

Environmental Studies Program: Ongoing Study

Field	Study Information
Title	Low-frequency Hearing in Pinnipeds
Administered by	Office of Environmental Programs, Center for Marine Acoustics
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Procurement Type(s)	Cooperative Agreement
Conducting Organization(s)	University of California Santa Cruz
Total BOEM Cost	\$199,937
Performance Period	FY 2022–2025
Final Report Due	September 25, 2025
Date Revised	October 2, 2023
Problem	Marine mammals may be affected by low-frequency noise produced by offshore energy development and mineral extraction. Very little work has been done to determine hearing capabilities of marine mammals at very low frequencies, so the degree to which they may be affected remains largely unknown.
Intervention	A specialized tank and underwater speaker system have been prepared and tested for conducting hearing tests at very low frequencies.
Comparison	Without this information, our estimates of potential noise impacts on pinnipeds are extrapolated from other unrelated species and are likely to be inaccurate.
Outcome	Obtaining data on hearing thresholds and critical ratios for two pinniped species will improve our understanding of the vulnerabilities of these species to anthropogenic noise and can potentially be interpreted more generally for other marine mammal species.
Context	Data for the California sea lions and bearded seals will be most useful for the California and Alaska regions, but information from these two representative pinnipeds will inform impact assessments in all BOEM regions.

BOEM Information Need(s): Activities from BOEM’s three programs introduce noise into the marine environment. In order to assess potential impacts of this noise on marine species, it is essential to have information about the hearing sensitivities of the species of interest. 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.

Background: 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 increases 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 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. Current investigations (funded by the Sound and Marine Life Joint Industry Program) 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. Testing in these ranges is important because many sound sources (e.g., airguns, marine vibroseis, pile-driving) have significant energy in low frequencies. This study will enhance our understanding of hearing sensitivity and critical bandwidths at these low frequencies, which may provide insights on low-frequency hearing in other marine mammals as well. This work is important to BOEM because many active acoustic sources – used across all three programs - introduce acoustic energy at these low frequencies.

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.

*The ability to provide both full sets of measurements will be dictated by the absolute hearing sensitivity of the animals at these low frequencies.

Methods: Trained animals will be subjected to behavioral audiograms, which requires extensive training and a proper laboratory setting. A calibrated underwater speaker and specialized tank will be necessary to test hearing at such low frequencies.

Specific Research Question(s):

- What is the bearded seal auditory threshold at 40 and 50 Hz?
- What is the critical bandwidth for bearded seals at the same frequencies?
- What is the California sea lion auditory threshold at frequencies below 100 Hz?

- What is the critical bandwidth for California sea lions at the same frequencies?

Current Status: The cooperative agreement was awarded on 8/18/2022. Lab work kicked off immediately thereafter to answer the research questions above. In addition to addressing the above research questions, supplemental data collection has been conducted to describe how the auditory systems of seals and sea lions process low-frequency sounds of different durations. Lab work is now complete for this study and the research team is working on writing up their results in a final report and manuscript for publication.

Publications Completed: None

Affiliated WWW Sites: None

References:

- Kastelein RA, Wensveen P, Hoek L, Terhune JM. 2009. Underwater hearing sensitivity of harbor seals (*Phoca vitulina*) for narrow noise bands between 0.2 and 80 kHz. *Journal of the Acoustical Society of America*. 126:476–483.
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- Sills JM, Southall BL, Reichmuth C. 2014. Amphibious hearing in spotted seals (*Phoca largha*): underwater audiograms, aerial audiograms and critical ratio measurements. *The Journal of Experimental Biology*. 217:726–734.
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- Southall BL, Bowles AE, Ellison WT, Finneran JJ, Gentry RL, Greene Jr. CR, Kastak D, Ketten DR, Miller JH, Nachtigall PE, Richardson WJ, Thomas JA, Tyack PL. 2007. Marine mammal noise exposure criteria: initial scientific recommendations. *Aquatic Mammals*. 33:411–521.