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TNO report

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Behavioural response study on the effects of continuous sonar on sperm whales in Norwegian waters

The 3S-2016-CAS cruise report

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[Photos: FPL, FPL, SI]

Contents

1 Introduction

There has been a significant increase of underwater anthropogenic noise in recent decades, leading to increased background noise levels and more frequent exposure of marine animals to high intensity impulse sounds such as seismic signals and naval sonar. Modern long range anti-submarine warfare surveillance sonars transmit very powerful sound pulses in the 0.1-10 kHz band. Potential negative effects of sonars on marine mammals have received particular attention after several atypical mass strandings of cetaceans in connection with naval sonar activity (D'Amico et al. 2009). These events triggered significant research effort which initially was highly focused on direct effects of noise, such as hearing impairment or neurological injury. Based on this research, accepted noise criteria for injury have been established (Southall et al. 2007). These injury criteria imply that acute effects are limited to the immediate vicinity of the transmitting source. However, behavioural responses to anthropogenic noise can also lead to other negative effects, such as habitat exclusion or cessation of important activities such as feeding, migration or reproduction. Since cetaceans generally have sensitive hearing in the frequency range of naval sonars (Popper & Ketten 2008), behavioural responses might be triggered at much lower levels than injury, and the potential for behaviourally mediated population level impacts cannot be ignored.

1.1 Behavioral response studies

Behavioural response studies (BRS) of free ranging cetaceans[1], in which animal borne tags are used to record behavioural responses during experimental and controlled sonar exposure experiments, have been conducted by research groups in the US (AUTEC project 2006-2009 (Tyack et al. 2011) and SOCAL project 2010-2016 (Southall et al. 2012)) and in Norway (Sea Mammals and Sonar Safety (3S) projects 2006-2010 (Miller et al. 2011) and 3S^2 2011-2015 (Kvadsheim et al. 2015)) over the past 10 years (Southall et al., 2016). Several species of toothed and baleen whales have been studied. These studies have shown large variation in responsiveness between different species, but also variation within a species depending upon the behavioural context of the animals and other factors. Behavioural responses such as avoidance of the sonar source, cessation of feeding, changes in dive behaviour and changes in vocal and social behaviour have been observed, and response thresholds quantified. Results from BRS, including the 3S-program, have helped navies to comply with international guidelines for stewardship of the environment, as well as rules and resolutions within Europe and the USA.

1.2 3S^3-project

The third phase of the Sea Mammals and Sonar Safety project was initiated in 2016 (3S^3). Research questions of this third phase are given below. In the first two phases; 3S (2006-2010) (Miller et al. 2011) and 3S^2 (2011-2015) (Kvadsheim et al. 2015) we looked at behavioral responses of six species of cetaceans to naval sonar

[1] For the scope of this cruise report we are not including the studies on captive animals, which sometimes is also referred to as BRS. Within this report we only refer to free ranging animals in their natural habitat, unless explicitly stated.

signals, and we addressed specific questions such as frequency specificity of behavioral responses and the efficacy of ramp-up. Another key output from the first two studies is dose-response functions describing the relationship between the acoustic received levels (RL) associated with observed responses. Sonar dose response functions for four species, killer whales (*Orcinus orca)* (Miller et al. 2014), long-finned pilot whales (*Globicephala melas*) (Antunes et al. 2015), sperm whales (*Physeter macrocephalus*) (Harris et al. 2015) and humpback whales (*Megaptera novaeangliae)* (Sivle et al. 2015), have been established and compared between species (Harris et al. 2015, Sivle et al. 2015). Such functions can be used to define an affected area around a source and estimate accumulated effects of operations on marine mammal populations. However, it is not obvious what is the best measure of exposure or sonar dose. The received RMS sound pressure level (SPL) is the most commonly used metric, but accumulated Sound Exposure Level (SEL) has also been used. The source levels of most BRS sources have been lower than the source levels of operational sonar sources. Using any measure of acoustic RL thresholds from BRS to predict impact of naval operations implies that there is no effect of distance, i.e. that whales respond only to sound levels rather than to where the sound originates from. Empirical information on whether and how source-whale distance might influence the SPL or SEL thresholds at which cetaceans behaviorally respond to sonar is necessary to predict and better manage unintended environmental consequences of sonar usage.

Further more, all BRS research so far has been done on pulsed active sonars (PAS), typically transmitting only 5-10% of the time (a short pulse followed by a long period of listening, referred to as a low *duty cycle*). Recent technological developments imply that in the near future naval sonars will have the capability to transmit almost continuously (Continuous Active Sonar (CAS)). This technology leads to continuous illumination of a target and therefore more detection opportunities (vanVossen et al. 2011). In many anti-submarine warfare scenarios CAS will give a tactical advantage with increased probability of detection, and therefore there is a strong desire within the navies to implement this technology in operational use. This raises imminent questions about the environmental impact of future sonar systems.

In the third phase of the 3S-project ($3S^3$), we address the following specific questions:

- Does exposure to continuous-active-sonar (CAS) lead to different types or severity of behavioural responses than exposure to traditional pulsed active sonar (PAS) signals, and does the CAS feature of high duty cycle lead to indications that use of sound by cetaceans is masked or interfered with?
- Does the distance to the source affect behavioral responses? Is it the received SPL level, the accumulated SEL or the range to the sonar (or a combination) which drives behavioral responses?

The $3S^3$ project consists of two separate but highly related and coordinated components: the ORBS (Off Range Beaked Whale Study) component and the CAS (Continuous Active Sonar) component. These two components are using similar technology, experimental design and analysis techniques and thus there is significant synergy between them, even though they are focused on different species. The two questions above have been addressed through two separate field efforts in 2016.

- 3S-2016-ORBS trial was a four week field effort focused on northern bottlenose whales (*Hyperoodon ampullatus*) conducted between Iceland and Jan Mayen in June 2016 (Miller et al. 2017).
- 3S-2016-CAS was a two week field trial focused on sperm whales conducted along the coast of Northern Norway in May 2016. The experimental design used here will primarily allow us to contrast behavioral responses to CAS versus PAS, but could also be used to contrast SEL versus SPL and acoustic RL versus range (this report).

1.3 3S-2016-CAS trial

This report summarizes the outcome of the 3S-2016-CAS trial conducted along the coast of Northern Norway between May 3rd and May 17th 2016. The objectives of the CAS-component of 3S^3 will be addressed by the following specific primary and secondary tasks.

Primary tasks:
1. Test the CAS-performance of the Socrates sonar source to assure that it can transmit the scheme needed for the CAS-experiment, and to measure the presence of harmonics in the different transmission modes.
2. Test the mixed-GPS-DTAG3 in DTAG2 housing concept, and start using that tag in the CAS experiments as soon as we are comfortable that it works.
3. Tag sperm whales with DTAG and record vocal-, movement- and dive behaviour, and thereafter carry out no-sonar control, pulsed sonar (PAS) and continuous active sonar (CAS) exposures.

Secondary tasks:
4. Tag killer whales or pilot whales with DTAG3 and do CAS experiment on them following the same protocol as with sperm whales
5. Tag minke whales (*Balaenoptera acutorostrata*) with DTAG3 and replicate the pulsed sonar experiment from 2011.
6. Test ARTS launching of the mixed-DTAG
7. Collect baseline data of target species.
8. Collect information about the environment in the study area (CTD and XBT measurements).
9. Re-approach of tagged animal after experimental cycle to collect biopsy sample.
10. Collection of bio-acoustic data using towed arrays.
11. Collect sightings of marine mammals in study area.

2 Methods

2.1 Equipment and staffing

Conducting controlled sonar exposure experiments on free ranging cetaceans at sea requires a variety of sophisticated equipment and expertise. The main platform of the trial was the FFI RV HU Sverdrup II (HUS) with a regular crew of 7. The research team consisted of 15 scientists with a multidisciplinary background, including experts in biology, underwater acoustics, oceanography, electronics, mechanical engineering, environmental science and operational sonar use. Detailed descriptions of data collection procedures and equipment can be found in the 3S-2016-CAS cruise plan (Appendix F). Here follows a short description of the basic experimental design of the experiments.

2.2 Basic experimental design

Our target species was primarily sperm whale (*Physeter macrocepahlus*), but pilot whales (*Globicephala melas*) and killer whales (*Orcinus orca*) were secondary back up species which we could work with opportunistically if we did not find sperm whales in areas with workable weather conditions. We operated in Andfjord and in the Malangen channel, as well as along the shelf break between Harstad and Tromsø in northern Norway. We searched for whales using both visual observers and the Delphinus acoustic array. When a target species was localized, a tag boat was launched and a DTAGv3 was deployed using the cantilever pole with sperm wales and hand held pole with pilot whales. Tag release time was set to 12-15 hrs. All target species have been studied by the 3S group before (Miller et al. 2011), and the basic design of the experiments was to replicate the previous dose escalation experiments to be able to use existing data in combination with new data.

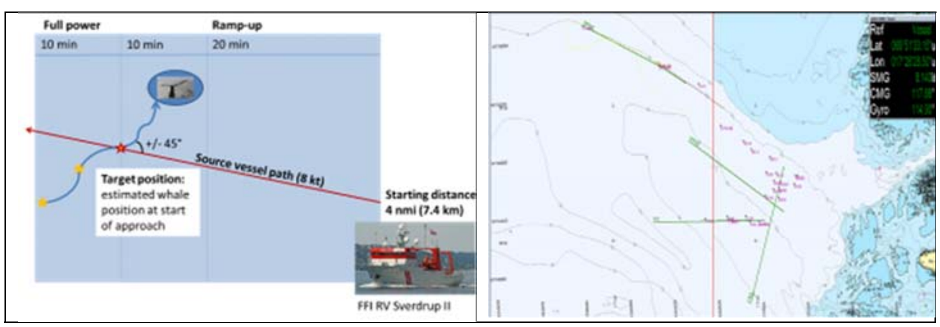


Figure 2.1. Planned geometry of CEE approaches (left) and example of actually sailed tracks during the four approaches during an experiment on a sperm whale on May 14th (right).

From tag-on to tag-off the focal whale was tracked using visual observers on HUS, aided by radio tracking of the VHF-beacon on the tag and acoustic tracking of vocalizing whales under water. During tracking HUS sailed in boxes of 2-3 nmi by 2-3 nmi around the focal whale. This sailing pattern was considered to be the optimal compromise between the visual effort, the acoustic tracking, the VHF tracking range and the desire not to affect the behavioral of the focal animal by the close presence of the ship. Good communication between the sonar operators tracking the whale acoustically under water and the marine mammals observers (MMOs) using visual and radio tracking of the whale at the surface was important to achieve good tracking from a moving platform at such distances. This communication was aided by a geographical display of the acoustic tracks on the MMO platform (Figure 3.6). MMOs recorded position of the focal whale and other animals in the area at each surfacing in Logger software (IFAW).

Table 2.1. During the Controlled Exposure Experiment (CEE) approaches, one of four different experimental treatments were used: No-sonar (NS), Continuous active sonar (CAS), Moderate source level pulsed sonar (MPAS), and high source level pulsed sonar (HPAS)

SIGNAL	NS	CAS	MPAS	HPAS
Start and end source level (dB re 1µPa·m)	No-signal	141-201	141-201	154-214
Ramp-up duration (min)	20	20	20	20
SL increase	No-signal	Linear, 1dB/pulse	Linear, 1dB/pulse	Linear, 1dB/pulse
Full power period (min)	20	20	20	20
SEL_{19s} (dB re 1µPa·s)	No-signal	154-214	141-201	154-214
Signal duration (s)	No-signal	19	1	1
Signal interval (s)	No-signal	20	20	20
Duty cycle	No-signal	95%	5%	5%
Frequency	No-signal	1-2 kHz	1-2 kHz	1-2 kHz
Signal shape	No-signal	HFM Upsweep	HFM Upsweep	HFM Upsweep
Pulse Shading/Signal rise time	No-signal	Cosine envelope with duration of 0.05 sec at start and end of pulse.		

After a period of 4 hours of baseline data collection, the experimental phase started with the first CEE approach session. Just prior to the CEE, the SOCRATES source was deployed and HUS positioned to approach the whale from a distance of 4 nmi (7.4 km) (Figure 2.1). The course and speed of the tagged whale was calculated from its visual and acoustic track using the NaviPac tool, which allowed the estimation of the expected future position of the whale at the start of the approach. The approach speed (8 knots) and course were kept constant throughout the 40 min approach. The approach course of the ship was determined to intercept the estimated position of the whale at the start of the approach at an angle of about 45˚ relative to the estimated travelling course of the whale (Figure 2.1).
Transmission started with a 20 min linear ramp-up (1 dB/pulse) at a level of 60 dB below maximum level, and continued with 20 min of full power transmission.
The transmission and approach scheme aimed to achieve a gradual increase of the received levels (RLs) (dose escalation). Four different approaches were conducted while subjecting the focal whale to one of four different treatments: (1) no-sonar, (2)

continuous active sonar or (3,4) pulsed sonar at two different source levels (Table 2.1). Between each approach the animal had to be relocated to estimate a start position and course of the next approach. The exposure sessions were always separated in time by at least 1 hour and 20 min from end of one approach to the start of the next, but it may take longer than that to relocate the focal whale and reposition the ship.
This experimental design enables us to determine response thresholds and characterize the severity of response to different stimuli. The no-sonar approach enables us to separate responses to the approaching ship alone from response caused by the sonar signals. By contrasting the response threshold and type of responses during CAS-exposures to the threshold and type of responses seen during PAS-exposures, we can look at the effect of continuous active sonar versus pulsed sonar. Similarly, the effect of range can be examined by contrasting the response to MPAS and HPAS, because these two experiments give the same received levels at different ranges. The question of SEL or SPL as the best metric of acoustic dose to explain behavioral responses can also be addressed, but with our experimental design this question is very interlinked with the CAS versus PAS question.
After the final exposure run, we collected post exposure data. The tagboat was deployed to collect a biopsy sample about one hour before the tag was expected to come off. Tissue samples are primarily used to determine the gender of the animal. Once the tag was recovered, data was downloaded while we transited at least 20 nmi away from the previous exposure before starting to tag the next whale.

2.3 Risk management and permits

Experimental exposure of marine mammals to high levels of sound implies some risk that animals are negatively affected, that is why it is important to study it. The experiments were conducted under permit from the Norwegian Animal Research Authority (permit no 2015/223222), and experimental procedures were also approved by the Animal Welfare Ethics Committee at the University of St Andrews. A separate risk assessment and management plan was developed for the trial to minimize risk to the environment (Appendix E). This document also specifies suitable mitigation measures, endpoints and responsibilities.

3 Results

3.1 Overview of achievements

Two of the primary objectives of the cruise were achieved, as well as most of the secondary objectives. A complete data inventory is listed in Appendix A.

Eight DTAG3s were deployed on sperm whales (primary target species), and one on a pilot whale (secondary species), which recorded a total of 125 hours of archival data (Table 3.8). Four of the sperm whales and the one pilot whale were subject controlled exposure experiments (CEEs) including both no-sonar and CAS and/or PAS exposures (Table 3.2). The DTAGv3 performed well overall and was successfully deployed using the cantilever pole, although in three instances the tag detached early resulting in three sperm whale deployments without a CEE.
The mixed-GPS DTAG3 and its launching were not tested due to delay in production. In addition we tested CAS performance of the Socrates sonar source and measured the generated harmonics (Section 3.4).

