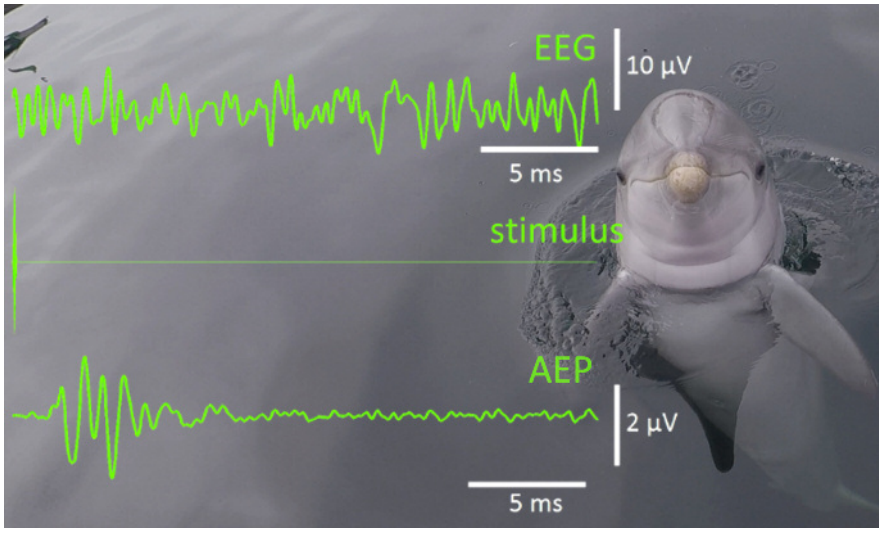
LIVING MARINE RESOURCES PROJECT 55

Dolphin Conditioned Hearing Attenuation

NEED

Multiple studies with several marine mammal species have demonstrated conditioned reductions in hearing sensitivity. These results raise more questions about the mechanisms marine mammals use to reduce their hearing sensitivity and implications for marine mammal hearing.

The Navy needs better understanding of the extent of control marine mammals may have over reducing their hearing sensitivity, what anatomical and physiological mechanisms they may be using, and the impact on temporary threshold shift (TTS) response. An investigation into any additional species available in captivity is needed.



Examples of a dolphin instantaneous electroencephalogram (EEG) and an auditory evoked potential (AEP) measured in response to a tone burst sound stimulus.

SOLUTION

This project will focus on three primary objectives:

1. Measure how quickly dolphins can learn to suppress (i.e., attenuate) their hearing in anticipation of an impending intense sound
2. Determine how long they can maintain the attenuation
3. Assess the role of outer hair cells in the conditioned hearing change.

Understanding the extent to which dolphins can voluntarily manipulate their hearing sensitivity and the underlying mechanisms is required to properly evaluate laboratory data relating hearing loss to noise exposures.

METHODOLOGY

This work will be co-funded by the LMR program and the Naval Innovative Science and Engineering (NISE) program. The project team will assess conditioned hearing attenuation in bottlenose dolphins by measuring changes in auditory evoked potentials (AEPs)—small voltages generated by the brain and auditory nervous system in response to sound—when dolphins are warned of an impending intense sound. The team will work with bottlenose dolphins from the United States Navy Marine Mammal Program (MMP) that are trained for behavioral hearing tests and for participation in AEP studies.

During each experimental trial, AEPs to a continuous sequence of tone bursts will be tracked first before a warning sound, then after the warning sound but before an intense sound and, finally, after the intense sound. Conditioned hearing changes are expected to be revealed by decreases in AEP amplitude and

increases in AEP latency occurring after the warning sound, but before the intense sound. This temporal separation will eliminate the possibility that AEP attenuation is a result of auditory masking or noise-induced hearing loss (i.e., caused directly by the intense sound). Across experimental sessions, features of the hearing test—the AEP stimulus, the warning sound and the intense sound—will be manipulated to reveal temporal and spectral characteristics of the conditioned hearing attenuation phenomenon. Measurements of AEPs in the presence of on- and off-frequency masking noise will be used to determine if outer hair cell function is affected during conditioned hearing attenuation. These data will reveal if the conditioned hearing attenuation is mediated by changes to outer hair cells/cochlear amplifier gain.

