

Cetacean social behavioral response to sonar exposure

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Award Number: N000141512341
<http://www.onr.navy.mil/Home/Science-Technology/Departments/Code-32.aspx>

LONG-TERM GOALS

The goal of this effort is to investigate cetacean social behavioral response to sonar signals.

OBJECTIVES

The scientific objectives of this effort are to determine:

- 1) social behavioral responses of cetaceans to sonar and to tagging, to investigate the biological relevance and severity of sonar responses;
- 2) the social behavior of Risso's dolphin (*Grampus griseus*) in two separate populations, to investigate the function and role of social behavior in shaping the behavioral response to sonar in social cetaceans;
- 3) the social behavior and behavioral response of Risso's dolphin in a habitat with limited anthropogenic noise disturbance.

APPROACH

Social, group-level cetacean behavioral responses to sonar signals, tagging effort and killer whale playbacks, as well as baseline behavior, are studied using controlled exposure experiments (CEEs). The CEEs are or have been conducted as part of the 3S/3S² and SOCAL behavioral response studies (BRS) off Norway and California. Visual sampling of cetacean group-level behavioral parameters is conducted, concurrent with focal individual tracking and data-collection from digital archival suction-cup tags and towed hydrophone arrays.

Additional data on the baseline behavior and behavioral response of the studied cetacean species is obtained during dedicated baseline behavior research at the Azores (shore- and vessel-based), during the Azores-Baseline Project, enabling the collection of larger sample sizes than is generally possible within the framework of CEEs, to augment the understanding of the natural behavior of the cetaceans studied in relation to observed behavioral responses to stimuli.

Applied focal follow sampling protocols for visual sampling of group behavior were developed specifically for the use in this project. Specific requirements for the protocols included systematic and generic collection of cetacean group behavior, providing quantitative, high quality data allowing for comparison across species, studies and areas. Generic properties of sampling protocols facilitating cross-comparison are deemed to be of special importance in BRS studies, which are conducted over a wide range of species and areas, and may be characterized by relatively limited sample sizes.

In cooperation with the 3S and SOCAL-BRS projects, and during the Azores-Baseline Project, we collect compatible datasets on the natural social behavior and social behavioral response of BRS target species. These datasets are then compared to allow for cross-species, cross-context (exposures) and cross-area investigation of the nature and magnitude of target species social response. Specifically, data collected during the 3S-Project allows for cross-species and cross-context comparison of behavioral response of social toothed whales. Data collected during the SOCAL-BRS and Azores-Baseline Projects allow for cross-area and cross-context comparison of cetacean behavioral response.

Key individuals

Dr. Fleur Visser (Kelp Marine Research & Leiden University, the Netherlands), project PI. Patrick Miller (SMRU, Scotland), Peter Tyack (SMRU, Scotland), Frans-Peter Lam (TNO, the Netherlands) and Petter Kvadsheim (FFI, Norway) form the board of the 3S-project. Brandon Southall (SEA.inc), is the PI of the SOCAL-BRS project. Together with Hans Slabbekoorn, associate professor at the Behavioural Biology Group of Leiden University, the Netherlands, they act as scientific advisors.

WORK COMPLETED

- Project publications
 - In FY15, the project contributed to 3 peer-reviewed publications and a technical report. A further 2 lead- and 2 co-author manuscripts are currently in review.
 - Manuscript detailing the nature and magnitude of cetacean social responses, and their biological relevance (objective #1), currently in review: *Visser F, Curé C, Kvadsheim PH, Lam FPA, Tyack PLT, Miller PJO (in review). Disturbance-specific social responses in long-finned pilot whales, Globicephala melas.*
- Fieldwork projects FY2015
 - Azores-Baseline field study (July/August 2015)
 - Data-collection: Social behavioral response & baseline social behavior
 - Baseline: Risso's dolphin (13 Dtag records; objective #2)
 - Additional baseline behavior collected on Cuvier's beaked whale (3 Dtag records), Northern bottlenose whale, short-finned pilot whale (2 Dtag records), Sowerby's beaked whale (extended value for objective #2)
 - Behavioral response (natural sounds, tagging): Risso's dolphin (objective #3).
- Cross-area, -context and -species comparison of (group-level) behavioral response
 - Data-analysis, processing and manuscript preparation of combined BRS datasets (3S, 3S², SOCAL-BRS and Azores-Baseline; 2008 – 2015; Objectives #1-3)
 - Cross-area comparison of Cuvier's beaked whale diving behavior (collaborative effort; extended value objective #2).
 - Progress meetings 3S² and SOCAL-BRS projects
 - Continued training of social behavior observer for SOCAL-BRS

