

Ceteacean Social Behavioral Response to Sonar

Fleur Visser
Kelp Marine Research
Loniustraat 9, 1624 CJ, Hoorn, the Netherlands
phone: (+31) 6 280 75 836 email: fvisser@kelpmarineresearch.com

Award Number: N000141110298
<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 1) to study social, group-level behavioral responses of cetaceans to sonar signals and other stimuli, including tagging; 2) to study natural, baseline social behavior; 3) to develop quantitative sampling methodology for the study of group-level and surface behavior of cetaceans; 4) to investigate the potential to study behavioral responses of cetaceans to sonar signals in situations where tagging is not at present possible (tagless playbacks); 5) to facilitate the compatibility of methods and the comparison of results between behavioral response studies.

APPROACH

Social, group-level cetacean behavioral responses to sonar signals and other stimuli (tagging effort, killer whale playbacks) as well as baseline behavior, are studied within the larger framework of controlled exposure experiments (CEEs) 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 takes place simultaneous with focal individual tracking and data-collection from digital archival suction-cup tags and towed hydrophone arrays.

Additional data on the baseline behavior of the studied cetacean species is obtained during dedicated baseline behavior research at the Azores (shore- and vessel-based), 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.

Focal follow sampling protocols for visual sampling of cetacean group behavior were developed specifically for the use in this project. Specific requirements for the protocols included non-biased, 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 of data 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.

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE 30 SEP 2013	2. REPORT TYPE	3. DATES COVERED 00-00-2013 to 00-00-2013			
4. TITLE AND SUBTITLE Cetecean Social Behavioral Response to Sonar		5a. CONTRACT NUMBER			
		5b. GRANT NUMBER			
		5c. PROGRAM ELEMENT NUMBER			
6. AUTHOR(S)		5d. PROJECT NUMBER			
		5e. TASK NUMBER			
		5f. WORK UNIT NUMBER			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Kelp Marine Research, Lonijsstraat 9, 1624 CJ, Hoorn, the Netherlands,		8. PERFORMING ORGANIZATION REPORT NUMBER			
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)			
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)			
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 8	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

In cooperation with the 3S and SOCAL-BRS projects, we test the compatibility of the developed group-level methodology within BRS projects, the potential for comparison of cetacean behavior between research areas and the performance of group-level focal follow protocols for use in tagless playbacks.

Data analysis specifically focuses on the integration between concurrent recordings of surface group behavior (focal follows), vocal behavior (suction-cup tags, towed hydrophone arrays), movement behavior (focal follow, tags) and diving behavior (tags).

Key individuals

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. Together with Hans Slabbekoorn, associate professor at the Behavioural Biology Group of Leiden University, the Netherlands, they act as scientific advisors. Brandon Southall (SEA.inc), PI of the SOCAL-BRS project, has a main role in the design and execution of tagless playbacks.

WORK COMPLETED

- Full implementation protocol for group behavior sampling across BRS studies
 - Status: operational in 3S², SOCAL-BRS and Azores-Baseline projects since 2011
 - Species: social odontocetes, beaked whales, baleen whales
- Fieldwork projects
 - PI, lead Azores-Baseline field study (July-August 2013)
 - Field-leader 3S-pilot whale baseline field study (June 2013)
 - 3S² and SOCAL-BRS field studies (June/July 2013; September 2013)
- Data-collection: Social behavioral response
 - Response to tagging and experimental sonar exposure in 3S² and SOCAL-BRS
 - Response to operational naval sonar source in SOCAL-BRS
 - Response to killer whale vocalizations in 3S²
 - Response to tagging and vessel noise exposure in Azores-Baseline
 - Species: Northern bottlenose whale, Risso's dolphin, short-finned pilot whale
- Data-collection: Baseline social behavior
 - 3S², Azores-Baseline and SOCAL-BRS projects
 - Species: Northern bottlenose whale, minke whale, short-finned pilot whale, Risso's dolphin
- Development and testing of protocols for tagless playbacks
 - Status: Finalized test-phase in SOCAL-BRS
 - Reported: recommendations for set-up tagless playbacks using visual observation techniques
 - Species evaluated: long-beaked common dolphin, bottlenose dolphin, killer whale
- Cross-study implementation of group sampling methodology
 - Protocols used in four BRS studies since 2011: 3S², SOCAL-BRS, Azores-Baseline, BRS-Med
 - Joint data-analysis with MOCHA Project
 - Presentation, use of social behavior data and results in MOCHA project
 - Continued training of social behavior observer for SOCAL-BRS
 - Cruise planning and progress meetings 3S², SOCAL-BRS and Azores-Baseline projects
- Project presentations
 - Presentation of project results at the 2013 Biennial Conference of the Society for Marine Mammalogy in Dunedin, New Zealand, Dec. 2013.