We achieved the following secondary tasks: A pilot whale was tagged and exposed to CAS, collection of biopsy samples and baseline data of tagged sperm whales (Section 3.6, Figure 3.11), collection of both acoustic (Table 3.4) and visual data (Table 3.7) of marine mammals in the study area, and measurement of environmental parameters using CTD and XBT casts (Table 3.9).

Table 3.1. Overview of weather and overall activity during the trial. Wind force is given on the Beaufort scale. The color code for operational status is: fully operational (green), partly operational/reduced effort (yellow) and not operational (red).

Date	Area	Weather	Wind	Sea State	Activity	Ops. Status
May 2.	Harstad				Rendezvous, joint briefing	No regular watches
May 3.	Harstad	In port			Mobilization	No regular watches
May 4.	Vågsfjord	Clouded	SW 4-6	3-4	Training, testing, transit	
May 5.	Malangen	Clouded	SE/SW 2-5	1-3	Testing, tagging SW, CEE-I	
May 6.	Malangs-channel	Clouded	SE/SW 3-4	3-4	CEE-I, tracking	
May 7.	Malangs-channel	Clouded, rain	SW 3-5	2-3	Tracking, testing SOC	
May 8.	Andfjorden	Clouded	WSW 3-6	1-3	Transit, searching	
May 9.	Outer Andfjord	Clouded, rain showers	W 4-5	3-4	Tagging SW, CEE-II	
May 10.	Shelf break Vesterålen	Clouded	NW/W 4-5	3-4	Tagging SW, CEE-III	
May 11.	Andenes	Clouded	SW 5-6	4-5	In port	
May 12.	Andfjorden	Clouded	SW 4-5	3-4	Tagging PW, CEE-IV	
May 13.	Malangs-channel	Changing cloud cover	S/SE 3-4	3-4	Tagging SW, CEE V	
May 14.	Malangs-channel	Changing cloud cover	SE/NE 2-4	2-3	CEE VI, Transit, Searching	
May 15.	Shelf break Senja	Changing cloud cover	W 2-4	2-3	Tagging SW, CEE VII, Transit	
May 16.	Andfjorden	Clouded, rain	WSW 3-7	3-4	Search, Tagging SW, CEE VIII Cruise de-brief, Transit	
May 17.	Tromsø	In port			Transit, de-mobilization	No regular watches
May 18.	Tromsø	In port			De-mobilization, departure	No regular watches

3.2 Main events

An overview of the cruise activities and weather is provided in Table 3.1. and Figures 3.1. There were two legs, with a bad-weather break roughly halfway (11th May) when the Sverdrup was in port in Andenes. Table 3.3 gives a detailed timeline for each experimental phase.

Experiments were achieved as planned, and the received levels measured from the tag exceeded 165, 170 and 180 dB (SPL_{max} re 1μPa) for CAS, MPAS and HPAS exposures respectively. As expected by the experimental design, visual, acoustic and VHF tracking of the tagged whale was lost when the ship moved to the start position of approach. The whale was usually found again towards the end of the approach, or soon after. In the case of sw16_131a, the whale was not found again due to poor offshore weather conditions.

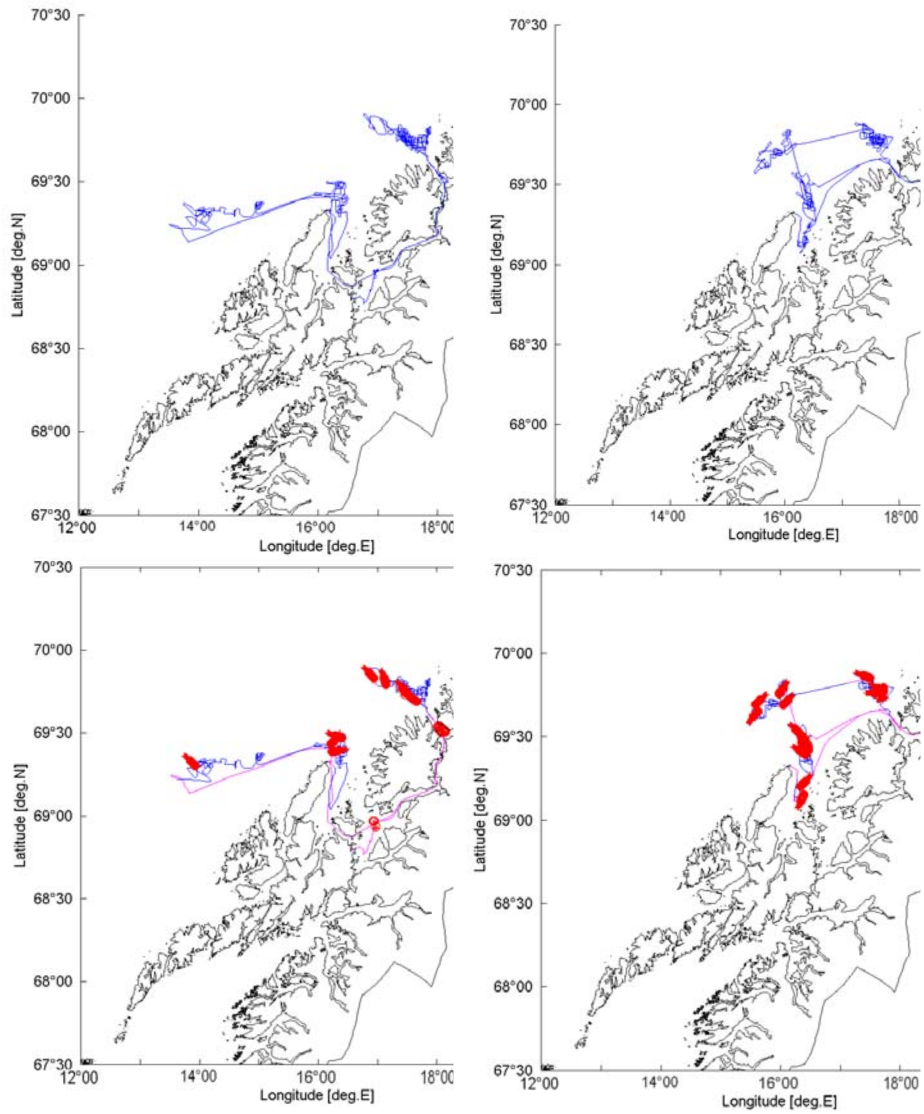


Figure 3.1. Sailed track of H.U. Sverdrup II from 3rd to 11th May 2016 (left) and from 12th to 17th May (right). Bottom panels shows periods with sonar transmissions in red and towing of Delphinus array in blue

Table 3.2. Overview of tag deployments and controlled exposure experiments. NS=no sonar runs, CAS= Continous active sonar runs, MPAS=Midium power (201dB max) pulsed sonar runs, HPAS=High power (214dB) pulsed sonar runs. Details of daily sailing tracks can be found in Appendix B.

CEE #	DTAG ID	Species	Date/Area	Runs
CEE I	sw16_126	Sperm whale	May 5-6. Malangs-channel	Baseline, CAS, MPAS, HPAS
CEE II	sw16_130	Sperm whale	May 9. Outer Andfjord	Baseline, NS, MPAS, CAS
CEE III	sw16_131	Sperm whale	May 10. Vesterålen	Baseline, NS
CEE IV	gm16_133	Pilot whale	May 12. Andfjord	Baseline, NS, CAS
CEE V	sw16_134a	Sperm whale	May 13. Malangs-channel	Baseline, NS
CEE VI	sw16_134b	Sperm whale	May 14. Malangs-channel	Baseline, NS, CAS, HPAS, MPAS
CEE VII	sw16_135	Sperm whale	May 15. West of Senja	Baseline, NS, HPAS, CAS, MPAS
CEE VIII	sw16_136	Sperm whale	May 16. Outer Andfjord	Baseline, NS, CAS, MPAS, HPAS

Table 3.3. Detailed timeline of effort.

Effort	Start time (UTC)	End time (UTC)	Deployment
Searching	05/05/2016 06:33:51	05/05/2016 13:46:00	
Tagging	05/05/2016 13:46:00	05/05/2016 15:07:00	sw16_126a
Baseline	05/05/2016 15:07:00	05/05/2016 21:35:00	sw16_126a
CAS	05/05/2016 21:35:00	05/05/2016 22:15:19	sw16_126a
MPS	06/05/2016 00:01:00	06/05/2016 00:41:01	sw16_126a
HPS	06/05/2016 02:28:00	06/05/2016 03:08:01	sw16_126a
Biopsy effort	06/05/2016 06:46:44	06/05/2016 11:30:00	sw16_126a
NS	07/05/2016 07:34:00	07/05/2016 08:14:01	sw16_126a
CAS	07/05/2016 10:17:00	07/05/2016 10:56:28	sw16_126a
Searching	08/05/2016 18:37:59	09/05/2016 02:20:04	
Tagging	09/05/2016 02:20:04	09/05/2016 03:57:46	sw16_130a
Baseline	09/05/2016 03:57:46	09/05/2016 08:49:00	sw16_130a
NS	09/05/2016 08:49:00	09/05/2016 09:29:01	sw16_130a
MPS	09/05/2016 13:15:00	09/05/2016 13:55:01	sw16_130a
CAS	09/05/2016 15:19:00	09/05/2016 15:59:19	sw16_130a
Searching	09/05/2016 21:07:45	09/05/2016 22:31:08	
Tagging	09/05/2016 22:31:08	10/05/2016 00:14:04	
Tagging	10/05/2016 00:59:57	10/05/2016 04:00:02	
Searching	10/05/2016 05:19:55	10/05/2016 06:23:18	
Tagging	10/05/2016 06:23:18	10/05/2016 08:54:06	sw16_131a

Effort	Start time (UTC)	End time (UTC)	Deployment
Baseline	10/05/2016 08:54:06	10/05/2016 12:23:00	sw16_131a
NS	10/05/2016 12:23:00	10/05/2016 13:13:01	sw16_131a
Searching	12/05/2016 09:45:00	12/05/2016 12:15:31	
Tagging	12/05/2016 12:15:31	12/05/2016 13:10:41	gm16_133a
Baseline	12/05/2016 13:10:41	12/05/2016 17:25:00	gm16_133a
NS	12/05/2016 17:25:00	12/05/2016 18:05:01	gm16_133a
CAS	12/05/2016 19:37:00	12/05/2016 20:17:19	gm16_133a
Biopsy effort	12/05/2016 21:35:58	12/05/2016 22:37:05	gm16_133a
Searching	13/05/2016 08:39:08	13/05/2016 12:59:35	
Tagging	13/05/2016 12:59:35	13/05/2016 13:42:30	sw16_134a
Baseline	13/05/2016 13:42:30	13/05/2016 18:39:00	sw16_134a
NS	13/05/2016 18:39:00	13/05/2016 19:19:01	sw16_134a
Searching	13/05/2016 19:25:00	13/05/2016 21:29:42	
Tagging	13/05/2016 21:29:42	13/05/2016 22:57:42	sw16_134b
Baseline	13/05/2016 22:57:42	14/05/2016 03:11:00	sw16_134b
NS	14/05/2016 03:11:00	14/05/2016 03:51:01	sw16_134b
CAS	14/05/2016 05:32:00	14/05/2016 06:12:19	sw16_134b
HPS	14/05/2016 07:43:00	14/05/2016 08:23:01	sw16_134b
MPS	14/05/2016 11:06:00	14/05/2016 11:46:01	sw16_134b
Searching	14/05/2016 20:06:03	14/05/2016 20:46:30	
Tagging	14/05/2016 20:46:30	14/05/2016 22:10:37	sw16_135a
Baseline	14/05/2016 22:10:37	15/05/2016 02:45:00	sw16_135a
NS	15/05/2016 02:45:00	15/05/2016 03:25:01	sw16_135a
HPS	15/05/2016 05:25:00	15/05/2016 06:05:01	sw16_135a
CAS	15/05/2016 08:04:00	15/05/2016 08:44:19	sw16_135a
MPS	15/05/2016 10:19:00	15/05/2016 10:59:01	sw16_135a
Searching	15/05/2016 19:39:27	15/05/2016 19:58:01	
Tagging	15/05/2016 19:58:01	15/05/2016 22:41:00	sw16_136a
Baseline	15/05/2016 22:41:00	16/05/2016 03:38:00	sw16_136a
NS	16/05/2016 03:38:00	16/05/2016 04:18:01	sw16_136a
CAS	16/05/2016 05:41:00	16/05/2016 06:21:19	sw16_136a
MPS	16/05/2016 08:30:00	16/05/2016 09:10:01	sw16_136a
HPS	16/05/2016 11:03:00	16/05/2016 11:43:01	sw16_136a
Biopsy effort	16/05/2016 14:34:24	16/05/2016 14:54:58	sw16_136a

3.3 Passive Acoustic detection (PAM) and tracking

The Delphinus array was towed extensively while searching, tagging and tracking sperm whales (see Table 3.4 for an overview of the recordings made). In total 190 hours of data was recorded, collecting almost 4 TB of acoustic data.

During the survey and tagging phases several software packages were used to Detect, Classify and Localize (DCL) the sperm whale vocalizations:

1. Carcharodon: Processing for the (16 beamformed) MF hydrophones (1-20 kHz), this was the main software package used for the detection, classification and localization of the sperm whale vocalizations (Figs. 3.2 and 3.3).
2. Thetis: Processing for the UHF hydrophones (1-150 kHz), the Left-Right ambiguity could be solved using the triplet sensor in the Delphinus array (Figure 3.4). Sperm whale detections could be passed on to Carcharodon for localization using the Target Motion Analysis (TMA) tools. This tool was only used sparsely as it did not have much added value compared to the Carcharodon software.
3. GIS: Used to combine and visualize the track of H.U. Sverdrup, the tracks of the tag boats and other boats using AIS, acoustic detections and bathymetry (Figure 3.5). The GIS display was mirrored on an Android 10-inch tablet located on the observation deck so that the visual observers had clear overview of their current position and course, the acoustic detections and the tag boats (Figure 3.6).

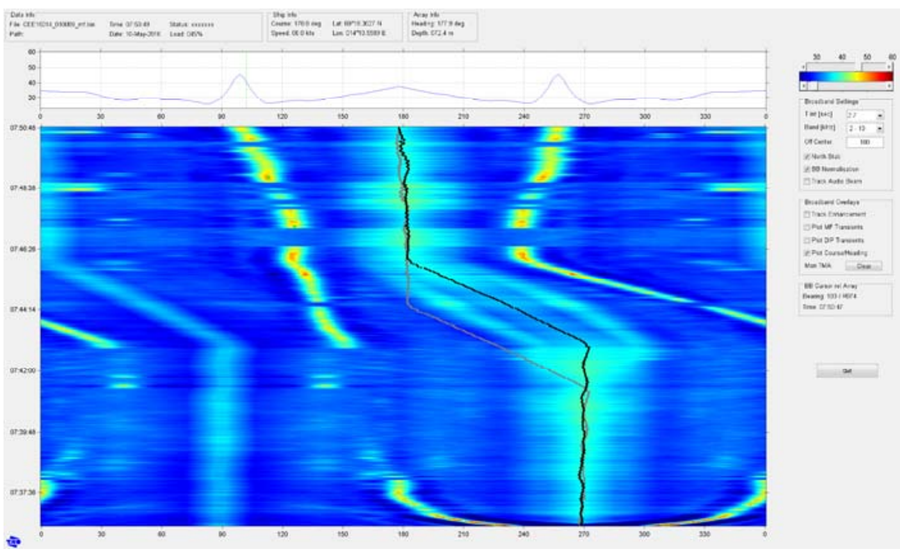


Figure 3.2 Screenshot of the Carcharodon broadband display showing an Amplitude-Bearing plot (top) and Bearing-Time plot (bottom). This display was mainly used to determine the bearing of the sperm whale vocalizations. The main beam is the track of Sverdrup, making a 90-degree turn around 07:44. Dots are GPS-positions of the vessel (in black) and modelled “delayed” array position (in grey). One clear sperm whale track shows up in the graph against the background. The green dots along those tracks are positions that are marked and passed on to the GIS-display for TMA-purpose (see Figure 3.5).