- Project presentations
 - 3S²-Symposium, University of St Andrews, October 2015
 - The biannual conference of the Society for Marine Mammalogy, San Francisco, December 2015
 - The annual conference of the society for behavioral biology, Amersfoort, November, 2015

RESULTS

Social response important factor in social toothed whale behavioral response

Analysis of the social behavioral response of long-finned pilot whales (*Globicephala melas*) revealed that a unifying characteristic of their behavioral response to natural and anthropogenic disturbance (including naval sonar) is to increase their level of social cohesion (Fig. 1). This indicates that sociality will be an important driver of the nature and magnitude of their chosen response tactics. Moreover, social responses were disturbance-specific, indicating that the pilot whales were able to adapt their social response to the type of threat they were exposed to (sonar, tagging effort or predator/competitor sounds). Long-finned pilot whale response to sonar revealed an anticipatory response-tactic, where individuals did not individually avoid the approaching source (and disperse), but convened at the surface (increased group size, preference for logging and shallow diving). This is most likely a social response which anticipates against potential loss of social cohesion, which may be induced by masking of their communication signals, or by the need for individuals to avoid a loud approaching sound source. Convening at the surface will allow the whales to also use visual cues to locate group members, and could enable a joint coordinated avoidance response, if this would be necessary. These findings implicate potential loss of foraging opportunities, particularly during exposures extending over multiple days, and limited opportunity for an early onset of (avoidance) responses to sudden, loud sounds. Currently, this work is taken further by a multi-species comparison of social behavioral response to naval sonar and other disturbance-types (objective #1).

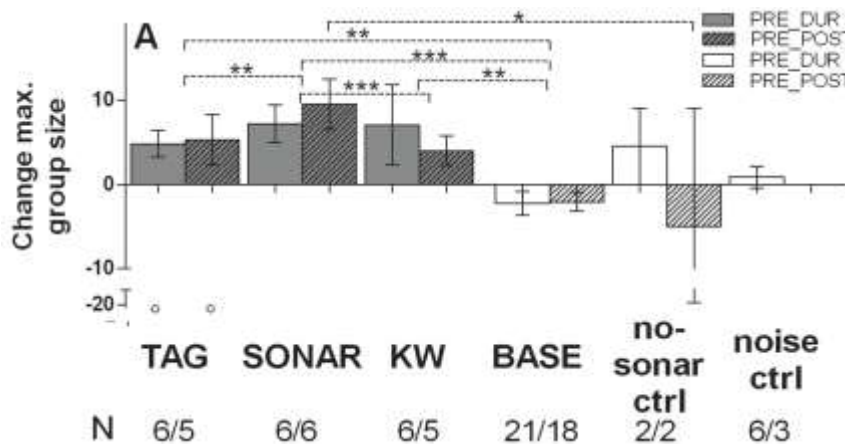


Figure 1. Changes in the aggregation behavior of long-finned pilot whales in response to 3 disturbance conditions (tagging effort (TAG), sonar exposure and killer whale playback (KW); grey bars) in comparison to 3 control conditions baseline (BASE), no-sonar control (ctrl) and noise control (white bars). Positive or negative change scores respectively indicate an increase or decrease in maximum group size. PRE_DUR: difference in behavior between during and pre-exposure

*period. PRE_POST: difference in behavior between post- and pre-exposure period. Error bars indicate SE, open circles indicate outliers. Dashed lines indicate significant changes at $p < 0.05$, $** < 0.01$ or $*** < 0.0001$. From Visser et al. (in review).*

