. Then, noise of specific bandwidths is added to the pure tones to obtain the critical bandwidth and critical ratio at each frequency.

Two frequencies will be tested for the two bearded seals: 40 Hz and 50 Hz (63 and 100 Hz are already being tested under an existing study). Four frequencies between 40-100 Hz will be tested for the California sea lion, to offer a comparison between otariids (CA sea lion) and phocids (bearded seal). This comparison will provide key insights into hearing in pinnipeds overall.

TASKS

Task 1: Test hearing capabilities of bearded seals. Produce auditory thresholds (in terms of pressure and particle motion) for 40 and 50 Hz, as well as critical bandwidths and critical ratios using behavioral response methods

Task 2: Test hearing capabilities of CA sea lions. Produce auditory thresholds (in terms of pressure and particle motion) for four frequencies between 40-100 Hz, as well as critical bandwidths and critical ratios using behavioral response methods.

Scientific integrity is vital to Department of the Interior (DOI) activities under which scientific research, data, summaries, syntheses, interpretations, presentations, and/or publications are developed and used. Failure to uphold the highest degree of scientific integrity will result not only in potentially flawed scientific results, interpretations, and applications but will damage DOI's reputation and ability to uphold the public's trust. All work performed must comply with the DOI Scientific Integrity Policy posted to <http://www.doi.gov>, or its equivalent as provided by their organization or State law.

BUDGET

FY21: \$200,000

PERIOD OF PERFORMANCE

36 months

DELIVERABLES

(1.) Post-award Teleconference: Under the moderation of the BOEM project officer (PO) and the BSEE contract officer for this cooperative agreement (CO), a post-award teleconference will be conducted. The participants will be the PO, CO, BOEM ESP contact, James Price. The teleconference will be conducted as soon after the BOEM funding award as is practical under the scheduling constraints of the participants.

A synopsis of the kick-off meeting will be drafted by the PO and distributed to the Chief of the Environmental Sciences Division and to all the participants of the teleconference.

(2.) Quarterly E-mail Progress Reports: The principal investigator shall produce quarterly reports briefly stating: progress made in the past quarter; any particular problems needing BOEM intervention to resolve; and anticipated progress to made in the next quarter.

(3.) Draft Final Report and Technical Summary: The principal investigator shall complete and submit a draft final report and draft technical summary to BOEM for scientific peer and editorial review. The report and technical summary shall be in the format specified at <http://www.boem.gov/Environmental-Studies-Program-Report-Specifications/> . The report shall contain the following language concerning its availability in ESPIS:

“To download a PDF file of this Environmental Studies Program report, go to the U.S. Department of the Interior, Bureau of Ocean Energy Management, Environmental Studies Program Information System website and search on OCS Study BOEM xxxx-xxx.”, where xxxx-xxx will be replaced with the assigned BOEM study number.

In addition, in the Acknowledgement of Sponsorship Section, the report shall contain the following disclaimer and acknowledgement language:

“Disclaimer: This report has been technically reviewed by BOEM, and it has been approved for publication. The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the opinions or policies of the U.S. Government, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.” ;

and

“Acknowledgement: Study collaboration and funding were provided by the U.S. Department of the Interior, Bureau of Ocean Energy Management, Environmental Studies Program, Washington, DC under Agreement Number _____.” .

(4.) Final Report and Final Technical Summary: The principal investigator shall revise the draft final report and draft technical summary according to feedback given by BOEM reviewers and the PO. She shall provide three high-quality, bound paper copies of the revised final report suitable for reproduction as well as electronic copies (MS-Word and .pdf), each containing searchable text, and formatted per BOEM report requirements.

Deliverables, Due Dates, and Distribution

Deliverable	Distribution	Due Date
A. Post Award Teleconference and Summary Notes	Chief, ESP—One (1) electronic copy ESP Contact—One (1) electronic copy CO—One (1) electronic copy COR—One (1) electronic copy All other participants in the teleconference—One (1) electronic copy	As soon as practical after BOEM funding award Summary Notes due approximately one (1) week after teleconference
B. Quarterly E-mail Reports	Chief, ESP—One (1) electronic copy ESP Contact—One (1) electronic copy PO—One electronic (1) copy CO—One (1) electronic copy COR—One (1) electronic copy	Within four (4) months from award and Quarterly afterward.
C. Draft Report and Technical Summary	Chief, ESP—One (1) electronic copy (in MS Word format) ESP Contact—One (1) electronic copy (in MS Word format) PO—One (1) electronic copy (MS Word) for report	Draft due two (2) months prior to the end of the period of performance

Deliverable	Distribution	Due Date
	CO—One (1) electronic copy of transmittal letter only COR—One (1) electronic copy	
D. Final Report and Technical Summary	Chief, ESP—One electronic copy (in pdf format) ESP Contact—One (1) electronic copy (in pdf format) PO—One (1) electronic copy in Adobe Acrobat (.pdf) format and labeled with the study title, BOEM report number, BOEM contract number, contractor name and date, and one (1) electronic copy in MS-Word format. Both copies must follow the required BOEM report formats. CO—One (1) copy transmittal letter only COR—One (1) electronic copy	Before the end of the period of performance
E. Submission of work to scientific journal for peer-review	ESP Contact—One (1) electronic copy (in pdf format) COR- One (1) electronic copy (in pdf format)	Before the end of the period of performance

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