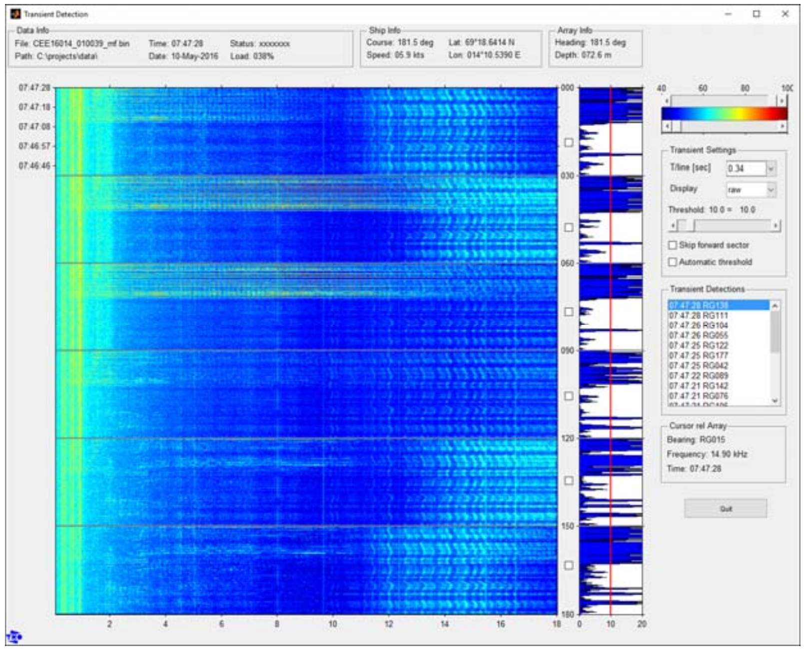


Figure 3.3. Screenshot of the Carcharodon transient detection display showing six time-frequency plots for six horizontal bearing sectors. This screen was mainly used for the initial detection and classification of sperm whale vocalizations.

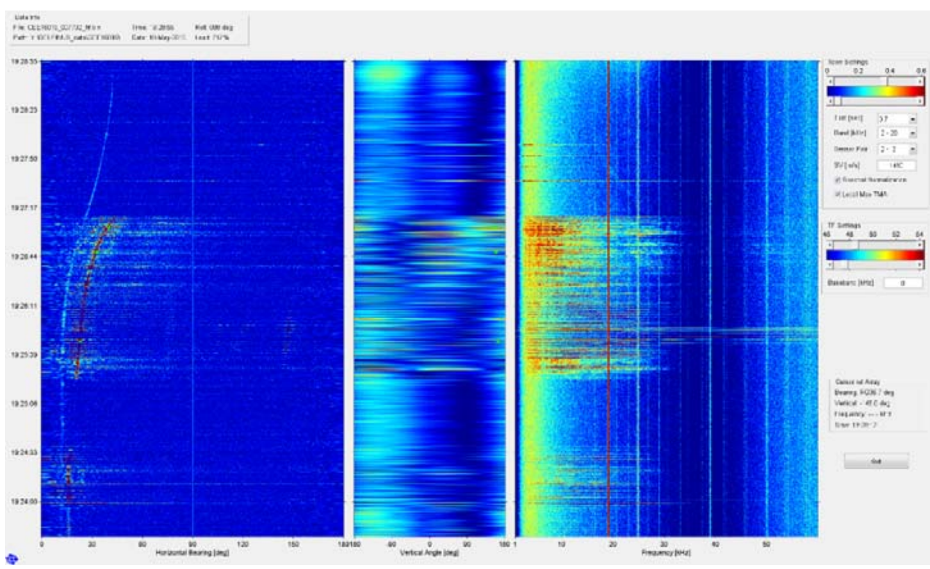


Figure 3.4. Screenshot of Thetis showing a horizontal bearing-time plot (left), vertical angle-time plot(middle) and time-frequency plot (right). The middle panel in particular shows that the detection was at starboard-side, using the information of the triplet-element.

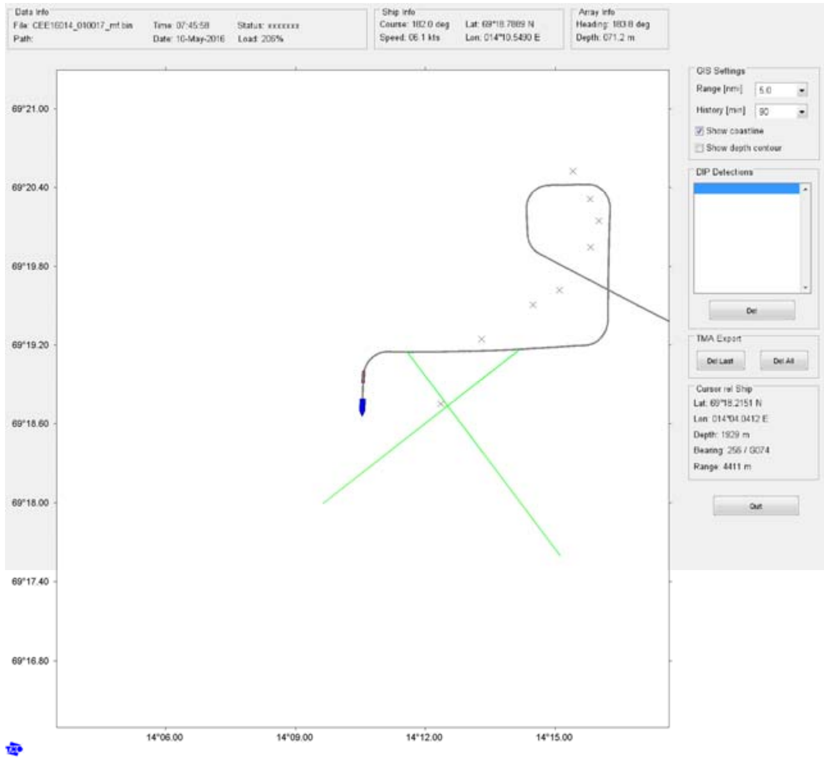


Figure 3.5. Screenshot of the Carcharodon GIS or TMA display. Own ship (track) and array (track) are depicted by the blue ship symbol and red box on the grey line. Bearings of the detected vocalizations are shown in green (Carcharodon). The estimated sperm whale location is marked by the cross (x), which is then exported to the second GIS display at the marine mammals observer station (Figure 3.6).

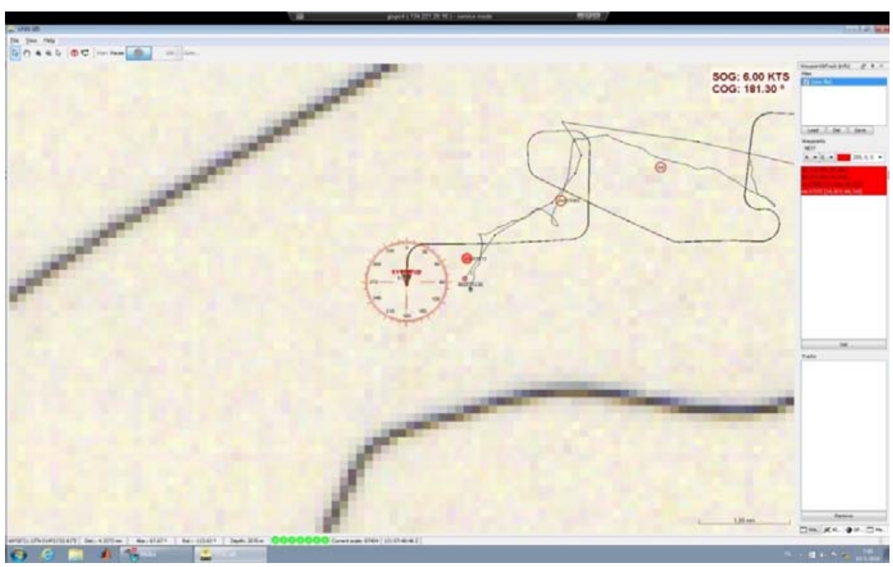


Figure 3.6. GIS display from the Delphinus system showing the estimated position of acoustic detections of sperm whales (pink dot). Black lines are the sailed track of the Sverdrup. The AIS position of the tag boat is also shown in this display (green dot).

Table 3.4. Overview of acoustic recordings and transmissions (Delphinus and SOC) during 3S-2016-CAS.

Exp Name	Sys	Date (start time)	Start Time (UTC)	Stop Time (UTC)	Duration [HH:MM]	Summary
CEE16001	Soc OWID	04-05-2016	19:00	20:00	01:00	Socrates harmonic's test, failed due to power supply issues.
CEE16002	Soc	05-05-2016	06:40	08:10	01:30	Socrates test with 440V/50Hz.
CEE16003	Delp	05-05-2016	10:15	18:03	07:48	Search for Sperm whales + tagging
CEE16004	Delp Soc	05-05-2016	18:04	01:13	07:09	Exposure of tagged sperm whale
CEE16005	Delp Soc	06-05-2016	01:55	09:11	07:16	Continue exposure of tagged sperm whale with HPAS.
CEE16006	Delp	06-05-2016	09:40	18:00	08:20	Track tagged sperm whale while waiting for tag off.
CEE16007	Delp	06-05-2016	18:01	06:30	12:31	Track tagged sperm whale while waiting for tag off.
CEE16008	Delp Soc	07-05-2016	06:30	15:25	08:55	Exposure on same tagged animal, tag stopped recording by this time.
CEE16009	Soc OWID	07-05-2016	20:20	22:00	01:40	Socrates harmonics testing
CEE16010	Delp	08-05-2016	17:10	23:48	06:38	Search for whales in Andfjord.
CEE16011	Delp	08-05-2016	23:50	07:53	08:03	Tracking and tagging sperm whales.
CEE16012	Delp Soc	09-05-2016	08:00	17:12	11:48	Exposure of tagged sperm whale.
CEE16013	Delp	09-05-2016	17:13	20:32	03:19	Transit to new area.
CEE16014	Delp	09-05-2016	20:38	08:42	12:04	Tracking and tagging sperm whales.
CEE16015	Delp	10-05-2016	08:43	10:38	01:55	Tracking of tagged sperm whale.
CEE16016	Delp Soc	10-05-2016	10:55	21:16	10:21	Exposure of tagged sperm whale.
CEE16017	Delp	12-05-2016	07:25	10:41	03:16	Search for whales in Andfjord.
CEE16018	Soc	12-05-2016	17:25	21:30	04:05	Exposure of tagged pilot whale
CEE16019	Delp	13-05-2016	08:10	15:42	07:32	Tracking and tagging sperm whales.
CEE16020	Delp Soc	13-05-2016	16:00	15:00	23:00	Exposure of tagged sperm whale.
CEE16021	Delp Soc	14-05-2016	16:00	11:02	17:02	Tagging and exposure of sperm whale
CEE16022	Delp	15-05-2016	11:02	13:50	02:52	Post exposure + tag recovery tagged sperm whale.
CEE16023	Delp	15-05-2016	16:46	22:43	05:57	Search for whales in Andfjord
CEE16024	Delp Soc	15-05-2016	22:43	09:15	10:32	Tagging and exposure of sperm whale
CEE16025	Delp Soc	16-05-2016	09:46	15:09	05:23	exposure and post exposure of sperm whale
Total					189:56	

Delp = Delphinus system. Soc = SOCRATES II sound source. OWID = single hydrophone recorder, recording ambient noise and/or received level.

3.4 Testing of source characteristics – Socrates harmonics

This section contains the analysis of spectral side lobe level of the Socrates 2 source when transmitting high power sonar signals. During the 3S-2016-CAS trial these side lobe levels has been measured using the OWID recorder, which has dynamic range of ≈ 90dB (16bit). The measurements have been conducted on May 7th between 20:30Z and 22:00Z.

Pulse schedule:
- CW pulses (with 5% envelope shading)
- Frequency: 1000, 1500, 2000 Hz
- Pulse length: (0.01, 0.1, 1 sec) combined in one 3 second wav file.
- Pulse repetition time: 10 sec (to reduce reverberation)
- Source Level: 214, 208, 201 dB re 1μPa^{2}m
- Source Depth: 110m and 200m

The recorded OWID data has been analysed in the following way:
- Reading data and scale using hydrophone sensitivity and OWID gain setting.
- Select individual transmissions.
- Compute the Power Spectral Density (PSD) for each transmission and select the peak spectra for each transmission.
- Normalize the peak spectra and average the 20 transmission.

The relative received spectra are show in Figure 3.7 and 3.8 for source depths of 110 and 200m. Table 3.5 and 3.6 show the relative receive levels, i.e. harmonic levels, for the 1st and 10th harmonic.

Table 3.5. Harmonic side lobe levels for source depth 110m.

Freq [Hz]	SL=201dB		SL=208dB		SL=214dB	
	1st Harm	10th Harm	1st Harm	10th Harm	1st Harm	10th Harm
1000	-29	-74	-39	-73	-37	-67
1500	-45	-76	-40	-74	-36	-65
2000	-44	-76	-41	-72	-36	-68

Table 3.6. Harmonic side lobe levels for source depth 200m.