Cross-area comparison of social behavior

During fieldwork for the Azores-Baseline Project in 2015, we collected 60+ hours of data on the baseline behavior and behavioral response of Risso's dolphins (objectives # 2 and 3), which feeds into the existing database on this species (2011-2014). In total, 13 individuals were equipped with a Dtags, including several longer-duration attachments (10-16 hour deployments, Table 1). Risso's dolphin tag attachment durations are typically relatively short (<5 hours) and these records are among the longest deployments collected for this species thus far. The 2015 data substantially augmented our database and has started to fill some important gaps (foraging data, night-time data). The data is currently being analyzed for cross-area comparison of Risso's dolphin behavior in the North Atlantic (Azores) and in the North Pacific (California; SOCAL-BRS).

In addition, we collected tag data from 3 deployments on Cuvier's beaked whale (*Ziphius cavirostris*), including one simultaneous deployment of 2 tags on two individuals in one group, and one 24.7-h deployment (Table 1). These deployments have resulted in high quality off-range datasets (long records, high quality movement and acoustic data across behavioral contexts, limited/no acoustic disturbance), and first records to be collected in the North Atlantic. Beaked whales, and particularly the Cuvier's beaked whale, are among the species that are most sensitive to naval sonar. Information on their natural behavior is essential to improve our understanding of their response. This is hard to obtain however, given their cryptic lifestyle and difficulty to approach for tagging. The 3 tag datasets obtained in 2015 are the first records of the diving, foraging and acoustic behavior of this species at the Azores. They showed foraging depths and acoustics consistent with those found in other areas, and the double tag record revealed coordination in the diving behavior of the two tagged whales. The tag records are currently being analyzed in detail for cross-area and cross-species comparison of beaked whale behavior.



Figure 2. Left: Risso's dolphin with Dtag (v3). Right: Cuvier's beaked whale with Dtag (v3). Both individuals were tagged at the Azores during the Azores-Baseline 2015 Project, under permit number SAI/DRA/2015/1267 (issued by Secretaria Regional da Agricultura e Ambiente, Portugal).

Ongoing – data analysis and collaborative efforts

There are currently 4 manuscripts in review and 6 manuscripts in preparation which use social behavior data collected as part of the current project, or using social behavior from the existing 3S, SOCAL-BRS and Azores-Baseline Project databases. These manuscripts represent collaborative efforts between the project partners and involve the sharing of data and expertise within and across research teams.

IMPACT/APPLICATIONS

Social behavior of cetaceans, social responses to changes in their environment and natural patterns of behavior form an essential element in our understanding of the complex nature of cetacean behavioral response to sonar. For example, understanding of the sonar response of long-finned pilot whales remained limited, until inclusion of social behavior response data revealed that the preference for shallow diving likely resulted from the drive to maintain group cohesion. The current project matches databases for cross-comparison of data between BRS projects, species and areas, enhancing the strength of each individual database (often with limited sample size) and our understanding of the biological relevance of observed responses. In turn, this will aid in the development of efficient mitigation measures. Our approach, visual observation in combination with multi-sensor data collection, may serve as a tool to tailor and specifically target BRS methodology to include species for which tagging methodology currently is not available.

Table 1. Dtag deployments Azores Baseline project 2015 (July-August 2015).

