

Cetaceans and Naval Sonar: Behavioral Response as a Function of Sonar Frequency

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LONG-TERM GOALS

The long term goal of this international cooperative research program is to investigate behavioral reactions and the sound exposures required to elicit them of herring, killer whales, pilot whales and sperm whales to Low Frequency Active Sonar (LFAS) and Mid Frequency Active Sonar (MFAS) signals, in order to establish safety limits for sonar operations for these species.

OBJECTIVES

The objective of this project is to quantify the behavioral reactions of cetaceans (killer whales, pilot whales and sperm whales) and herring to controlled presentations of military sonar signals at 2 different frequencies (LFAS:1-2 kHz and MFAS:6-7 kHz), and relevant control sounds within Norwegian waters. These data will be used to help establish safety limits for sonar operations.

APPROACH

This research effort seeks to quantify the risk of behavioral change as a consequence of sonar exposure, to discover what factors affect the probability of behavioral effects (e.g. received level at the animal, distance of the source, sound propagation conditions, frequency or amplitude of the sonar signal, behavioral state of the animal) and to understand what are the consequences for the animals and for human users of marine resources (such as tour operators). 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.

Our approach involves field trials using two ships, the R/V H.U. Sverdrup II (180 ft) and the MS Strønstad (94 ft). The Sverdrup is the main operational vessel from which the sonar source, Socrates sound source (TNO) is deployed, as well as the Delphinus hydrophone array (TNO) for passive acoustic monitoring. The Strønstad functions as the main animal tracking and observation vessel and is also equipped with a towed array, Beamer (SMRU). The research trial involves close collaboration among 4 institutions FFI, TNO, SMRU and WHOI, with each institution providing the personnel listed below:

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14. ABSTRACT The long term goal of this international cooperative research program is to investigate behavioral reactions and the sound exposures required to elicit them of herring, killer whales, pilot whales and sperm whales to Low Frequency Active Sonar (LFAS) and Mid Frequency Active Sonar (MFAS) signals, in order to establish safety limits for sonar operations for these species					
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FFI Personnel: Cruise leadership and permits, VHF-tracking, marine mammal observers, local knowledge, CTD/TL-measurements, tag-boat drivers, ARTS tagging.

SMRU Personnel: PI BRS cetaceans, DTAG-technician and tagger, marine mammal observer, visual trackers, photo id/documentation, VHF-tracking, acoustic tracking, acoustic measurements and analysis.

WHOI Personnel: DTAG pole tagger/ DTAG-technician

TNO Personnel: Software and hardware operators and technicians for Socrates sound source and Delphinus towed hydrophone array, marine mammal observers, visual observations,

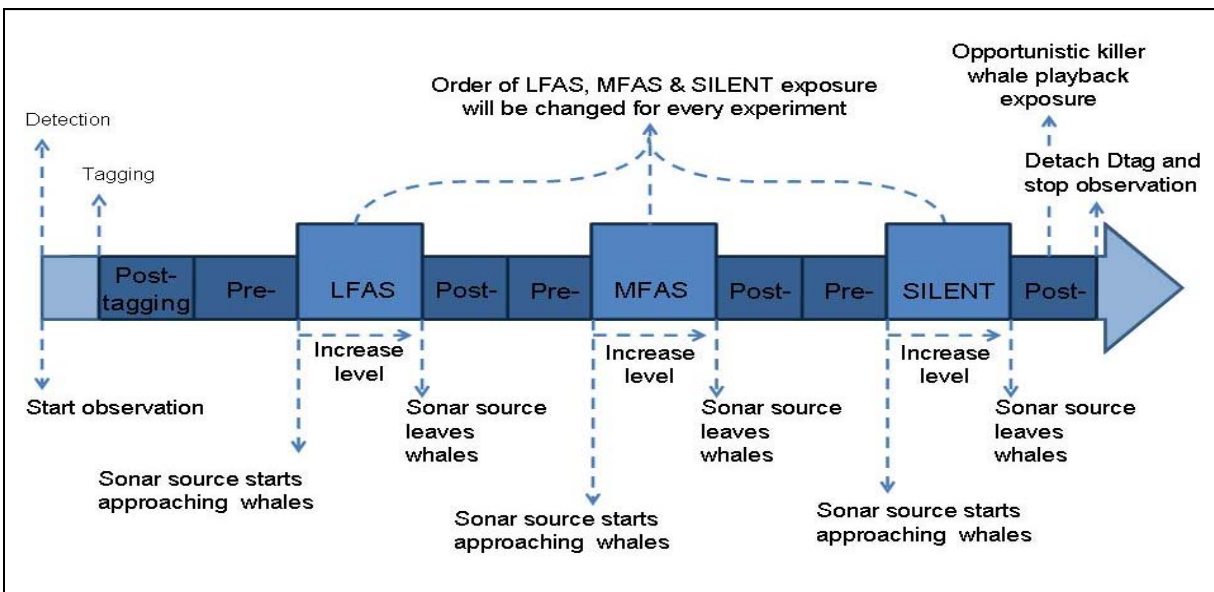


Figure 1. *The different steps in the multiple stimulus presentation used in the 3S experiments.*