Freq [Hz]	SL=201dB		SL=208dB		SL=214dB	
	1st Harm	10th Harm	1st Harm	10th Harm	1st Harm	10th Harm
1000	-35	-73	-46	-65	-40	-59
1500	-44	-71	-36	-66	-33	-59
2000	-39	-73	-36	-68	-34	-62

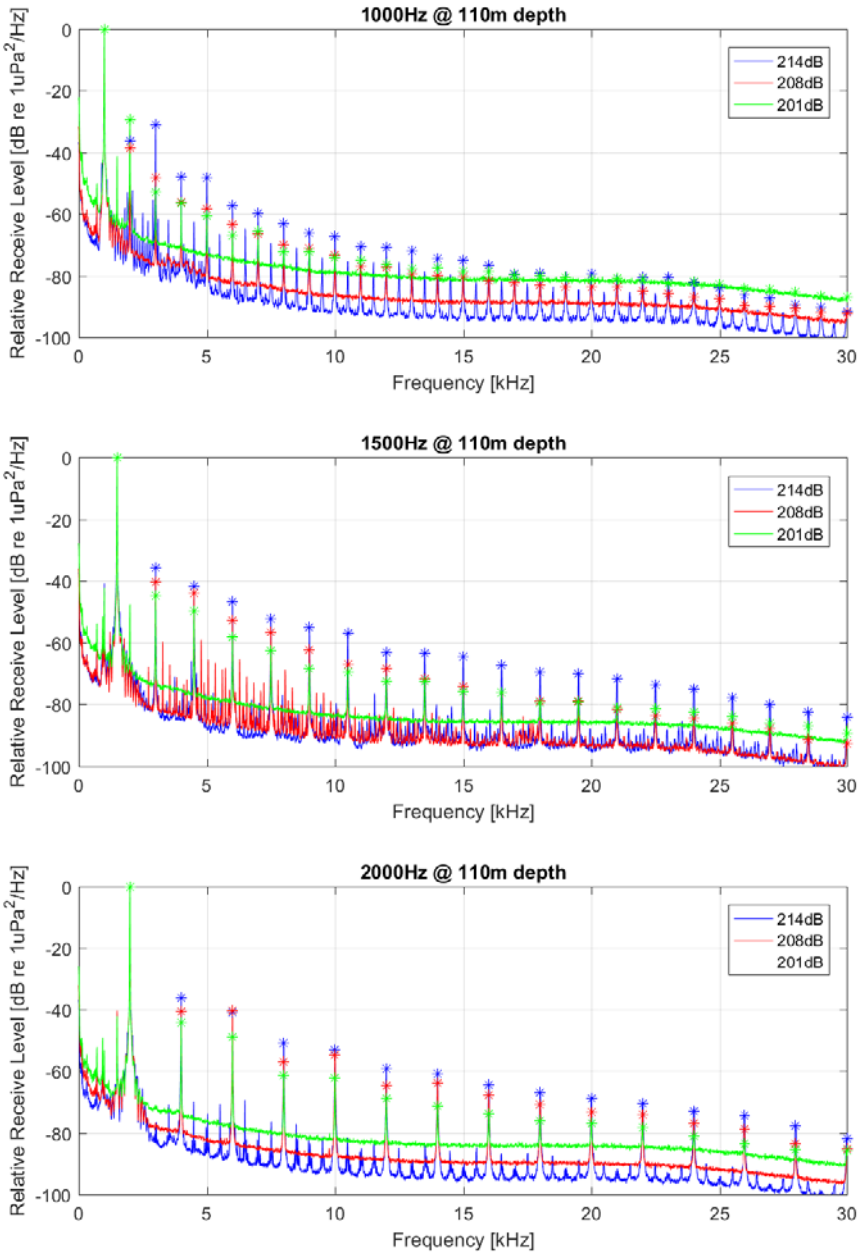


Figure 3.7. Averaged spectral levels at source levels at various frequencies and source levels and a source depth of 110m. Stars mark the peak harmonic levels.

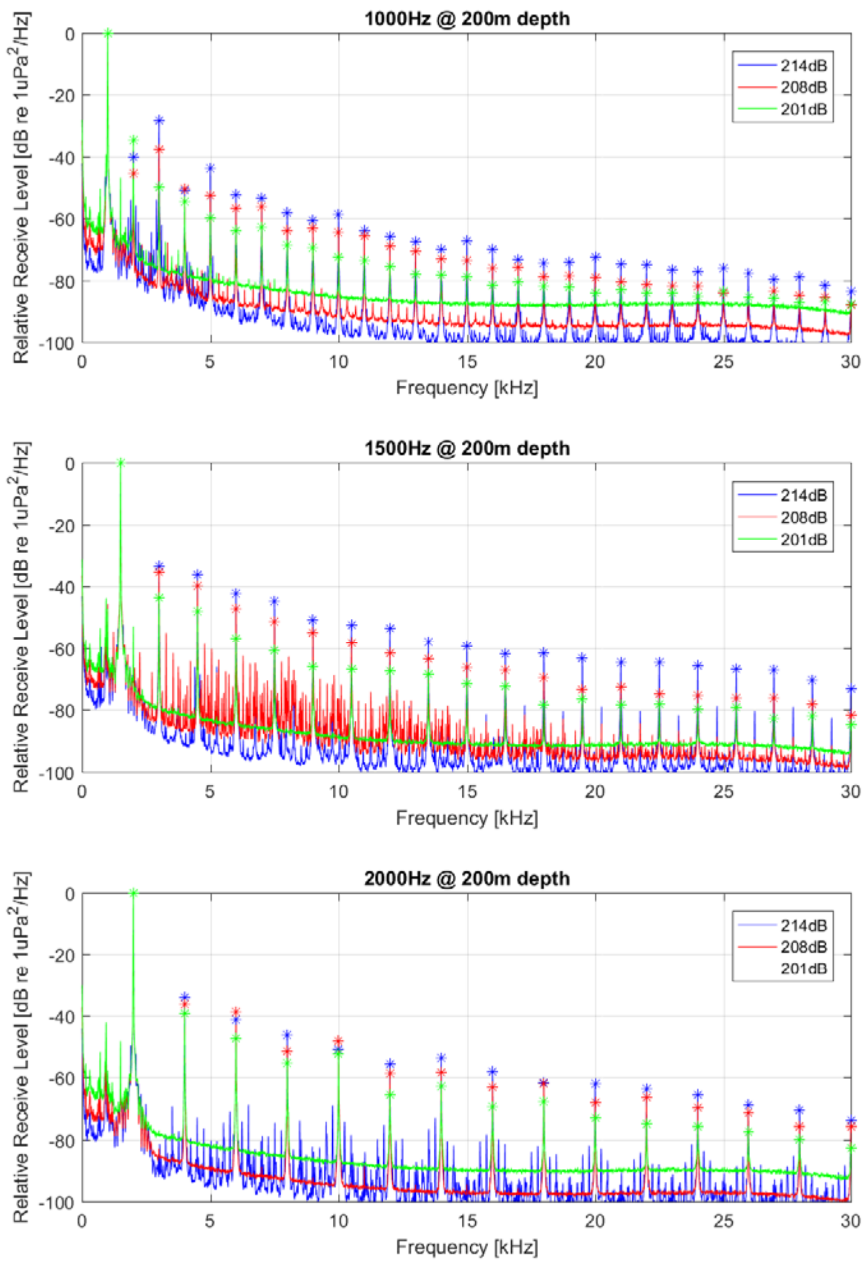


Figure 3.8. Averaged spectral levels at source levels at various frequencies and source levels and a source depth of 200m. Stars mark the peak harmonic levels.

Observations and remarks:

- On general the harmonic levels showed some (non-)linear variation with:
    - Transmit Frequency, this variation is very unpredictable, especially at 1000 Hz the harmonics have much different behaviour compared to 1500 and 2000 Hz. Furthermore, there was some additional spectral leakage visible, especially during transmissions at 1500 Hz.
    - Source Level, in general we saw an increase in the harmonic levels when the source level increases. This increase is in the order of 0.5-1.0 dB / dB SL.
    - Source Depth, in general we a saw a small increase of the harmonic levels when the source depth increases. This is a counter intuitive result but probably has to do with the resonant modes of the FFR transducer.
- The harmonics are probably caused by both the:
    - Transducer (FFR).
    - Power amplifier.

  We expect that most of the harmonics are caused by the transducer, but some of the harmonics could also be caused by the amplifier being driven to the design limits.
- On average the harmonic levels are:
    - 1^{st}: -38.3±4.5 dB
    - 10^{th}: -68.9±5.4 dB
    - From the first harmonic the harmonics decrease with 4dB / octave.

3.5 Visual tracking and data collection

Whale locations were calculated using vessel position and field-estimated range and bearing to the sighting. 42% and 8% of the field estimates of range were calculated based on the reticle count of the big eyes and hand-held binocular, respectively. When reticles could not be counted to the sighting, e.g. due to poor weather conditions (sea state, swell, showers), the ranges were estimated by eye. Half of the field estimates were reported as estimates by eye, although these were often guided by the binocular observations. There were relatively many days with poor visibility conditions (Table 3.1).
A total of 302 sperm whale, 6 killer whale and 10 long-finned pilot whale sightings were recorded, excluding re-sightings (Table 3.7, Figure 3.9). A sighting of a dolphin species (likely white beaked dolphin) and a baleen whale (minke or humpback) were also recorded. Horizontal tracks of the tagged whales consisted of an additional 294 location fixes, an average of 37 fixes per deployment (Figure 3.10). Excluding re-sighting data, average group sizes were 1.0 for sperm whales (max 4), 6.9 for killer whales (max 20) and 7.4 for pilot whales (max 10).
All sightings in detail are provided in Appendix C.

Table 3.7. Summary of sightings[2].

Species	Number of		Group size (average)			Sighting distance from ship (m)		
	sightings	Animals	low	best	high	average	minimum	maximum
Sperm whale	302	310	1.0	1.0	1.0	1900	150	7000
Long-finned pilot whale	10	70	5.0	7.0	10.0	1216	150	2402
Killer whale	6	40	4.7	6.7	9.3	1376	120	4500
Baleen whale sp.	1	1	1.0	1.0	1.0	1126	1126	1126
Dolphin sp.	1	3		3.0		500	500	500
Total sum	320	424						
Total average			2.9	3.7	5.3	1223.5	409.2	3105.6

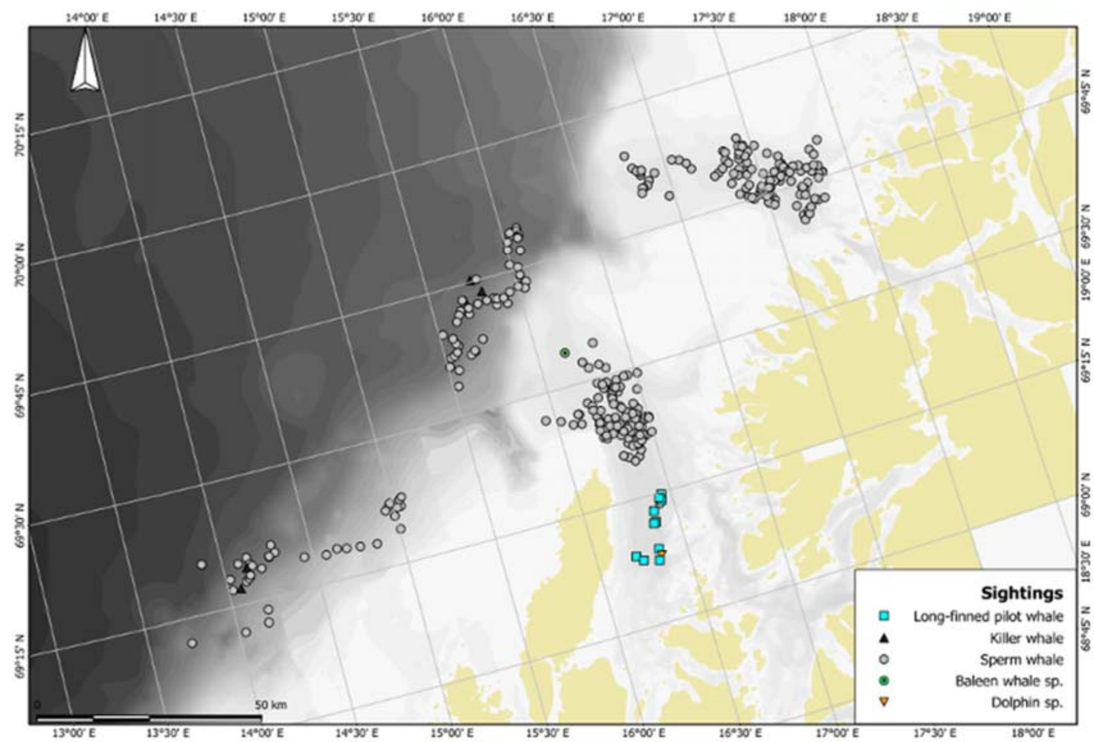


Figure 3.9. Map of sightings at 3S3 CAS trial 2016. Depth contours are shown at 100m intervals.

[2] The total number of animals was calculated by summing group size estimates; when group size was not recorded (18 sperm whale sightings, 7 long-finned pilot whale sightings), species-averages were used.

3.6 DTAG deployments and dive profiles

Eight DTAG3s were deployed on sperm whales, and one on a pilot whale (Table 3.8). Tag deployment locations and visual tracks of tagged whales are shown in Figure 3.10. Photos of all tagged whales are collected in Appendix D.

Initially, a less conservative burn time of 1:30 was set to release the DTAG3 after 16 hours. The tag did not come off the animal and was not recovered until 48 hours later. From thereon, the release wires were burnt for 15 min in seawater prior to the on-animal deployment, and a more conservative burn time was set (5 hours).
With this 'pre-burn', five tags released from the whale a maximum of 1.5 hours after programmed release time and three tags prior to the programmed time.

Dive profile data showed that sperm whales spent the majority of time doing relatively shallow (100-300m) foraging dives (Figure 3.11). Animal sw16_131a also conducted a few dives up to 600m and over 1000m. Resting dives were apparent in sw16_126a en sw16_134a. There were no obvious changes in the dive profile of sperm whales in response to the exposures.

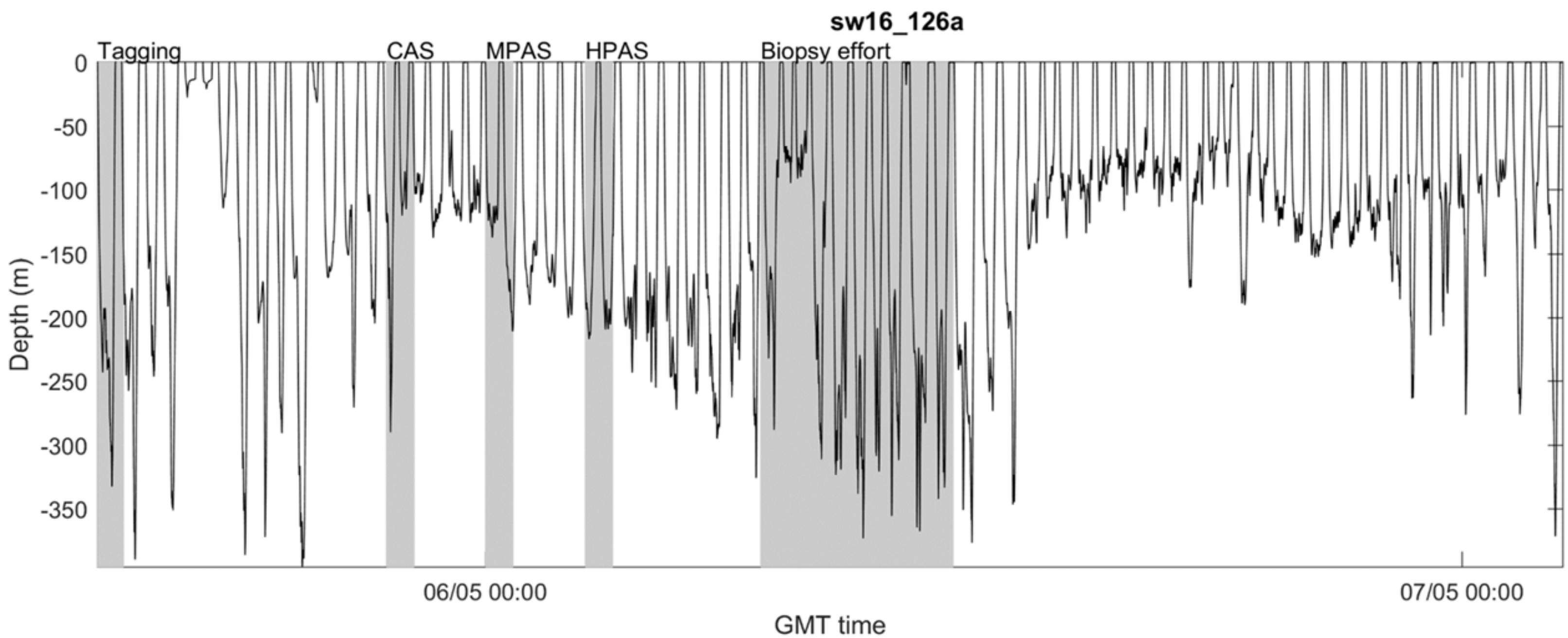
The pilot whale conducted two deep foraging dives in the baseline, one during the no-sonar approach and another two prior to the CAS exposure (Figure 3.11).