RESULTS

Operational protocol for group sampling of cetaceans

Application of the group sampling protocol during the 2013 fieldwork off Jan Mayen, California and the Azores on a set of target cetacean species confirmed that the group behavior sampling protocol is widely applicable to cetacean species forming relatively stable, small-medium sized groups (<30). The project has thereby delivered a group sampling protocol enabling the comparison of social, surface behavior data across BRS studies. Additional added value of the protocol was found in the recording of surface behaviors for species which typically spend longer times at or near the surface, including when foraging, potentially limiting the capability of the tag to differentiate between behavioral states (e.g. baleen whales). The protocol has to date been used to record short- and long-finned pilot whale, Risso's dolphin, killer whale, sperm whale, Northern bottlenose whale, Sowerby's beaked whale, humpback whale, Cuvier's beaked whale, bottlenose dolphin, false killer whale, blue whale, fin whale, and minke whale social and/or surface behavior in waters off Norway, Spitsbergen, Jan Mayen, the Azores, California and Cape Hatteras and in the Mediterranean Sea and the Gulf of St Lawrence.

Cetacean social behavioral response and natural behavior

Northern bottlenose whale – 3S²

During the 3S²-13 cruise off Jan Mayen (Norway), we collected group behavior data and tracks of 63 Northern bottlenose whale groups, concurrent with acoustic data-collection from the towed array (Fig. 1). This represents a unique dataset on the group behavior of Northern bottlenose whales, and is the first of its kind to be collected in the waters off Jan Mayen. The success in obtaining a large dataset and prolonged trackings of Northern bottlenose whale groups to a large degree resulted from combined localization of the focal group at the surface (visual observations) and sub-surface (acoustically, by towed array), which was integrated to optimize the sailing track of the research vessel for tracking of the focal group (boxing strategy; Kvadsheim et al. 2013). Focal follows included both tagging and baseline phases (Fig. 2). One CEE was conducted (Kvadsheim et al. 2013).



Figure 1. Groups of three and five Northern bottlenose whales observed off Jan Mayen, July 2013. Pictures: E. Grønningsaeter for the 3S-Project.

