Investigating Bone Conduction as a Pathway for Mysticete Hearing

Need

There is a need to improve understanding and measurement of auditory capabilities and sensitives of low-frequency cetaceans (mysticetes) to anthropogenic sound. Research needed to generate a mysticete audiogram includes developing and validating finite element modeling (FEM) methods, developing and testing in-situ auditory evoked potential (AEP) measurement methods for mid- and high-frequency hearing sensitivities of mysticetes, developing tools for AEP measurements below 1 kHz, evaluating behavioral response methods and identifying other appropriate approaches or methods.

Solution

This project addresses the portion of the need related to developing and validating FEM methods. The project team, led by Drs. Ted Cranford and Petr Krysl, have developed methods to simulate the excitation of the hearing apparatus in a model of a whale's head. The model is derived from computed tomography (CT) scans of preserved specimens and will be used to investigate whether bone conduction is a valid pathway for hearing in mysticetes, as first demonstrated by this team.

Methodology

The FEM methods involve combining high-resolution CT scans with measurements of tissue properties and custom-built software to simulate sound propagation through the model of the specimen. For this project, the specimen is a specially prepared head of a gray whale calf provided by the Natural History Museum of Los Angeles County. These tools have previously produced computational audiograms for a fin whale and minke whale.

This project methodology includes a combination of FEM simulations and two interdependent lab experiments.

Experiment 1

The primary goal of this experiment is to develop techniques to record the excitation of the gray whale skull and hearing apparatus. Researchers will attach sensors to the gray whale skull and test the configuration in a specialized tank at the Scripps Institution of Oceanography. The techniques that will be evaluated include the optimal placement of the sensors and transducers on the skull, methods of acoustic isolation of the tympanic bullae (hollow bony structure that encloses the middle ear), and number and types of attachments for suspension of the skull in water.

Gray whale.
Steven Swartz, NOAA/NMFS

Experiment 2

The primary goal of this experiment is to measure the mechanisms and pathways of sound transmission from the water into the skull and hearing apparatus of the whale at frequencies below 1 kHz. Researchers will attach the sensors that have been configured in the first experiment to investigate the actual mechanisms by which sound enters the skull in an acoustic environment that approximates the natural exposure conditions experienced by a whale. These conditions are afforded by the U.S. Navy Transducer Evaluation Center (TRANSDEC)

The gray whale head (left) used for this project, and the 3D reconstruction of it from CT scans (right).

facility in San Diego, CA.This facility provides a large (6 million gallon) anechoic (echo-free) test tank and provides exceptional instrumentation and acoustic data gathering capabilities.

Researchers will suspend the prepared skull and introduce underwater sound at various frequencies to measure skull responses to the vibrations. It is anticipated that the lowest frequency that can be tested will be 500 Hz, as determined by the wavelength of sound that can be supported by the dimensions of the test tank.

Schedule

Tasks for the first experiment, testing of the whale skull in a small tank, will begin in 2019 and be completed by early 2021. Based on results from that effort, methods will be refined, and the second experiment, testing of the whale skull at the TRANSDEC facility, will commence in mid-2021. Final manuscripts will be submitted to peer-reviewed journals by the end of 2023.

Benefits

By clarifying sound transmission pathways and validating FEM simulation results, this project can inform estimates of how anthropogenic sound might affect mysticetes. Understanding more about pertinent issues associated with low-frequency anthropogenic sound can help to refine the mysticete audiogram, estimate exposure levels and identify mitigation strategies for environmental compliance.

About the Principal Investigators

Ted Cranford is an adjunct professor of research at the San Diego State University Research Foundation. He earned his Ph.D. in Biology at the University of California, Santa Cruz. His interests include functional morphology, marine mammal science, bioacoustics and ecomorphology.

Petr Krysl is a professor of computational mechanics at the University of California, San Diego, Department of Structural Engineering. He holds a Ph.D. in Theoretical and Applied Mechanics from the Czech Technical University in Prague. His interests include finite element method development as applied to biomechanics, mesh generation methods and high-performance computing.

BOEM Bureau of Ocean Energy Management

NOAA FISHERIES

The Subcommittee on Ocean Science and Technology (SOST) authorized establishment of an Interagency Task Force on Ocean Noise and Marine Life (ITF-ONML). A subset of the ITF-ONML's member agencies partnered to jointly fund research on the auditory capabilities of mysticetes. This project is one of three projects that was selected for funding. Each project was funded by various agency partners.