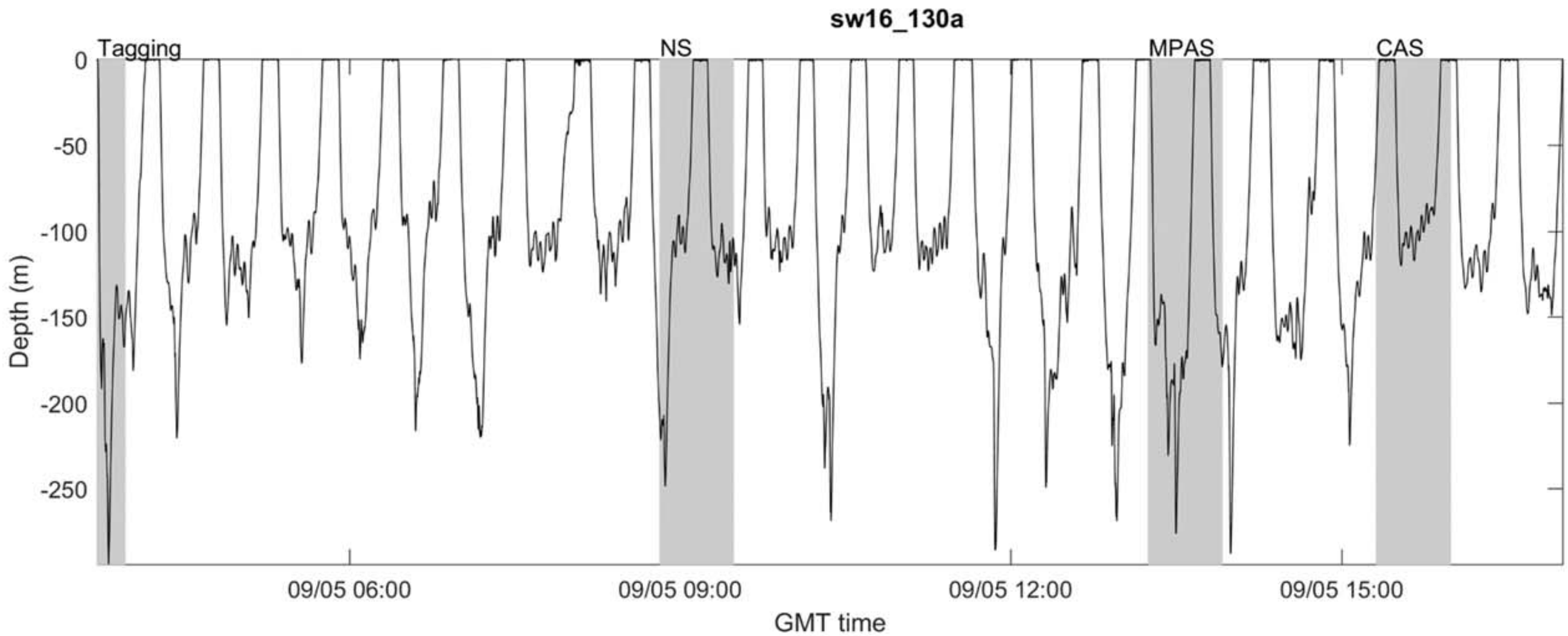
Acoustic and movement data were recorded successfully in eight tags, and only one tag came off a sperm whale too prematurely to record useful data. Almost all tagged whales had a short term and mild response to tagging (Scored as 1), except sw16_126a that did not respond at all (Scored 0) and sw16_135a that approached the boat closely in a forceful manner (Scored as 2).

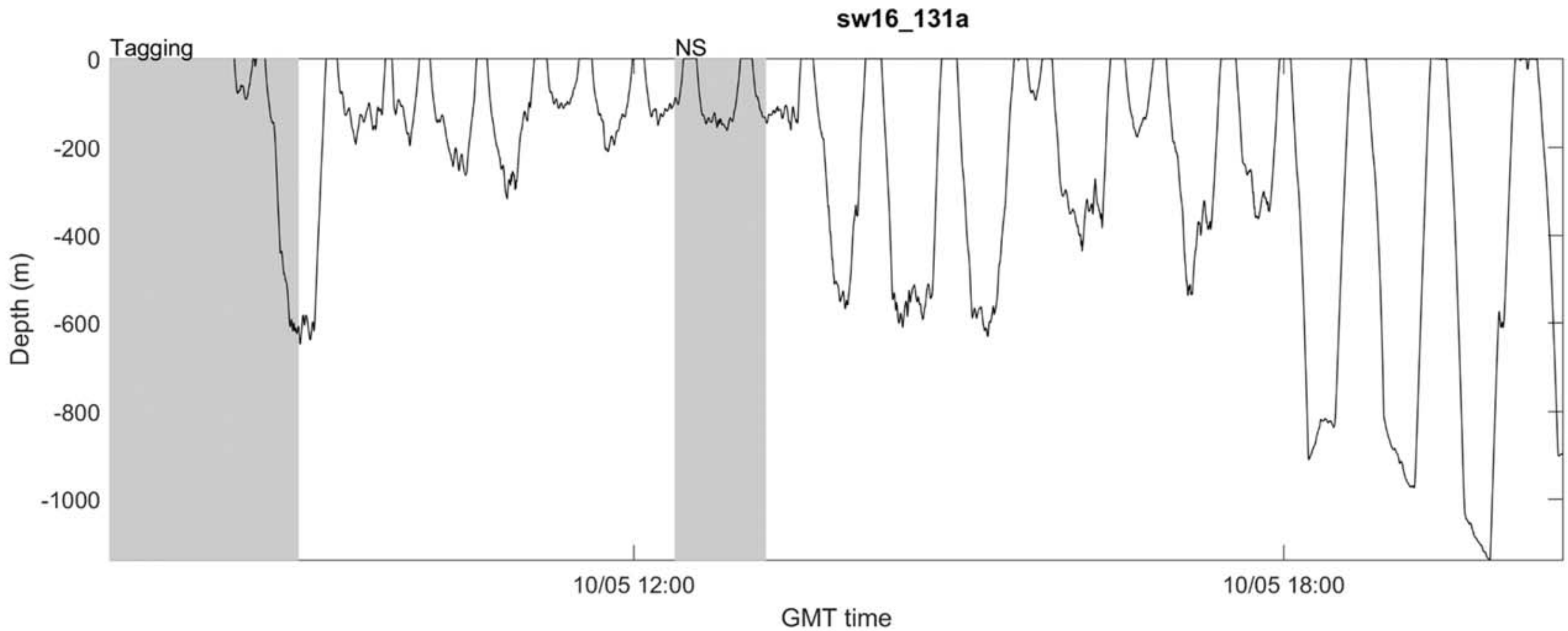
Table 3.8. DTAG deployments.

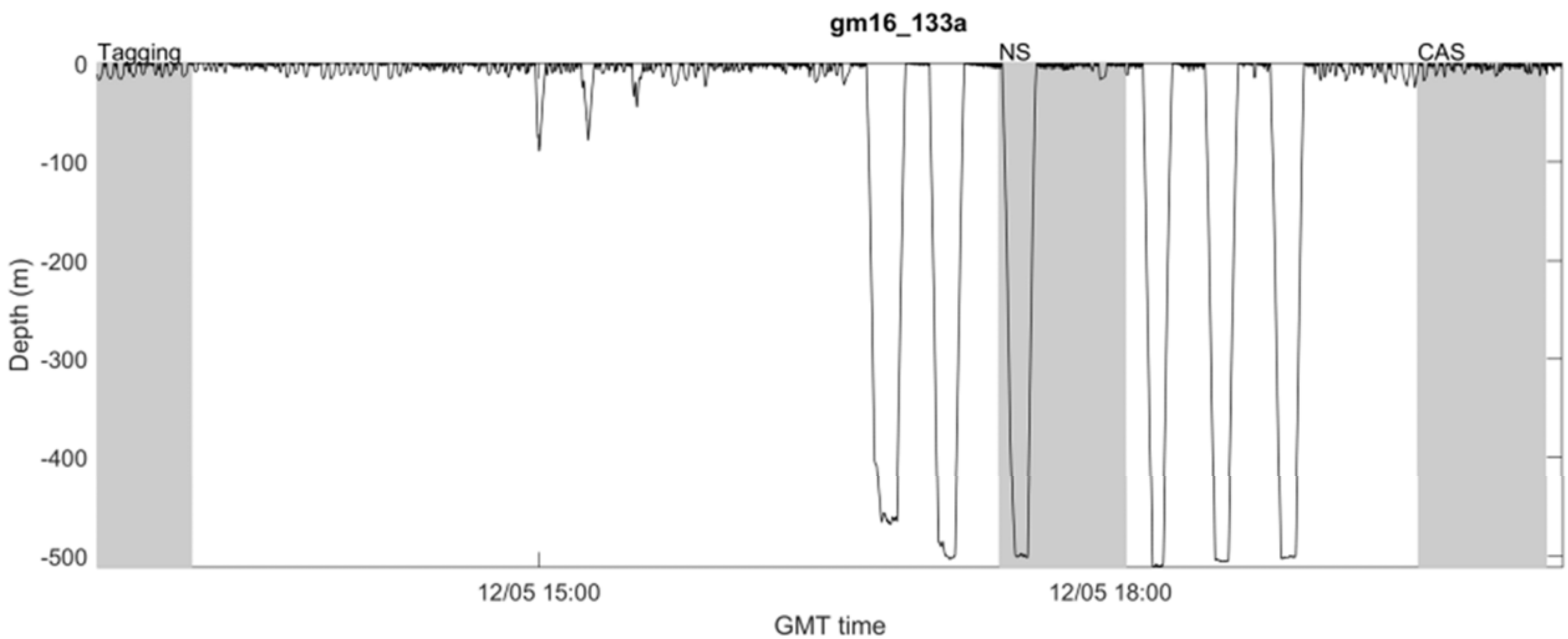
Deployment	Sighting number	Tag-on time (UTC)	Tag-on position	Tag-off time (UTC)	On-animal hours	Tag type, Method	Reaction	Notes
sw16_126a	21	05/05/2016 14:28:36	69° 45.596 N 17° 33.396 E	07/05/2016 02:28:42	36.00	DTAG3, Cantilever pole	0	1:30-hour burn time was not enough so releases did not fire
sw16_130a	115	09/05/2016 03:42:46	69° 22.550 N 16° 25.900 E	09/05/2016 17:00:24	13.29	DTAG3, Cantilever pole	1	
sw16_130b		09/05/2016 23:34:00	69° 22.270 N 14° 59.370 E	09/05/2016 23:38:00	0.07	DTAG3, Cantilever pole	1	Tag came off - no data downloaded
sw16_131a	207	10/05/2016 07:10:00	69° 18.207 N 14° 10.306 E	10/05/2016 20:34:36	13.41	DTAG3, Cantilever pole	1	
gm16_133a	230	12/05/2016 12:40:57	69° 07.884 N 16° 14.835 E	12/05/2016 20:22:24	7.69	DTAG3, Handheld pole	0	Large adult, with another larg(ish) animal and small animal with calf
sw16_134a	243	13/05/2016 13:18:45	69° 48.365 N 17° 23.571 E	13/05/2016 19:01:08	5.71	DTAG3, Cantilever pole	1	
sw16_134b	255	13/05/2016 22:22:25	69° 45.950 N 17° 39.290 E	14/05/2016 14:41:13	16.31	DTAG3, Cantilever pole	1	Tag came off during biopsy effort; no sample
sw16_135a	296	14/05/2016 21:32:19	69° 42.740 N 15° 50.920 E	15/05/2016 13:15:21	15.72	DTAG3, Cantilever pole	2	Whale appeared to investigate boat during tagging effort
sw16_136a	371	15/05/2016 22:11:54	69° 21.970 N 16° 30.220 E	16/05/2016 14:33:33	16.36	DTAG3, Cantilever pole	1	

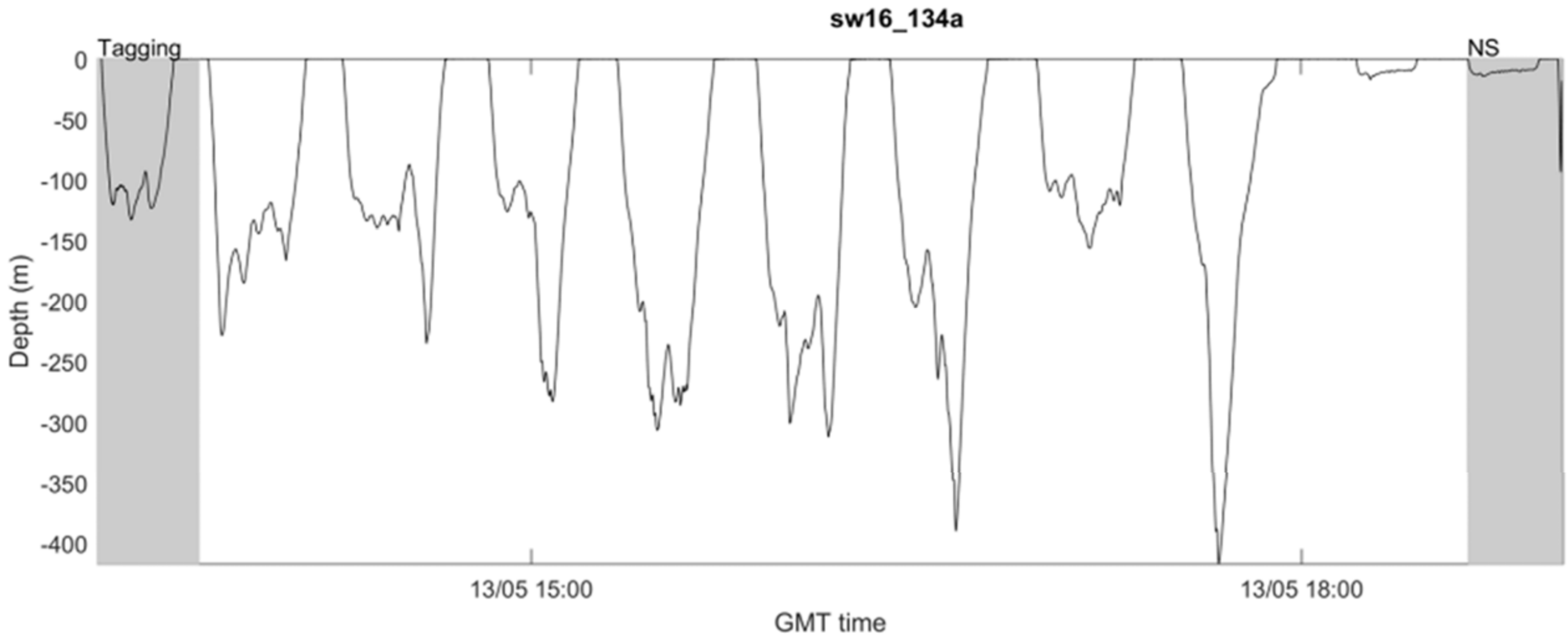
Figure 3.11. Dive profiles of all DTAG records.