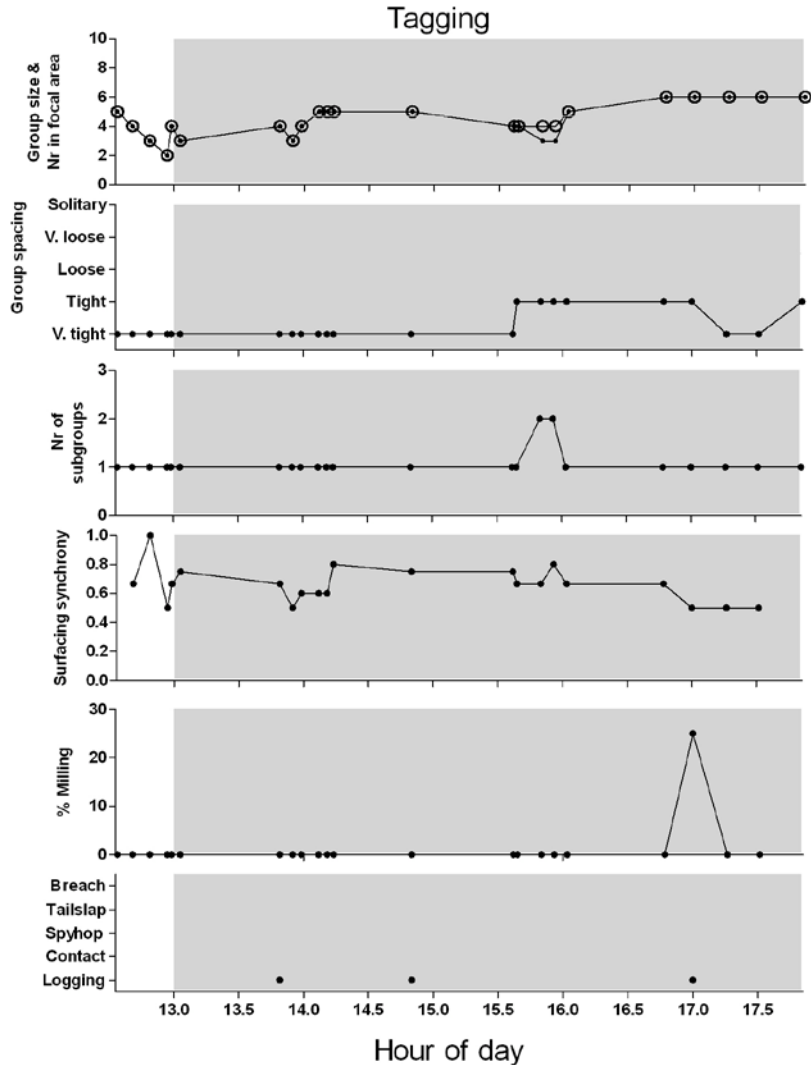


Figure 2. A 5.3h focal follow of a group of 2-6 Northern bottlenose whales, conducted July 3rd, 2013. The stacked graphs show (top to bottom) the group behavior parameters 1) group size and number of individuals in the focal area, 2) group spacing, 3) the number of subgroups within 200m, 4) surfacing synchrony, 5) the percentage milling of the focal group and 6) the presence of surface display events during tagging effort of the focal group.

Risso's dolphin – SOCAL-BRS & Azores-Baseline

In total 37 hours of group behavior and tracking data was collected for 10 Risso's dolphin focal groups during experimental research effort in SOCAL-13, concurrent with data-collection from the digital archival tags. The presence of a second trained observer for the collection of the group behavior data allowed for extended data-collection, and for simultaneous focal follows on two different groups with tagged individuals during the CEE's. Group behavior data was collected during 3 experimental exposures to mid-frequency active (MFA) sonar, of which one was exposure to a real navy source, operating in the area of the tagged whale group. In addition, group behavior was recorded during 3 control exposures (silent).

In total 126 hours of shore- and vessel-based group-level behavior and tracking data was collected during 68 focal follows of Risso's dolphin groups during the Azores-Baseline project in 2013 (Figs. 3 & 4). The shore-based observations allow for extended investigation of baseline behavior, without any vessels present near the focal whales. A digital archival tag was deployed during 10 of these focal follows, for a total duration of 20 hours.

This large, multi-sensor dataset allows for analysis of Risso's dolphin natural patterns of behavior, of behavioral responses to tagging and vessel noise using behavioral metrics from the different data-streams. In addition, it allows for the comparison of Risso's dolphin natural behavior, and behavioral responses, between two BRS research areas, California and the Azores. The tagging data obtained for Risso's dolphin in the Azores forms the first extended dataset able to give insight into underwater behavior and vocalizations of the species in the North Atlantic ocean.