The experiments involve a sequence of phases, from searching for potential subjects, to tracking a focal group, to tagging, playback, post-playback observations and recovery of the tag. During the searching phase, observation teams on both ships conduct visual surveys and both towed hydrophone arrays are deployed to listen for cetacean sounds. All visual sightings are recorded in Logger, acoustic detections are recorded by system-specific software. Upon an acoustic detection of a target cetacean, the vessel is maneuvered in the direction of the animals to obtain visual detection. Upon visual detection of a cetacean species that is a potential subject for the experiment, the observation team on board Strønstad starts a track with visual observations of the group. During tracking, the travel path, as well as individual and group behavioral parameters are monitored at a rate of 1 record per ~1.5 minute. Following 30 minutes of baseline data collection (pre-tagging phase), one or both tag boats are launched from Sverdrup to commence tagging with Dtags using either a pole, or the ARTS system for deployment. The tagging phase ends when one or two tags have been deployed, or the decision is made to leave that group. The following phase, the experiment, consists of a block design including LFAS, MFAS, killer whale sounds and silent approaches, including pre- and post exposure intervals before and after each block (see Figure 1). During the experiment, the Strønstad stays in good sighting range of the tagged animal for tracking, while the Sverdrup is positioned following a predetermined protocol

for the transmission of sonar sounds to the tagged animal with Socrates, and maneuvers accordingly. The playback protocol calls for positioning the ship about 4 nmi away from the subjects. The initial course of the source ship (Sverdrup) upon start of transmission is determined based on a visual fix before the start of transmission. The ship then approaches the subjects at a speed of 7-8 knots, adjusting course to head towards later sightings of the whales. It ramps up the source level of the source and then continues to approach with the source at maximum level. During the tracking of sperm whales, the individuals are tracked acoustically during dives and these acoustic locations may also be used to direct the ship with respect to the whales. Once the source ship is 1 km from the whales, it maintains the same course and transmits until the standard end of the transmission sequence. The goal of the playback protocol is to conduct a silent playback, MFAS and LFAS in a random sequence to each animal. If there is time, this may be followed by a killer whale or other playback. The 3S09 cruise was also able to test a new protocol designed to test the efficacy of ramp-up. Following the release of the tag(s), both ships return to searching phase and data checking/processing.

WORK COMPLETED

The 3S group currently involving four main partners (FFI, TNO, SMRU and WHOI) conducted in May-June 2009 a research trial in Norwegian waters to investigate behavioral reactions of killer whales, pilot whales and sperm whales to Low Frequency Active Sonar (LFAS) and Mid Frequency Active Sonar (MFAS) signals, in order to establish safety limits for sonar operations. The research group consisted of 29 scientists from 9 different countries. All work was conducted under a Norwegian research permit. The tasks of this research trial were as follows:

Primary tasks:

1. Tag killer whales, pilot whales and sperm whales with DTAG recording behavior, and thereafter carry out controlled exposure experiments (CEE) where the tagged animals are exposed to LFAS-, MFAS sonar signals and control experiment without any active transmission.
2. Test new techniques for deployment of DTAGs

Secondary tasks:

1. Carry out control experiments where tagged animals are exposed to a playback of killer whale sounds.
2. Carry out pilot experiments where tagged animals are exposed to LFAS or MFAS up-sweep and down-sweep signals.
3. Do pilot studies on cetaceans to investigate the effectiveness of sonar ramp-up.
4. Collect group behavioral data to investigate the effect of tagging
5. Carry out pilot CEE experiments on new species (minke whales, bottlenose whales).
6. Retrieve information about the acoustic environment of the study area by CTD or XBT measurements, and do acoustic propagation modelling.
7. Tag animals and record natural undisturbed behavior.