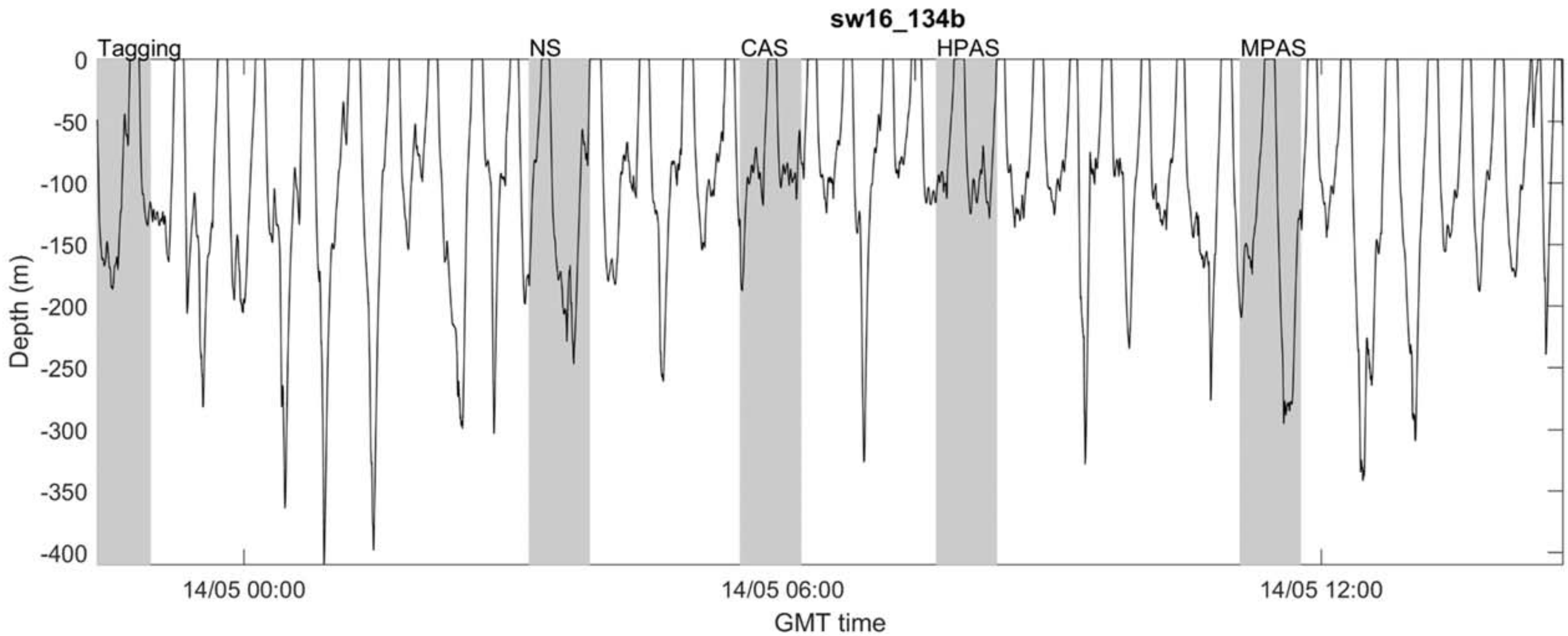

sw16_130a
Tagging
NS
MPAS
CAS
0
-50
-100
-150
-200
-250
Depth (m)
09/05 06:00
09/05 09:00
09/05 12:00
09/05 15:00
GMT time

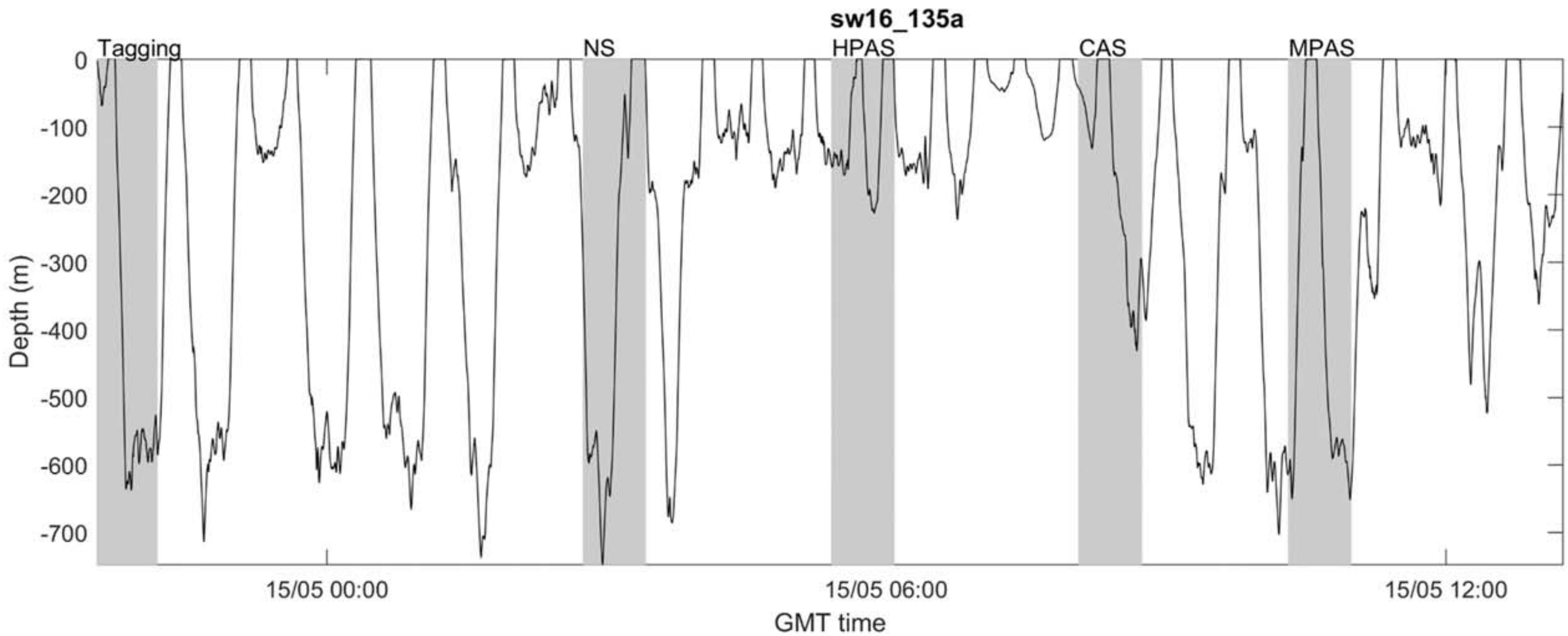

sw16_131a
Tagging
NS
0
-200
-400
-600
-800
-1000
Depth (m)
10/05 12:00
10/05 18:00
GMT time

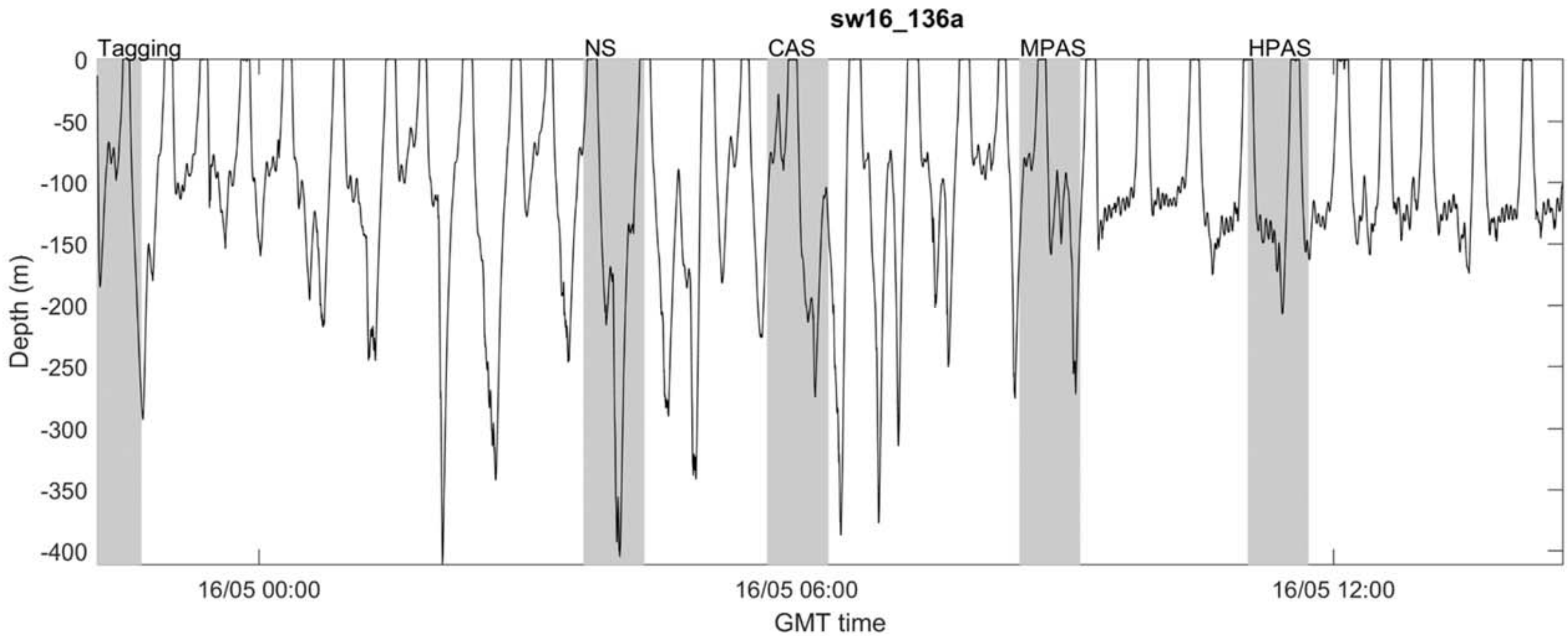

gm16_133a
Tagging
NS
CAS
0
-100
-200
-300
-400
-500
Depth (m)
12/05 15:00
12/05 18:00
GMT time



sw16_134a
Tagging
NS
0
-50
-100
-150
-200
-250
-300
-350
-400
Depth (m)
13/05 15:00
13/05 18:00
GMT time


sw16_134b
Tagging
NS
CAS
HPAS
MPAS
0
-50
-100
-150
-200
-250
-300
-350
-400
Depth (m)
14/05 00:00
14/05 06:00
14/05 12:00
GMT time


sw16_135a
Tagging
NS
HPAS
CAS
MPAS
0
-100
-200
-300
-400
-500
-600
-700
Depth (m)
15/05 00:00
15/05 06:00
15/05 12:00
GMT time


sw16_136a
Tagging
NS
CAS
MPAS
HPAS
0
-50
-100
-150
-200
-250
-300
-350
-400
Depth (m)
16/05 00:00
16/05 06:00
16/05 12:00
GMT time

3.7 Photo-id

Identification photographs were taken of tagged whales after tagging, and opportunistically of other non-tagged whales. See appendix D for photos of all tagged whales. Sea state and light conditions limited the quality of some photographs (e.g., sw16_134b). Four tagged sperm whales (sw16_126a, sw16_130a, sw16_134a and sw16_134b) and the tagged pilot whale gm16_133a had sufficient markings and quality of photos to be potentially matched with known individuals.

3.8 Environmental parameters

Measurements of sound propagation conditions were made in connection with each sonar exposure experiment. The DTAG had two hydrophones, which measure the sound levels on the animal during the sonar exposures. However, in order to understand the response of the animal, it is important in our analysis to have an idea of the overall sound picture in the environment. To achieve this, sound speed profiles (Figure 3.12) are used as input to sound propagation models (Figure 3.13). Temperature profiles (XBT) are collected during each exposure run (Table 3.9).
It was also planned to perform a CTD after each experiment, but because of technical problems with the CTD sensor these measurements were not performed.

Table 3.9. Overview of XBT's during 3S-2016-CAS.

XBT Name	Date	Time (UTC)	Max Depth [m]	Latitude	Longitude
T7_00012.EDF	05-05-2016	07:33	350	69 29.6431N	18 06.6195E
T7_00013.EDF	05-05-2016	22:00	200	69 46.1752N	17 25.8170E
T7_00014.EDF	06-05-2016	00:23	310	69 49.7486N	17 06.6954E
T7_00015.EDF	06-05-2016	02:50	370	69 51.5247N	16 51.6955E
T7_00016.EDF	07-05-2016	07:56	370	69 42.6021N	17 34.0538E
T7_00017.EDF	07-05-2016	10:39	256	69 43.6914N	17 27.9550E
T7_00018.EDF	07-05-2016	20:43	370	69 31.7992N	18 00.9816E
T7_00019.EDF	09-05-2016	09:12	240	69 28.8563N	16 18.0151E
T7_00020.EDF	09-05-2016	13:37	480	69 23.5603N	16 20.8475E
T7_00021.EDF	09-05-2016	15:41	370	69 27.6432N	16 17.2856E
T7_00022.EDF	10-05-2016	12:42	730	69 19.9990N	13 50.2639E
T7_00023.EDF	12:05-2016	17:45	260	69 06.7129N	16 20.3092E
T7_00024.EDF	12-05-2016	20:00	460	69 13.7939N	16 24.6481E
T7_00025.EDF	13-05-2016	19:08	260	69 45.2822N	17 36.3586E
T7_00026.EDF	14-05-2016	03:30	420	69 45.7070N	17 32.6506E
T7_00027.EDF	14-05-2016	05:53	430	69 45.1943N	17 41.4396E
T7_00028.EDF	14-05-2016	08:06	380	69 47.3745N	17 37.4526E
T7_00029.EDF	14-05-2016	11:28	300	69 51.9863N	17 23.3674E
T7_00030.EDF	15-05-2016	03:04	730	69 36.9736N	15 32.2255E
T7_00031.EDF	15-05-2016	05:52	730	69 42.7788N	15 38.4434E
T7_00032.EDF	15-05-2016	08:27	520	69 42.9946N	16 06.9538E
T7_00033.EDF	15-05-2016	10:42	730	69 47.2134N	16 02.3450E
T7_00034.EDF	16-05-2016	03:52	450	69 25.4605N	16 17.2401E
T7_00035.EDF	16-05-2016	06:05	400	69 27.1802N	16 26.9923E
T7_00036.EDF	16-05-2016	08:55	370	69 27.7056N	16 21.7136E
T7_00037.EDF	16-05-2016	11:26	300	69 32.3828N	16 15.7312E

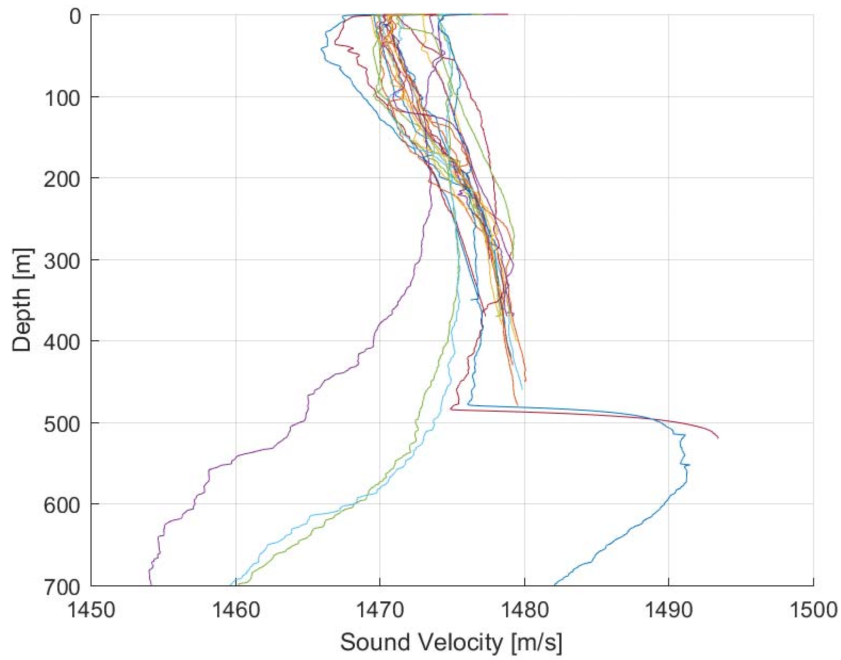


Figure 3.12. All 22 XBT profiles as recorded during the 3S-2016-CAS trial.