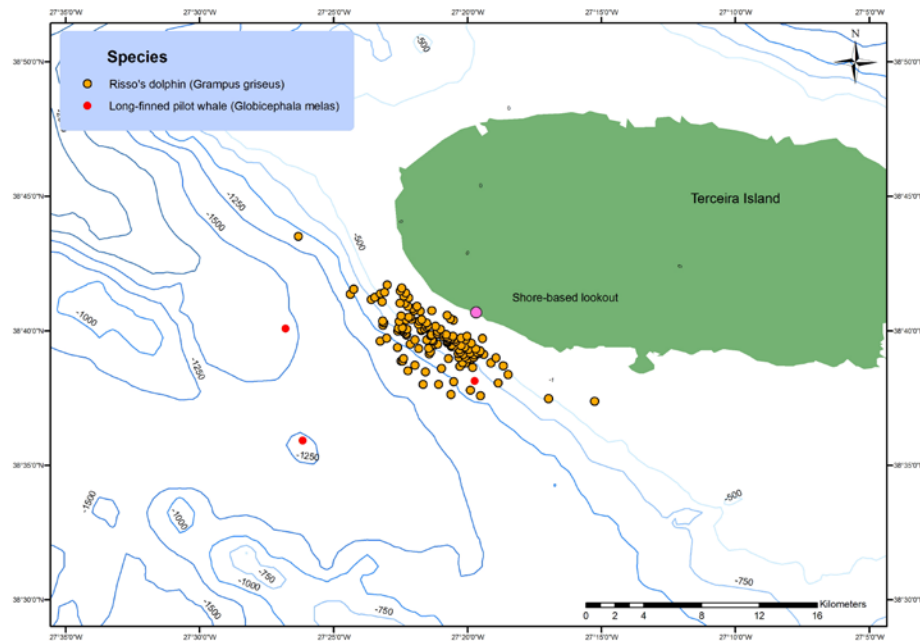


Figure 3. Shore-based sightings of Risso's dolphins (yellow circles) and long-finned pilot whales (red circles) off Terceira Island, Azores during the Azores-Baseline project in July and August 2013. In total 30 of the 161 sightings of Risso's dolphins resulted in longer-term (>15 min.) focal follow observations.

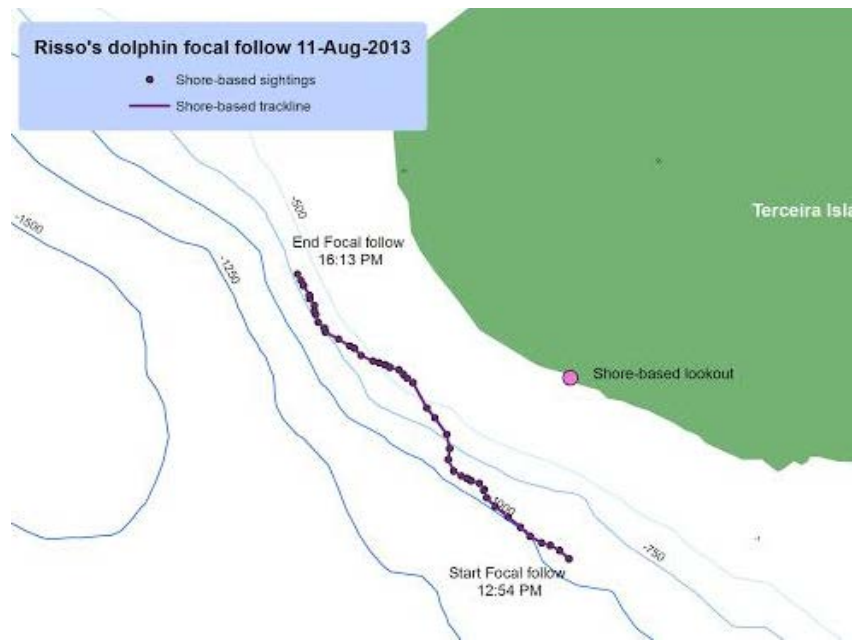


Figure 4. Example of a 3 hour shore-based tracking of a group of Risso's dolphins, collected August 11, 2013.

Data analysis

During field efforts between 2011 and 2013, a large amount of data was collected on the group-level behavior of BRS target species. Concurrent sampling of behavior with digital archival tags, towed arrays and photo-identification during baseline, tagging and exposures phases, have yielded multi-sensor databases from which natural patterns of behavior of the target species, and their behavioral responses to tagging and sonar exposure can be analyzed. Analytical effort will focus on the humpback whale (18 focal follows; 11 CEEs), Risso's dolphin (110 focal follows; 7 CEEs; 2 areas), long-finned pilot whale (12 focal follows; 3 CEEs) and Northern bottlenose whale (63 focal follows; 1 CEE), in close cooperation with the research groups of the 3S² and SOCAL-BRS projects.

Tagless playback protocols

Tagless playbacks are particularly important for species for which it is currently not possible to deploy a tag for longer durations (> 30 minutes), but which generally occur in high densities (high probability of being exposed to sonar). These species include pelagic *Delphinids* such as common and bottlenose dolphins. The size and fluid nature of groups of these species require a different protocol than is used for the previously studied species. A structural difference is that it is not possible to select a focal individual and its associated focal (sub)group for the duration of the follow; the entire group needs to be included in sampling. Methods for optimal conduct of tagless playbacks were evaluated during SOCAL-BRS field efforts in 2011 and 2012, and formalized in recommendations for the set-up of tagless playbacks in future research projects, in 2013. Continued evaluation effort will include exploration of alternative methodology, for example including shore-based tracking, or advanced video technology.