The four tasks of the study are:

Task 1: Refine procedures and conduct baseline testing

Work includes fabricating the hearing test apparatus and developing custom software for data collection, establishing the specific stimulus frequencies, levels and timing relationships, and defining the number of AEP trials required to rapidly measure AEPs while maintaining sufficient signal-to-noise ratios required for comparing AEPs. Methods for measuring growth of masking for on-/off-frequency maskers will be defined and tested. Finally, baseline data will be collected before any intense sounds are presented. Baseline data are required to ensure the warning sound does not affect AEPs and to establish the dolphins' AEP amplitudes and latencies before any behavioral conditioning occurs.

Task 2: Measure learning of conditioned attenuation

Testing will be done using at least two dolphins naïve to the conditioned hearing change paradigm or other intentional exposure to intense sound. Testing will begin by presenting the intense sound alone (i.e., without the warning sound) at fixed intervals. This will show if animals anticipate the next intense exposure in a sequence (without an explicit warning) and attenuate their hearing, at what received sound pressure levels (SPL) conditioned attenuation begins and how many exposures are necessary to establish the conditioned effect. Subsequent testing will feature a warning sound followed by a more intense sound. The warning/intense sound pair will be presented at randomized intervals, for which the dolphins are presumably not able to attenuate their hearing based on the timing of the intense noise, but instead rely on the warning sound.

Bottlenose dolphins.
Gary Barone, NOAA

Task 3: Determine role of outer hair cells in conditioned attenuation

AEP measurements in the presence of masking noise will be used to determine if outer hair cell function is affected during conditioned hearing attenuation. These data will reveal if the conditioned hearing attenuation is mediated by changes to outer hair cells/cochlear amplifier gain. The basic approach and trial sequence will be similar to that employed in Task 2 with AEPs measured before and after a warning sound paired with a more intense sound. The AEP stimulus and intense sound frequencies and SPLs will be constant. Three masking conditions during AEP measurements will be: 1) unmasked (no tonal masking noise), 2) on-frequency masked (short-duration tone-burst masker centered at the AEP test stimulus frequency) and 3) off-frequency masked (short-duration tone-burst masker with frequency below the AEP test stimulus frequency).

Task 4: Measure duration of conditioned attenuation

To determine how long the conditioned attenuation can be maintained, the time interval between the warning and intense sound will be randomized, with the upper limit for the time interval slowly increased over successive sessions to reveal how long dolphins can maintain the conditioned hearing attenuation. The frequency and SPL of the hearing test and intense sounds will be fixed. Testing will be conducted with two dolphins.

SCHEDULE

The project will begin in early fiscal year 2022 (FY22) and is expected to be completed by the end of FY23. Each of the four tasks is estimated to be completed within sequential six-month periods. The team will provide quarterly reports to LMR throughout the project and expects to complete applicable manuscripts by the end of the project's second year.

NAVY BENEFITS

The results will improve understanding of the potential impacts of conditioned hearing attenuation on marine mammal hearing and on current acoustic criteria. The data will support developing accurate acoustic criteria and ensure compliance with environmental laws (e.g., Marine Mammal Protection Act, National Environmental Policy Act).

TRANSITION

Manuscripts describing the results of Task 2 and Tasks 3 and 4 will be submitted to peer-reviewed journals. Results will inform acoustic criteria development.

ABOUT THE PRINCIPAL INVESTIGATOR

James Finneran has worked as a research scientist at the Naval Information Warfare Center (NIWC) Pacific since 2002, investigating marine mammal echolocation and marine animal auditory capabilities and studying the physiological effects of sound on marine animals. Dr. Finneran earned his Ph.D. in Mechanical Engineering from The Ohio State University.

Key contributors include Dr. Jason Mulsow and Dr. Dorian Houser from the National Marine Mammal Foundation.

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.navfac.navy.mil/lmr.