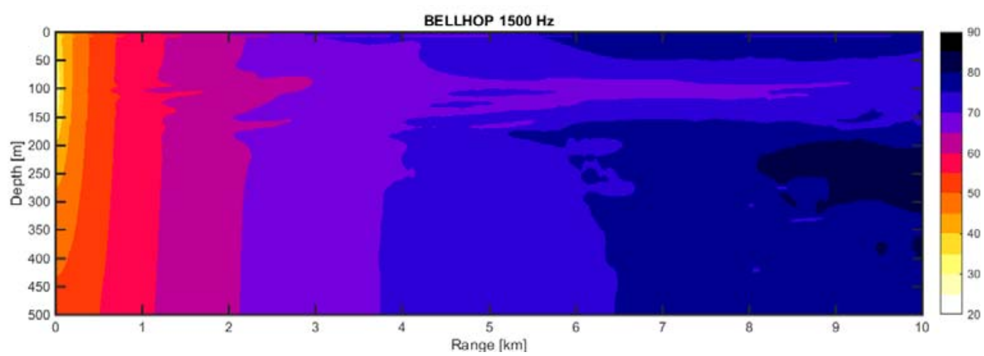


Figure 3.13. Transmission loss estimate by the Bellhop propagation model for XBT #T7_00027.EDF.

4 Discussion

During the trial we deployed eight DTAGs on sperm whales and one on a pilot whale. We collected a total of 125 hours of tag data, including >50 hours of baseline data. We conducted 7 no-sonar exposures, 9 pulsed sonar exposures at two different source levels, and 6 CAS exposures. The data collection rate was very high during this trial, despite the fact that we had relatively poor weather conditions. The limiting factor during behavioral response studies is often the ability to deploy tags on whales. During this trial the tagging efficiency was very high, even under difficult weather conditions tags were deployed with minimal time usage, often within 1 hour. The availability of tags did not limit our ability to collect data, but in the end of the trial we only had one fully functional tag unit, and we should therefore plan for a higher redundancy in future trial. We consider that we are well on schedule with the collection of data to compare responses to CAS versus PAS in sperm whales, which is one of the primary objectives of the project.
Our experimental design seems to work well, although we need to analyze the tag data to get the final confirmation that we are achieving the desired dose escalation. This is the first time we have been tracking the tagged whale from the source ship. Boxing and tracking the animals at a distance worked well, except that in some cases there were difficulties to relocate the animal after the exposure run. The use of the mixed DTAG in our experiments may improve this, and at the same time increase data quality since the tag will be logging animal positions also when the animal is beyond visual detection range from the source boat

Primary tasks:

√ 1. Test the CAS-performance of the Socrates sonar source to assure that it can transmit the scheme needed for the CAS-experiment, and to measure the presence of harmonics in the different transmission modes.
o 2. Test the mixed-GPS-DTAG3 in DTAG2 housing concept, and start using that tag in the CAS experiments as soon as we are comfortable that it works.
√ 3. Tag sperm whales with DTAG and record vocal-, movement- and dive behaviour, and thereafter carry out no-sonar control-, pulsed sonar (PAS) and continuous active sonar (CAS) exposures.

Secondary tasks:

√ 4. Tag killer whales or pilot whales with DTAG3 and do CAS experiment on them following the same protocol as with sperm whales
o 5. Tag minke whales (Balaenoptera acutorostrata) with DTAG3 and replicate the pulsed sonar experiment from 2011.
o 6. Test ARTS launching of the mixed-DTAG
√ 7. Collect baseline data of target species.
√ 8. Collect information about the environment in the study area (CTD and XBT measurements).
√ 9. Re-approach of tagged animal after experimental cycle to collect biopsy sample.
√ 10. Collection of bio-acoustic data using towed arrays.
√ 11. Collect sightings of marine mammals in study area.

Figure 4.1. Two of the three primary tasks of the trial and four of the eight secondary tasks were achieved.

We also conducted a series of tests of the CAS performance of the SOCRATES source, and are now comfortable that it works well for our experiments. We found that the harmonics levels are higher during full power PAS transmission (HPAS) than during transmissions with reduced source level (CAS and MPAS). However, this was expected and is probably a realistic feature also in operational sonar systems.

The mixed DTAG with GPS and ARGOS sensors were not tested during the trial (task 2) due to delay in production. This was considered a very important task, but the tag was simply not available at the start of the trial. Thus, two of the three primary tasks for the trial (section 1.3) were achieved successfully (Figure 4.1).

In addition to the primary tasks we also achieved the following secondary tasks (Figure 4.1): collection of biopsy samples and baseline data of tagged sperm whales (Section 3.6, Figure 3.11), collection of both acoustic (Table 3.4) and visual data (Table 3.7) of marine mammals in the study area, and measurement of environmental parameters using CTD and XBT casts (Table 3.9). We did not collect any data on minke whales (task 5). A few minke whales were sighted, but there was no opportunity to try to tag. Secondary tasks are not supposed to affect primary tasks and since minke whales are very difficult to tag it is not realistic that we will be able to collect minke whale data unless it is given a higher priority. Given that we have finalized analysis and published existing minke whale data (Kvadsheim et al. 2017), we should probably just close the book on this now. We also did not test ARTS launching of the mixed DTAG (task 6), because the mixed DTAG was not available during the trial.

4.1 Recommendation for future work

(1) Test the mixed DTAG.

Since there was no opportunity to test the mixed DTAG during the trial this should have a high priority in the upcoming 3S3-ORBS trial to Jan Mayen focussing on bottlenose whales (Miller et al. 2017). This is also already part of the objective of this trial. Testing of the mixed DTAG should also include ARTS launching of the tag.

(2) Implement the mixed DTAG.

If the regular DTAGs can be replaced by mixed DTAGs in our experiments this will give a higher data quality since the tag is collecting a continuous track of the whale. It might also increase the number of tagged subjects since we may be able to deploy multiple tags and expose several tagged animals at the same time.
This could be particularly valuable to assess the received level versus range question.

(3) Bring more tags.

Some of the tags might fail or be lost during trials and we should increase our redundancy of tags to avoid that availability of tags will limit our data collection.
This year it did not, but with 1 of 2 tags failing it was a narrow escape.

(4) Replace minke whales with other secondary species

We should consider to terminate the minke whale effort, and instead replace minkes with humpbacks in the permit. Humpback whales will give us more opportunities to work with as secondary species, and they are also a convenient species to work with for tag testing purposes.

5 References

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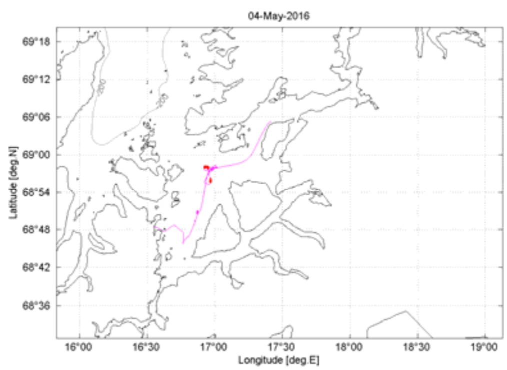
A Data inventory

Folder	Subfolders/files	Summary of content
Documents	Bridge Logs	Daily text files created by cruise leader with the GPS event logger on the bridge, screenshots, overall activity record, weather and some specific event summaries
	Briefs	PPTs of cruise briefing and debriefings
	Daily Orders	Daily work plans that we put up daily to inform the team about weather, work area, etc
	individual files	Cruise plan, reticle-to-distance conversion table, TNO events log book, TNO summary information about acoustic recordings and number of whales clicking
acousticDataAndResults	harmonicsAnalysis	Tests to quantify harmonics in source signal
	OWID_data	Acoustic recording and GPS track during harmonics tests
	plot_tracks	Plots of daily sailing tracks including scripts
	screendumps	Screenshots of TNO PAM systems
dtag3	tag2	Raw DTAG3 data (.dtg, .swv, .xml) and meta data (cal and prh)
	individual files	Logbook kept by tag technicians, dtag3 prep protocol, etc
GPSlogs	Logger	NMEA dumps (asci text files) create by NMEA terminal. Includes GPS and heading feed from Sverdrup when Logger was on.
	Mobhus	Tagboat tracks recorded with Garmin handheld GPS and stored in gpx (general exchange) and/or gdb (Mapsource) format. GPX is in standard ASCI txt format
	Sverdrup	Raw NMEA logs from GPS on TNO container and all data combined in Matlab workspace files including scripts
Logger backup	logger_backup	Daily backups of raw logger database
	Old versions data checking	Previous version of the Checked_database logger XLS file
	individual files	Checked_data logger files that will be imported back into Access to create MASTER database
picture and video	Pictures	All photos organised by Cruise Highlights, Photo ID data and fun pics
	Video	GoPro videos of TNO and Lars
SocratesLogs		Log files of SOCRATES II source. Times of transmissions in the transmission.log file in each subfolder
XBT		XBT profiles including sound speed profiles and raw XBT data for use in MK21 program

B Daily Sail Tracks

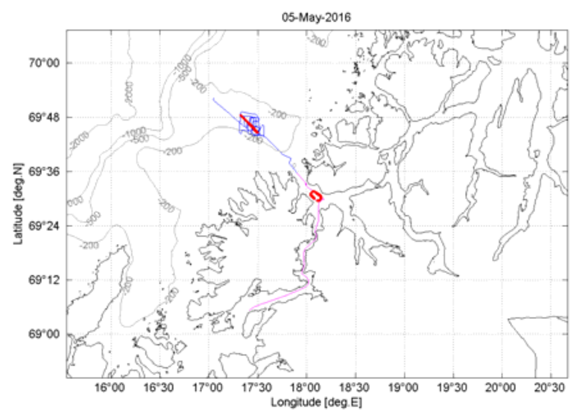
Daily sail tracks of H.U. Sverdrup II during the 3S-2016-CAS trial. Red track means SOCRATES source was being used, blue means Delphinus acoustic array was deployed and magenta means neither systems were deployed.

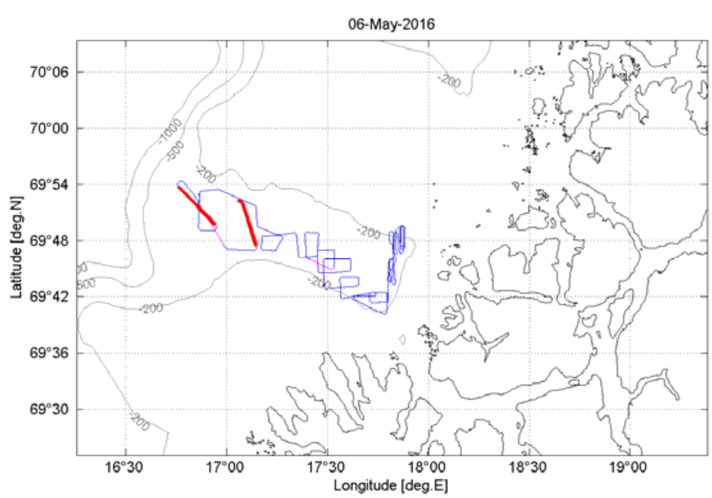
May 3rd: In port in Harstad for embarkment and mobilization.



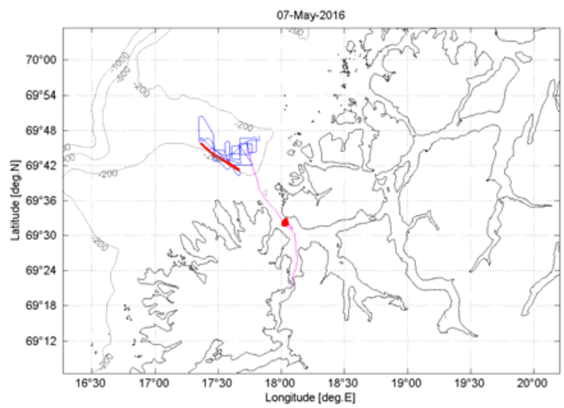
May 4th: Test of VHF-tracking systems and harmonics of SOCRATES source in Vågsfjorden. Source failed due to failure in the ship's power supply.

May 5th: Transited to Malangen. Repeated test on VHF-tracking systems and test on SOCRATES source. Both tests were successful. Transited to Malangen channel. Tagged sperm whale sw16_126 and started to conduct CEE I





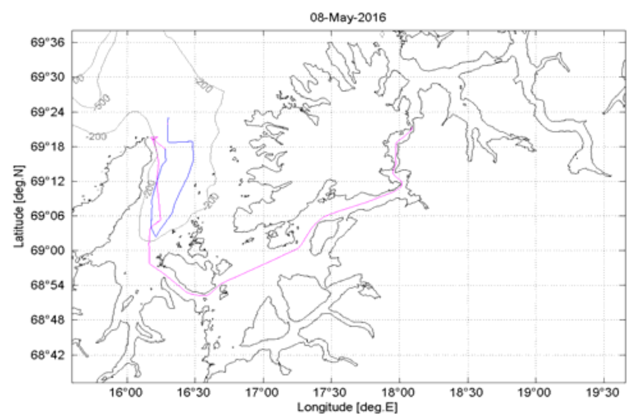
May 6th: Completed CEE I. Tag release failed. Continued to track tagged whale sw16_126 waiting for the tag to come off.

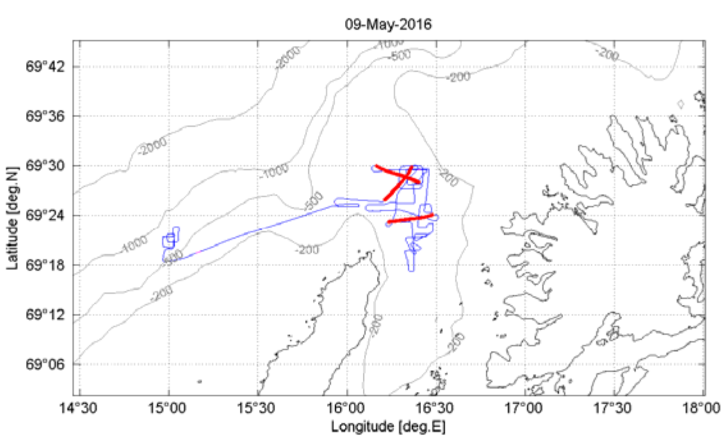


<u>May 7</u>

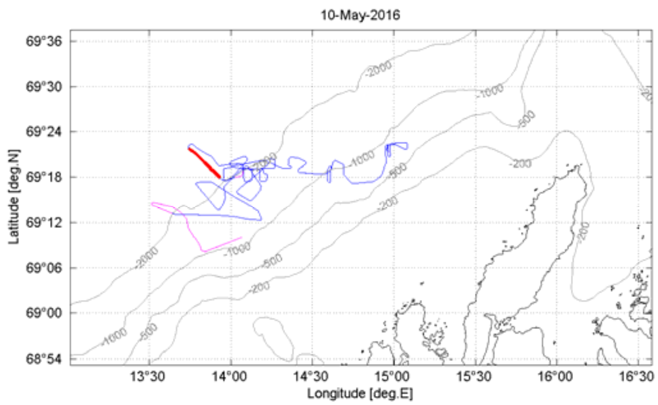
<u>May 7th</u>: Continued to track tagged whale sw16_126 waiting for the tag to come off. After 40 hrs we decided to repeat exposure experiment. After 2 runs, the tag finally released after 50 hrs on the whale. The tag had stopped recording after about 40 hrs.
Transited to Malangen to conduct final tests of harmonics of the SOCRATES source.