Cooperation between BRS research projects

Exchange of methods and knowledge between BRS research projects in the field was deemed highly valuable since the start of the research project in 2011. It strongly facilitated the implementation and exchange of different methods, and cooperation in data analysis. Exchange of scientists between the 3S/Azores-Baseline and SOCAL-BRS project took place in 2012 and 2013. The use of the operational protocols in different BRS projects facilitates future cross-comparison and potential joint analysis of BRS data.

IMPACT/APPLICATIONS

Social behavior of cetaceans, and social responses to changes in their environment form an essential element in our understanding of the complex nature of cetacean behavioral response to sonar. The generic nature of the methods and protocols developed in this effort can facilitate future cross-comparison of data between BRS projects, species and areas. It also may serve as a tool to extend BRS methodology to include species for which tagging methodology currently is not available.

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 is now continuing in 3S². ONR Award number: N000141010355

SOCAL-BRS. Cooperation in the development and execution of tagless playbacks and group sampling methodology in BRS. SOCAL-13 project website: <http://sea-inc.net/SOCAL-brs/SOCAL-13/>

Azores' Beaked whale project: Cooperation in tagging and tracking effort of target species in the Azores. ONR Award number: N000141210897

REFERENCES

Kvadsheim et al. (2013). Behavioural response studies of cetaceans to naval sonar signals in Norwegian waters - 3S-2013 Cruise Report. FFI-rapport 2013

PUBLICATIONS

*Visser F, Miller PJO, Antunes RA, Oudejans MGO, Mackenzie ML, Aoki K, Lam FPA, Kvadsheim PH, Huisman J and Tyack PL (in review). The social context of individual foraging behaviour in long-finned pilot whales (*Globicephala melas*).*

Aoki K, Sakai M, Miller JO, Visser F and Sato K (2013) Body contact and synchronous diving in long-finned pilot whales. Behavioural Processes 99: 12-20.

Miller PJO, Kvadsheim PH, Lam FPA, Wensveen PJ, Antunes RN, Alves AC, Visser F, Kleivane L, Tyack PL and L Doksaeter-Sivle (2012). The severity of behavioral changes observed during

experimental exposures of killer (Orcinus orca), long-finned pilot whale (Globicephala melas), and sperm whale (Physeter macrocephalus) whales to naval sonar. Aquatic Mammals 38: 362-401.

Lam FP, Kvadsheim PH, Miller PJO, Tyack PL, Ainslie M, Curé C, Kleivane L, Sivle LD, van IJsselmuide SP, Visser F, von Benda-Beckmann AM, Wensveen PJ, Dekeling RPA (in review). Controlled sonar exposure experiments on cetaceans in Norwegian waters; overview of the 3S-project. In: Proceedings from The Effect of Noise on Aquatic Life 3rd International Conference, Budapest, Hungary, August 11-16 2013.

Curé C, Antunes R, Samarra F, Alves A, Visser F, Kvadsheim P and Miller PJO (2012) Responses of male sperm whales (Physeter macrocephalus) to killer whale sounds: implications for anti-predator strategies. Nature Scientific Reports 3: 1579.

Curé C, Antunes R, Samarra F, Alves A, Visser F, Kvadsheim P and Miller PJO (2012) Pilot whales attracted to killer whale sounds: acoustically-mediated interspecific interactions in cetaceans. PLoS ONE 7(12): e52201. doi:10.1371/journal.pone.0052201.

Kvadsheim, P., Lam, FP., Miller, P., Wensveen, P., Visser, F., Sivle, LD., Kleivane, L., Curé, C., Ensor, P., van Ijsselmuide, S., and Dekeling, R. (2012). Behavioural responses of cetaceans to naval sonar signals in Norwegian waters – the 3S-2012 cruise report. FFI-rapport 2012/02058. (<http://rapporter.ffi.no/rapporter/2012/02058.pdf>).