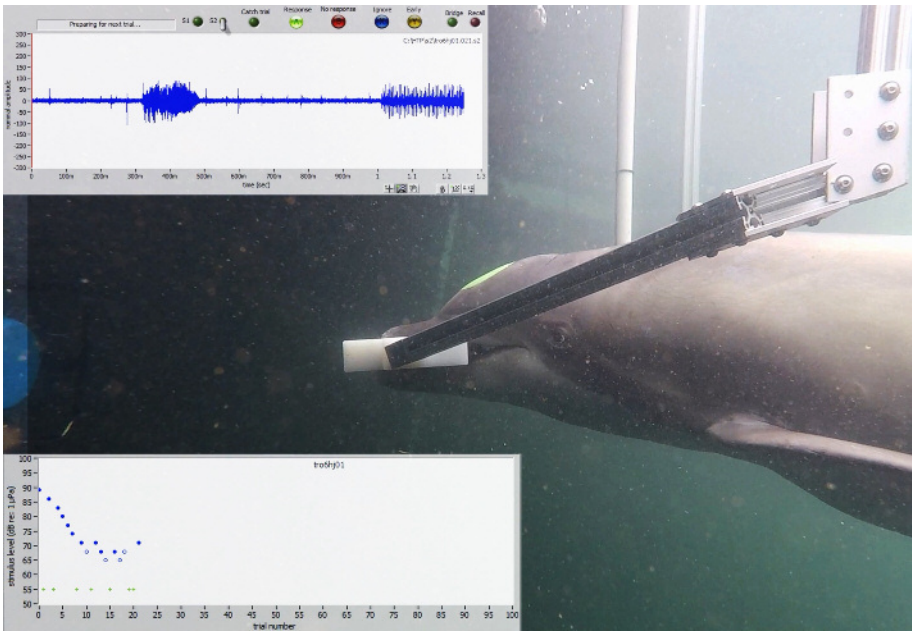
LIVING MARINE RESOURCES PROJECT 51

Dependence of TTS on Exposure Duration During Simulated Continuously Active Sonar: Examining the Equal-energy Hypothesis for Long-duration Exposures

NEED

Results from previous behavioral response studies have indicated that both the type and the duration of Navy sonar signals may play a role in observed responses in marine mammals. As sonar technologies change, the Navy needs new information on the effects of new types of sonar on marine mammal hearing and behavior. Continuously active sonar is a type that can operate at lower energy levels than traditional pulsed signals, but operates at higher duty cycles (i.e., transmits for a longer time). In 2017, LMR began investing in studying and collecting data on behavioral response to continuously active sonar as part of the third phase of the Sea Mammals and Sonar Safety (3S3) project (LMR Project 29). The Navy needs more information to further understand the effects of continuously active sonar on marine mammals, particularly with additional marine mammal species.



Bottlenose dolphin on a biteplate for behavioral hearing measurement.
Upper inset: The dolphin's whistle responses to test stimuli (followed by a buzzer sound indicating a correct response) are monitored using a hydrophone.
Lower inset: Over many trials, stimulus levels are decreased following correct responses to stimuli (closed circles are "hits") and increased when the dolphin does not detect the stimuli (open circles are "misses"). The average level of the transitions between hits and misses is used to define hearing threshold.

James Finneran

SOLUTION

This project is measuring temporary threshold shift (TTS) in the bottlenose dolphin using auditory evoked potential (AEP) and behavioral threshold measurements for longer duration signal exposure with signal qualities simulating continuously active sonar (CAS). The focus is to determine if equal energy exposures result in equal TTS, independent of exposure duration. In current Navy noise effects analyses, estimates of TTS onset are based on the equal energy hypothesis, which states that exposures of equal sound exposure levels (SEL) result in equal TTS. Therefore, the short, high sound pressure levels (SPLs) of pulsed sonar are considered equivalent—in terms of TTS—to lower SPL continuous exposures that have the same cumulative SEL. However, while source and received SPLs of CAS may be lower than those of pulsed sonars, accumulated SEL may be high due to the high duty cycles of CAS, as fewer quiet periods will be present during which SEL does not accumulate.