The cruise planning meeting took place in February 2009. The 3S-09 cruise took place along the coast of Northern Norway between 66° and 70° northern latitude between May 14 and June 11, 2009. We deployed 17 Dtags to sperm whales, killer whales and pilot whales. These tags have recorded the behavior of the tagged animal for 176 hrs total. We conducted 6 sonar exposure experiments using the Socrates sonar source transmitting signals in different frequency bands and waveforms and conducted the same number of negative and positive controls using vessel approaches without sonar transmission and playbacks of killer whale sounds, respectively. In addition we have conducted a pilot experiment

on how to study effects of ramp up using a different exposure protocol, and collected baseline data on all three species. In carrying out these experiments we have also systematically collected focal follow and group behavioral data according to predefined protocols and we have collected data on the effects of tagging. We also achieved significant progress in developing new techniques for deployments of tags using both the remote launching system ARTS and a specially designed setup with a very long hand held pole for sperm whale tagging. In addition, we have collected data on the acoustic transmission conditions in the environment and collected data on passive acoustic detection and tracking of marine mammals from two towed arrays (Delphinus (TNO) and Beamer (SMRU)).

RESULTS

Table 4.1 summarizes the main data collecting events of the trial.

Table 4.1. Main 3S data collecting events.

Event/ Species	Date/ Area	Data collection	Comments
1.Exercise CEE	May 16. Tysfjord	Exercise	Exercise regular CEE protocol with tagged buoy in Tysfjord. Calibrate Dtags.
2. Pilot whales	May 17. Vestfjord	Baseline	3dtags deployed, 25.5h of recording
3. Pilot whales	May 18. Vestfjord	Sonar exposure	2dtags deployed, 28.5h of recording. LFAS-MFAS-Silent-LFAS down sweep-orca-experiments.
4.Sperm whale	May 20. Bleikdjupet	Sonar exposure	1dtag deployed, 15.5h of recording. LFAS-MFAS-Silent-Orca-experiments.
5.Sperm whale	May 21. Off shore	Sonar exposure	1dtag deployed, 15h of recording. LFAS-MFAS-Silent-orca-LFAS down sweep-experiments.
6.Killer whales	May 23. Off shore	Baseline	1dtag deployed, 13h of recording.
7.Killer whales	May 24. Off shore	Sonar exposure	2dtags deployed, 24.5h of recording. LFAS-MFAS-orca-LFAS down sweep-experiments.
8.Pilot whales	May 26. Vestfjord	Sonar exposure	1dtag deployed, 2.5h of recording baseline behavior.
9.Exercise ramp-up	May 28. Ofotfjord	Exercise	Exercise ramp up protocol with tagged tag boat
10.Sperm whale	June 2. Andfjord	Baseline	1dtag deployed, 8.5h of recording of baseline data, but without visual tracking
11.Pilot whales	June 5. Ofotfjord	Sonar exposure	1dtag deployed, 18h of recording. LFAS-MFAS-Silent-Down sweep-Orca experiments.
12.Pilot whales	June 6. Ofotfjord	Sonar exposure	1dtag deployed, 8.5h of recording. Ramp up experiment.

13.Killer whales	June 8. Andenes	None	None, 18 hrs of non successful tagging attempts. Vocalization data recorded
14.Sperm whale	June 8. Andenes	Baseline	1dtag deployed, 2.5h of recording of baseline data.
15.Sperm whale	June 9. Blue ocean	Sonar exposure	1dtag deployed, 15h of recording. LFAS-MFAS-Orca and LFAS down sweep experiments.

IMPACT/APPLICATIONS

The success of this project in achieving large numbers of playbacks for several stimulus types and several species affirms the role of CEEs in effects studies. This project continues to build a strong international team, platform, and technology with excellent skills for developing and conducting studies on the effect of sonar on marine life. The results show little adverse effect of sonar on herring, and the differential response of killer whales to low vs mid-frequency sonar suggests potential use of frequency as a mitigation measure.

RELATED PROJECTS

The 3S project involves a collaboration between the Norwegian Defence Research Establishment (FFI), Maritime systems, Norway, TNO Defense Security and Safety, Observations Systems, The Netherlands, the Sea Mammal Research Unit, University of St. Andrews, Scotland and the Woods Hole Oceanographic Institution, USA. The SMRU and WHOI efforts are supported by ONR, and the 3S project includes cost sharing from the Norwegian and Dutch navies. The ONR projects Behavioral Response of Odontocetes to Playback of Anthropogenic and Natural Sounds (N00014-07-1-0988) and Tagging and Playback Studies to Toothed Whales (N00014-09-1-0528) are part of collaborative research programs that aim to study how tagged beaked whales respond to mid-frequency sonar compared to control sounds, and to compare responses of beaked whales vs other odontocetes to playbacks of mid-frequency sonar sounds vs other anthropogenic signals. Ultimately these studies all aim to define dose: response curves for risk to beaked and/or other whales for exposure to naval sonars, and to suggest improvements for mitigation.

PUBLICATIONS

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