Species		Date	Tag on time UTC/Local	Tag off time UTC/Local	Duration (hour)
Short-finned pilot whale	<i>G. macrorhynchus</i>	7-7-2015	14:54:14	20:31:00	5.6
Short-finned pilot whale	<i>G. macrorhynchus</i>	7-7-2015	16:01:59	20:47:00	4.8
Risso's dolphin	<i>Grampus griseus</i>	23-7-2015	11:25:46	12:25:52	1.0
Cuvier's beaked whale	<i>Ziphius cavirostris</i>	24-7-2015	14:38:27	15:20:00	24.7
Cuvier's beaked whale	<i>Ziphius cavirostris</i>	31-7-2015	8:45:21	20:34:00	11.8
Cuvier's beaked whale	<i>Ziphius cavirostris</i>	31-7-2015	8:46:52	21:02:00	12.3
Risso's dolphin	<i>Grampus griseus</i>	10-8-2015	9:18:42	10:02:04	0.7
Risso's dolphin	<i>Grampus griseus</i>	10-8-2015	9:06:03	10:02:06	0.9
Risso's dolphin	<i>Grampus griseus</i>	16-8-2015	11:41:38	15:05:00	3.4
Risso's dolphin	<i>Grampus griseus</i>	17-8-2015	13:08:40	13:15:30	0.1
Risso's dolphin	<i>Grampus griseus</i>	17-8-2015	13:53:00	0:52:00	11.0
Risso's dolphin	<i>Grampus griseus</i>	17-8-2015	9:41:20	2:21:20	16.4
Risso's dolphin	<i>Grampus griseus</i>	18-8-2015	17:45:08	17:45:16	<1min
Risso's dolphin	<i>Grampus griseus</i>	19-8-2015	12:57:03	12:57:20	<1min
Risso's dolphin	<i>Grampus griseus</i>	19-8-2015	11:32:10	11:57:31	0.4
Risso's dolphin	<i>Grampus griseus</i>	20-8-2015	10:55:27	10:55:49	<1min
Risso's dolphin	<i>Grampus griseus</i>	20-8-2015	9:45:29	9:59:45	0.2
Risso's dolphin	<i>Grampus griseus</i>	20-8-2015	10:20:10	12:43:03	2.4

RELATED PROJECTS

3S Project. A substantial part of this work is and has been executed as an integral part of the 3S project, in close cooperation with the 3S research team. Group sampling methodology for BRS as described here was developed within the 3S project and used in 3S². ONR Award number: N000141010355

SOCAL-BRS. Cooperation in the development and execution of tagless playbacks, cross-study, -species and -area comparison of response, and group sampling methodology in BRS. SOCAL-15 project website: <http://sea-inc.net/SOCAL-brs/SOCAL-15/>

PUBLICATIONS

Visser F, Curé C, Kvadsheim PH, Lam FPA, Tyack PLT, Miller PJO (in review). Disturbance-specific social responses in long-finned pilot whales, *Globicephala melas*.

- Visser F. et al. (in review). *Vocal foragers and silent crowds: the socio-behavioural context of long-finned pilot whale vocalisations.*
- Arranz P, DeRuiter SL, Stimpert AK, Neves S, Friedlaender AS, Goldbogen JA, Visser F, Calambokidis J, Southall BL, Tyack PL (in review). *Discrimination of fast click series produced by Risso's dolphins for echolocation or communication.*
- Wensveen P. et al (in review). *The effectiveness of ramp-up of naval sonar to reduce sound levels received by marine mammals: experimental tests with humpback whales.*
- Kvadsheim et al. (2015). *The 3S2 experiments – studying the behavioral effects of naval sonar on Northern bottlenose whales, humpback whales and minke whales. 3S2 Technical Report. FFI-rapport 2015/01001. <http://rapporter.ffi.no/rapporter/2015/01001.pdf> [published].*
- Sivle LD, Kvadsheim PH, Curé C, Isojunno S, Wensveen PJ, Lam FPA, Visser F, Kleivane L, Tyack PL and Miller PJO (in press). *Severity of putative behavioural responses of humpback whale, minke whale and Northern bottlenose whale to naval sonar. DOI 10.1578/AM.41.4.2015.xxx [published, refereed].*
- Miller PJO, Kvadsheim PH, Lam FPA, Tyack PL, Curé C, DeRuiter SL, Kleivane L, Sivle L, van IJsselmuide SP, Visser F, Wensveen PJ, von Benda-Beckmann AM, Martin-Lopez L, Narazaki T and Hooker SK (2015). *Northern bottlenose whales are sensitive to noise disturbance. Royal Society Open Science 2:140484[published, refereed].*
- Curé C, Doksæter Sivle L, Visser F, Wensveen PJ, Isojunno S, Harris C, Kvadsheim PH, Lam FPA, Miller PJO (2015). *Predator sound playbacks reveal flight responses in a fight strategist baleen whale. MEPS 526:267-282 [published, refereed].*