

Behavioral Responses of Odontocetes to Playback of Anthropogenic and Natural Sounds

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LONG-TERM GOALS

The long-term goal of this research project is to safely study responses of beaked whales to naval sounds in order to understand the causal chain of events leading from sound exposure to risks of stranding and to measure the exposure required to elicit responses that are safe but indicate potential for risk. The project is designed to provide critical information required to develop measures to protect beaked and other whales from risk of exposure to sonar and other sounds.

OBJECTIVES

A critical objective for understanding possible links between sonar exposure and injury or stranding involves developing techniques to safely study how beaked whales respond to sound. The objective of this project is to establish, test and refine new protocols for studying beaked whales using established sound playback experiment paradigms; to define responses of beaked whales and other species of odontocete whales to mid-frequency active (MFA) sonar, to a control noise stimulus with similar timing and bandwidth, and to natural sounds such as those from killer whales; and to measure exposure parameters for sounds that evoke a behavioral response.

APPROACH

The approach for this study involves controlled exposures to tagged whales where the scientific team controls the sound source (Tyack et al. 2003). This research effort seeks to quantify the risk of behavioral change as a consequence of sonar exposure and to discover what factors affect the probability of behavioral effects (e.g. received level at the animal, distance of the source, sound propagation conditions, waveform of the sound signal, behavioral state of the animal). Our experimental approach gives us the ability to study the causal relationship between sonar exposure and behavioral responses, and the factors that determine behavioral responses.

Field efforts were conducted at the Atlantic Undersea Test and Evaluation Center (AUTEK) on Andros Island, Bahamas, adjacent to the deep canyon of the Tongue of the Ocean (TOTO). AUTEK has a 600 square mile, permanent range of 82 bottom mounted hydrophones which can be used for detecting and locating cetaceans on the range using marine mammal monitoring equipment developed by NUWC-NPT. This capability for real time monitoring was a critical part of our experimental approach, as we

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used the range to find whales, and to determine in real time when they started and stopped producing echolocation clicks during deep foraging dives, responses that were used to control the playbacks. The design of these playback experiments called for tagging the subject with a calibrated sound and orientation recording tags (Digital Archival Tag – DTAG: Johnson and Tyack 2003), measuring pre-exposure behavioral data, conducting a playback, and then measuring post-exposure behavioral data. For beaked whales, playbacks were started when the whales started producing echolocation clicks during a deep foraging dive, and were stopped when they ceased echolocating. Playbacks to other species had timing similar to those for beaked whales. Working at AUTECH requires close collaboration with NUWC and its marine mammal monitoring (M3R) team. Tagging research has been conducted on this site to establish baseline data and continued collaboration will occur with the Bahamas Marine Mammal Research Organisation (BMMRO) for long term studies of these populations. This project requires extensive collaboration with biologists from the Sea Mammal Research Unit (SMRU) at the University of St. Andrews, biological oceanographers from Duke University, and bioacousticians at Cornell University.

WORK COMPLETED

A behavioral response study took place in the Tongue of the Ocean between 18 August and 5 October 2008. The general objective was to conduct playbacks of MFA sonar sounds and control sounds to odontocete whales, to measure behavioral responses to these playbacks and to measure the received levels of sound and other elements of exposure required to evoke these responses. There was an emphasis on conducting playbacks on Blainville's beaked whales, *Mesoplodon densirostris*. In order to conduct this study, it was necessary to apply for and receive scientific research permits from the US and Bahamian governments and for an assurance from Institutional Animal Care and Use Committees from WHOI and the Bahamas Marine Mammal Research Organisation. The WHOI team helped design and plan the study, built, tested and calibrated sound and orientation recording tags (Digital Archival Tag – DTAG: Johnson and Tyack 2003), tagged beaked, pilot, false killer, and melon-headed whales, and is helping to analyze and write up the results.

A total of 6 playbacks were conducted in 2008 on 4 species of odontocete cetacean that were tagged with Dtags. This adds to two playbacks conducted to one Blainville's beaked whale and one playback conducted to two pilot whales during 2007. In addition, observations were made of odontocete vocalizations at a group/population level using the AUTECH hydrophone array during playbacks. Mapping of potential prey and oceanographic parameters in this habitat also provided an insight into the factors that may affect beaked whale distribution at AUTECH in addition to anthropogenic acoustic activity. This integrated data set provides a significant advance in our understanding of the responses of odontocetes, and beaked whales in particular, to MFA sonar and control signals such as a noise stimulus (PRN) with the same timing and bandwidth as the MFA stimulus, and the sounds of killer whales.