METHODOLOGY

The project goals are to:

1. Determine the extent to which the equal energy hypothesis can be used to predict TTS for exposures up to 60 minutes.
2. Determine if linear frequency modulation (LFM) common to CAS reduces TTS effects relative to continuous wave (CW) tones with equal SEL.

The research team will collect hearing data from two bottlenose dolphins at both a frequency representative of CAS (3 kilohertz [kHz]) and a frequency closer to the region of best hearing sensitivity (28 kHz).

Bottlenose dolphin on the biteplate station for noise exposures. The noise levels received by the dolphin are continuously monitored using hydrophones placed on the lower jaw.
Jason Mulsow

Data collection will begin with baseline hearing measurements. The dolphins will be trained to station on an underwater biteplate for hearing tests. Prior to all noise exposures, the team will measure both baseline behavioral (3 and 28 kHz) and AEP (28 kHz only) hearing thresholds at the exposure center frequency and surrounding frequencies (up to one octave above). The researchers will develop procedures for determining hearing thresholds in approximately 2–3 minutes for both behavioral and AEP methods so that thresholds can be measured on a short time scale relative to recovery.

For tests to determine noise levels, the dolphins will be trained to position themselves on a second underwater biteplate for noise exposures. Testing at 28 kHz will be completed before testing at 3 kHz begins. Following pre-noise hearing tests, the noise levels will start near the hearing threshold and be slowly increased over many sessions to train the dolphins to tolerate noise exposures while remaining on the biteplate. They will be intermittently reinforced with fish every 1–2 minutes. Maintaining this stationing behavior is crucial to ensure that the dolphins are within the calibrated sound field and receiving the appropriate noise levels.

The fatiguing stimuli used to induce TTS will be both CW tones, and LFM tones with bandwidths characteristic of CAS. Energy in the LFM signals will be modulated over approximately one-half octave, thus it is expected that TTS effects will be smaller than those observed for CW tones, which have noise energy distributed over a larger area in the frequency map in the inner ear.

In preliminary testing, noise levels will be progressively raised from low levels, with intermittent hearing tests conducted throughout the noise exposures to ensure that excessively large TTS are not induced during long duration exposures. This will minimize the chance of inducing a permanent threshold shift. To evaluate the effect of exposure duration on TTS, an experimental matrix (including control exposures) will be established for the CW and LFM tones to create multiple equal energy conditions with various durations. This will be initiated after approximately 6 decibel of TTS is detected using either behavioral or AEP methods during preliminary testing. The team will compare the CW and LFM exposures to determine if patterns differ between these sources despite having equal SEL. Hearing recovery will be monitored in the hours and days (if necessary) after a noise exposure to ensure a return to normal hearing prior to subsequent exposures. The health and welfare of the dolphins will be monitored by the attending veterinarians and animal care staff at the Naval Information Warfare Center, Pacific over the course of the study.

SCHEDULE

Initial animal training, baseline hearing and 28 kHz TTS measurements will be initiated during 2022. During 2023, work will shift to 3 kHz TTS measurements. Conference presentations will be given each year, and a manuscript will be drafted following the completion of the study.

NAVY BENEFITS

The data from this project will test how conservative the equal energy assumption may be for moderate-level CW and LFM exposures at durations of up to an hour. A potential goal is to determine a duration-based correction factor for TTS onset criteria to include in Navy criteria. Additionally, comparing CW and LFM TTS data will inform if the LFM is less likely to induce TTS. These results will support the Navy's acoustic effects criteria development.

TRANSITION

Data will be presented at conferences and a manuscript will be submitted for publication in peer-reviewed journals. Data and reports will be provided to the LMR program to be available for Navy acoustic effects analyses.

ABOUT THE PRINCIPAL INVESTIGATORS

Jason Mulsow is Deputy Director of the Biologic and Bioacoustic Research program at the National Marine Mammal Foundation (NMMF). His research uses behavioral and electrophysiological methods to examine sound reception and production in cetaceans and pinnipeds. He has worked on examining the effects of noise on marine mammals and in the development of criteria for estimating and mitigating such effects. Dr. Mulsow earned his Ph.D. in ocean sciences at the University of California, Santa Cruz.

Co-investigators are Dr. Alyssa Accomando, NMMF and Dr. James J. Finneran, Naval Information Warfare Center, Pacific.

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.