LIVING MARINE RESOURCES PROJECT 11

# Primary Audiograms of Hearing in Baleen Whales

## THE NEED

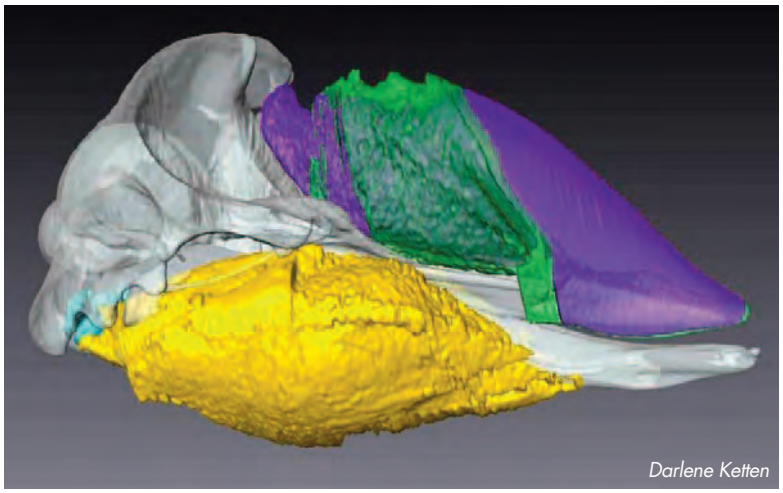
The Navy is responsible for compliance with a suite of Federal environmental laws and regulations that apply to marine mammals and other marine protected species. As part of the compliance process associated with these regulations, the Navy is responsible for implementing a marine species monitoring program to assess potential impacts from Fleet and System Command military readiness activities involving active sonar and underwater detonations from explosives and explosive munitions. However, the level of impact associated with these sounds is difficult to determine without a thorough understanding of how these animals hear and the relative effects of sounds at different frequencies on each species.

At present, the Navy is relying on behavioral and other studies involving bottlenose dolphins and sea lions, as these species are relatively easy to work with in captivity. However, for species that are rare or difficult to keep in captivity, such as baleen whales or beaked whales, a different approach is needed.

## THE SOLUTION

The goal of this project is to determine how sound travels within the auditory system of baleen and beaked whales both on and beneath the ocean's surface, and to use this information to produce a model audiogram (a graphic representation) depicting the standard threshold for hearing frequencies in these animals.

The proposed models will be built using techniques developed by the Principal Investigator's research team under previous funding from the Chief of Naval Operations Energy and Environmental Readiness Division. That work provided the first audiogram of a minke whale, the smallest of the baleen whales. They also tested the accuracy of their modeling methods by comparing their model audiogram for bottlenose dolphins with live captive dolphin behavioral audiograms.




Three-dimensional reconstruction of the melon (purple), jaw fats (gold), and skull (white) from CT scans of a Cuvier's beaked whale (*Ziphius cavirostris*).

## THE METHODOLOGY

At present, the scientific community lacks precise knowledge of how the tissues for sound reception (the ear and jaw fats) in many cetacean species compare with those of land mammals. This study addresses how whale middle and inner ears are similar to those of land mammals in some ways yet also have differences that provide very wide hearing ranges and are able to operate both at surface and under deep dive conditions.

The team uses ultra-high resolution computerized tomography (CT) scans in order to measure tissue

architectures in 3D and combines these data with neuroanatomical data from existing histology cases and measures of elasticity and stiffness of middle and inner ear components. The specimens are obtained from both archived ears from past studies and recent strandings.

## THE SCHEDULE

The first task is to build a data set of 3D visualizations of whole whale heads and ears based on CT scans and digitized histology sections. These data represent macro to micro coded maps of tissue densities and distributions from which the inner ear frequency responses are calculated.

Secondly, elasticity and stiffness measurements of both inner and middle ear structures will be made utilizing nano probe piezoelectric technology built specifically for large whale ears. (Piezoelectricity is the ability of certain biological material to produce an electric charge in response to applied mechanical stress.) Models will be made by combining the output data of both tasks along with researchers' previous methodology. These will help to determine sound exposures that produce responses ranging from minimal detection to levels that could produce auditory damage. Publication of preliminary results on all phases is expected in 2016.

## NAVY BENEFITS

This project will provide data for understanding potential effects of Navy underwater activities on a number of rare or endangered whale species. The data will provide a scientifically valid risk assessment of susceptibility to hearing loss for those species based on measures of auditory system dynamic properties.

The data will also aid in species-specific risk assessments for hearing impacts and for developing effective mitigation procedures. They will also provide head and ear anatomical guides that are imperative for effective electrode and sound source placements for proposed auditory brainstem response measures on live, stranded whales.

## TRANSITION

Ongoing results of this research will be provided in the form of annual reports and presentations at meetings. Results will be published in peer-reviewed articles. The data are expected to provide a resource for Environmental Impact Statements and will inform decisions related to operation safety and mitigation.

## ABOUT THE PRINCIPAL INVESTIGATORS

Darlene Ketten is Chief Scientist of the Marine Imaging Facility of Woods Hole Oceanographic Institution. She holds a M.S. degree in Biological Oceanography from Massachusetts Institute of Technology and a Ph.D. in Neuroethology and Experimental Radiology from The John Hopkins Medical Institutions.

Aleks Zosuls is a biomedical engineer at Boston University. He holds a B.S. in Biomedical Engineering from Boston University.

## About the LMR Program

The Living Marine Resources (LMR) program seeks to develop, demonstrate, and assess data and technology solutions to protect living marine resources by minimizing the environmental risks of Navy at-sea training and testing activities while preserving core Navy readiness capabilities. For more information, contact the LMR program manager at exwc_lmr_program@navy.mil or visit www.lmr.navy.mil.