The field operations in 2008 were interrupted by a succession of tropical storms and hurricanes that threatened the region during the time of the study. This meant that the number of playbacks achieved was lower than had been expected if weather conditions had been more typical for the time of year. There were a total of 9 playbacks on animals in BRS08, 5 of BRS_PRN1 and 4 of BRS_MFA1. For each sequence of transmissions, a full ramp up sequence was performed starting at a source level of 160 dB re 1 μ Pa at 1 m through maximum target source level of 211 dB, increasing the source level by 3 dB every 25 seconds and continuing transmissions for approximately 5 minutes at full power for a

shallow source depth. When source was deployed deep, transmissions were ceased when chief scientist called for stop transmission.

Table 1. Summary of BRS 08 playbacks

Date	Waveform Sequence	Tagged Species	Ramp-up # xmn	Max SL #xmn	Source depth (m)	Comments
22-Sep	PRN 1 MFA 1	Short finned pilot whale	16 17	14 14	23.4	1 transmission missed during ramp up, lost tag
26-Sep	PRN 1 MFA 1	False killer whale	17 17	13 14	25.6	
27-Sep	PRN 1	Blainville's beaked whale	17	3	66	Stopped playback when M3R notified that whale stopped clicking
28-Sep	MFA 1 PRN 1	False killer whale	17 17	13 13	25.6 25.6	Source was towed at 0.5kts during transmission
29-Sep	PRN 1 MFA 1	Short finned pilot whale	17 17	13 13	25.6	
29-Sep	PRN 1 MFA 1	Melon headed whale	17 17	13 13	25.6	2nd tagged whale, same playback

RESULTS

The extensive data sets emerging from this study still require some further analysis, but the following results are indicated by analyses to date. Integrating across the results from both BRS-07 and BRS-08 as well as analyses of likely beaked whale responses to sonar at the group/population level, the emerging pattern of response is as follows:

- (i) Based upon multi-year photo-identification and habitat mapping, Blainville's beaked whales are a resident species within the study area and individuals forage within the study area over multiple years. They appear to be able to survive, breed and forage successfully within this habitat in spite of considerable transmissions from naval acoustic sources, including on occasions MFA used at full power. Beaked whale distributions appear to be generally congruent with apparent food availability within the water column.
- (ii) While engaged in deep foraging dives, beaked whales responded to playback of sounds by premature cessation of echolocation clicks and by an unusually slow and long ascent. This response was statistically significantly different from 33 baseline dives (effect of playback on duration of clicking: $p < 0.001$). The whales responded to the anthropogenic stimuli by silencing at received levels of 138 dB (re 1 μ Pa rms averaged over 200 msec) for the sonar stimulus and 142 dB for the PRN stimulus. Both this response, and the exposure required to evoke it are similar to the response of a Cuvier's beaked whale, *Ziphius cavirostris*, in the Ligurian Sea to the sound of a noisy ship passing overhead (Aguilar et al. 2006). In this case, the whale ceased clicking during exposure to broadband noise at 136 dB and ascended prematurely from the dive. The response to killer whale sounds occurred soon after the stimulus was audible above background noise, at a received level of 98 dB. After the killer whale playback, the whale made a directed avoidance

response, swimming in an unusually linear path northward out of TOTO for ten hours. These results suggest that beaked whales are sensitive to noise at levels well below the current criteria used by US regulators for onset of behavioral disruption (160 dB re 1 μ Pa). While the sample size is very small, the combination of received levels required to evoke a response and the strength and duration of responses suggest that beaked whales have a similar response to all anthropogenic stimuli tested, but that they may respond more strongly and at a lower level to the sounds of killer whales. This interpretation is complicated by the fact that the killer whale playback was the second in a series of two playbacks to the same individual whale on the same day. This makes it difficult to tease apart the relative roles of waveform vs the combined effect of two playbacks.

- (iii) Other species tested appear to be less sensitive to MFA and control sounds than beaked whales. Although reactions to sonar sounds and control sounds were observed in some cases, there was less of a tendency for these species compared to beaked whales to silence and move away from the playback. A more common response was an increase in calling rate, coupled with increased cohesion. This suggests a social defense against predation, which may pose less of a risk of stranding than a strategy to flee.

IMPACT/APPLICATIONS

This study aims to reduce risks to whales and to foster the development of mitigation measures by defining the mechanisms by which beaked whales and other species are affected by sonars.

RELATED PROJECTS

ONR: Tagging and Playback Studies to Toothed Whales N00014-09-1-0528

SERDP: Acoustic Response and Detection of Marine Mammals on Navy Ranges Using a Digital Acoustic Recording Tag.

Naval Oceanographic Office: Behavioral Response Study (BRS-07) analysis and Supplemental Funding for BRS08

Marine Mammal Monitoring on Navy Ranges (M3R; David Moretti PI, NUWC-NPT)

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