<u>May 8th</u>: Transited to Andfjord. Searched acoustically in Andfjord. Not workable conditions for tagging.



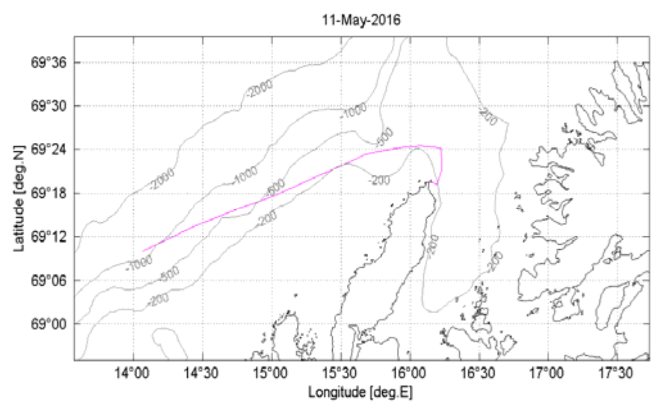


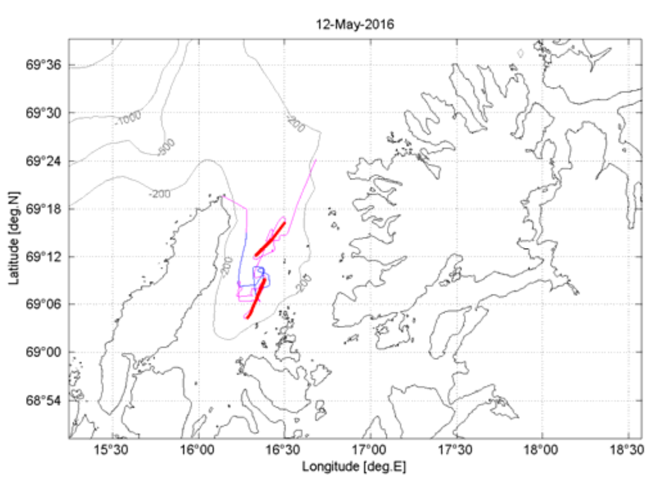
<u>May 9th</u>: Tagged sperm whale sw16_130 in outer Andfjord. Conducted CEE II.
Transited 25 nmi WSW along shelf brake, out of the ensonified area and started searching for new animals.



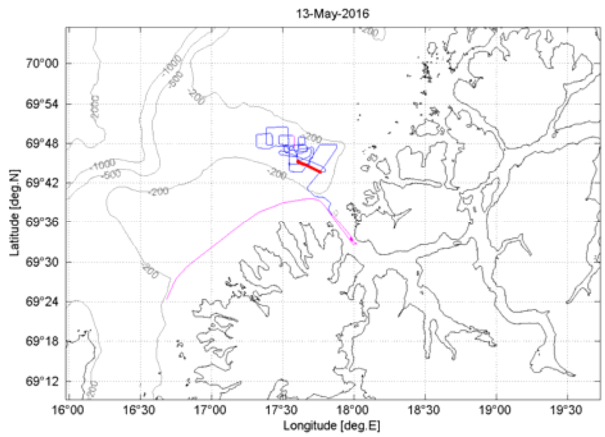
<u>May 10th:</u> Tagged sperm whale sw16_131. Conducted the no sonar run (CEE III), but never re-located the animal after that. After 12 hrs the tag was recovered 11 nmi SW of the last known position.

<u>May 11th:</u> Transited to Andenes due to expected bad weather. Stayed in port in Andenes all day



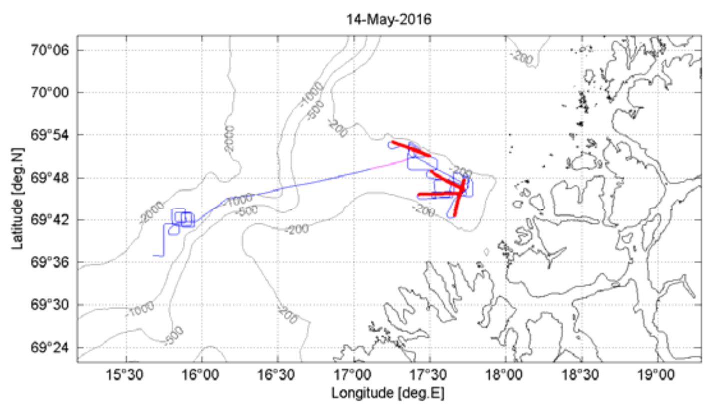


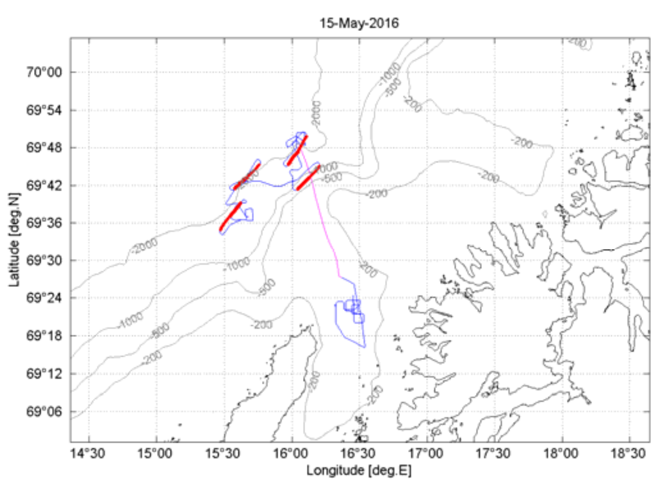
<u>May 12th:</u> Difficult but improving conditions in Andfjord. Tagged pilot whale gm16_133 and conducted CEE IV with no-sonar and CAS-runs before the tag released. Transited north-wards out of the ensonified area



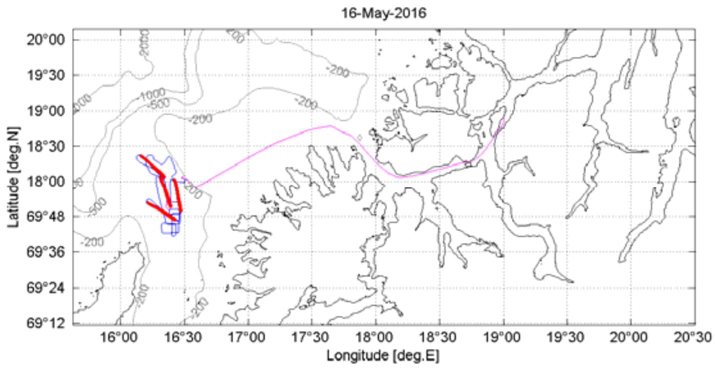
<u>May 13th:</u> Transited to Malangen for VHF range test on DTAG with repaired antenna. Tagged sperm whale sw16_134a in the Malangs-channel. The tag released during the no-sonar run (CEE V)

<u>May 14th:</u> Tagged sperm whale sw16_134b in the Malangs-channel. Conducted CEE VI. Transited WSW out of the ensonified area and started searching for new target animals.





<u>May 15th:</u> Tagged sperm whale sw16_135 off the shelf break and conducted CEE VII. Transited S out of the ensonified area and started searching for new target animals.



<u>May 16th:</u> Tagged sperm whale sw16_136 in outer Andfjord and conducted CEE VIII. This was the 5th full CEE in 5 days! Transited to Tromsø.

<u>May 17th:</u> In port in Tromsø for de-mobilization. Celebrated trial result and Norwegian national day.

<u>May 18th:</u> Off-loaded all gear and disembarked. End of trial.

C Sightings

GpsTime	Species	Sighting number	Group size			Position	
			Low	Best	High	Latitude	Longitude
05/05/2016 11:34:22	PM	10	1	1	1	69.73557281	17.53578949
05/05/2016 11:56:21	PM	11	1	1	1	69.746315	17.52361298
05/05/2016 12:04:41	PM	12	1	1	1	69.7607193	17.52709961
05/05/2016 12:23:28	PM	13				69.74758148	17.51173782
05/05/2016 12:32:05	PM	15	1	1	1	69.73207855	17.50241661
05/05/2016 12:46:46	PM	16	1	1	1	69.73461151	17.4982605
05/05/2016 12:50:47	PM	17		1		69.74694824	17.4974823
05/05/2016 13:21:54	PM	18	1	1	1	69.75498962	17.4612236
05/05/2016 13:57:08	PM	20	1	1	1	69.74906158	17.42504311
05/05/2016 14:21:54	PM	21	1	1	1	69.75636292	17.3991394
05/05/2016 14:32:37	PM	22	1	1	1	69.77415466	17.40087509
05/05/2016 14:56:38	PM	23	1	1	1	69.75295258	17.41636467
05/05/2016 15:28:49	PM	24	1	1	1	69.76656342	17.35712051
05/05/2016 16:23:29	PM	25	1	1	1	69.80823517	17.40831757
05/05/2016 18:04:59	PM	26	1	1	1	69.7987442	17.42726707
05/05/2016 19:40:12	PM	27	1	1	1	69.76480103	17.52283287
05/05/2016 19:57:59	PM	28		1		69.76025391	17.49800873
05/05/2016 23:42:45	PM	30	1	1	1	69.84247589	17.13527107
06/05/2016 00:04:47	PM	31	1	1	1	69.86585236	17.08338356
06/05/2016 01:35:55	PM	32	1	1	1	69.84441376	16.88552666
06/05/2016 01:46:18	PM	33	1	1	1	69.85569763	16.92771912
06/05/2016 01:59:24	PM	34	1	1	1	69.85921478	16.84869003
06/05/2016 02:12:34	PM	35	1	1	1	69.86518097	16.85128212
06/05/2016 02:16:02	PM	36	1	1	1	69.90433502	16.79133606
06/05/2016 02:34:57	PM	37	1	1	1	69.87732697	16.81443596
06/05/2016 02:58:47	PM	38	1	1	1	69.83620453	16.87127304
06/05/2016 03:05:05	PM	39	1	1	1	69.83337402	16.84593582
06/05/2016 03:08:11	PM	40	1	1	1	69.80404663	16.97144127
06/05/2016 03:31:43	PM	41	1	1	1	69.83416748	16.83857536
06/05/2016 03:32:27	PM	42	1	1	1	69.82474518	16.82853127
06/05/2016 03:40:08	PM	43	1	1	1	69.86949158	16.8332386
06/05/2016 04:09:20	PM	44	1	1	1	69.8680191	16.86035919
06/05/2016 04:45:52	PM	45	1	1	1	69.87078857	17.04427147
06/05/2016 05:02:23	PM	46	1	1	1	69.85561371	17.11697197
06/05/2016 05:44:31	PM	47	1	1	1	69.81887054	17.27731514
06/05/2016 05:46:39	PM	48	1	1	1	69.81484222	17.25119781

GpsTime	Species	Sighting number	Group size			Position	
06/05/2016 07:53:19	PM	50	1	1	1	69.77844238	17.42188263
06/05/2016 09:25:20	PM	51	1	1	1	69.75840759	17.47697067
06/05/2016 09:29:32	PM	52	1	1	1	69.76463318	17.4785614
06/05/2016 12:18:57	PM	54	1	1	1	69.72675323	17.5259552
06/05/2016 13:05:09	PM	55	1	1	1	69.71121979	17.64344597
06/05/2016 14:13:14	PM	57	1	1	1	69.69000244	17.66335869
06/05/2016 14:39:51	PM	58	1	1	1	69.69082642	17.69257736
06/05/2016 14:51:53	PM	59	1	1	1	69.67997742	17.66587639
06/05/2016 15:08:36	PM	60	1	1	1	69.69580841	17.69774055
06/05/2016 15:17:21	PM	61	1	1	1	69.68885803	17.69891548
06/05/2016 16:02:52	PM	62	1	1	1	69.70974731	17.76722908
06/05/2016 16:09:30	PM	63	1	1	1	69.71360016	17.75185394
06/05/2016 16:36:45	PM	64	1	1	1	69.7102356	17.80778313
06/05/2016 17:20:40	PM	65	1	1	1	69.74832153	17.74016762
06/05/2016 17:23:26	PM	66	1	1	1	69.77413177	17.72421646
06/05/2016 17:37:37	PM	67	1	1	1	69.75993347	17.84052277
06/05/2016 17:40:49	PM	68	1	1	1	69.75888824	17.83798409
06/05/2016 18:22:40	PM	69	1	1	1	69.75871277	17.81812286
06/05/2016 20:54:45	PM	71	1	1	1	69.82302094	17.86454201
06/05/2016 23:27:07	PM	72	1	1	1	69.8094101	17.80685806
06/05/2016 23:54:57	PM	73	1	1	1	69.79743958	17.82288742
07/05/2016 00:04:43	PM	74	1	1	1	69.7739563	17.82525635
07/05/2016 01:20:04	PM	75	1	1	1	69.76721191	17.78234482
07/05/2016 01:32:24	PM	76	1	1	1	69.78600311	17.72011948
07/05/2016 01:54:28	PM	77	1	1	1	69.78775787	17.68912888
07/05/2016 02:16:47	PM	78	1	1	1	69.7374115	17.71580124
07/05/2016 02:52:41	PM	79	1	1	1	69.74414063	17.70336723
07/05/2016 03:25:29	PM	80	1	1	1	69.74248505	17.70724869
07/05/2016 03:47:28	PM	81	1	1	1	69.72991943	17.68061256
07/05/2016 04:06:54	PM	82	1	1	1	69.76833344	17.5961113
07/05/2016 04:35:06	PM	83	1	1	1	69.72661591	17.70793152
07/05/2016 04:59:40	PM	84	1	1	1	69.70095062	17.71790886
07/05/2016 12:04:20	PM	88	1	1	1	69.80649567	17.46228981
07/05/2016 12:16:50	PM	89	1	1	1	69.84120178	17.43185806
07/05/2016 12:25:53	PM	90				69.83297729	17.34415436
07/05/2016 12:26:31	PM	91	1	1	1	69.83306885	17.41010094
07/05/2016 12:29:17	PM	92	1	1	1	69.83943939	17.33443832
07/05/2016 12:32:40	PM	93				69.83166504	17.34683418
07/05/2016 12:38:29	PM	94				69.82501984	17.30657005

GpsTime	Species	Sighting number	Group size			Position	
07/05/2016 12:41:35	PM	96	1	1	1	69.81387329	17.39353371
07/05/2016 12:58:31	PM	97	1	1	1	69.79136658	17.33071327
09/05/2016 00:21:30	PM	100	1	1	1	69.36331177	16.38060379
09/05/2016 00:36:21	PM	101	1	1	1	69.33356476	16.33328056
09/05/2016 00:40:55	PM	102	1	1	1	69.32991791	16.39146614
09/05/2016 01:40:14	PM	104		1		69.33925629	16.30724144
09/05/2016 01:46:05	PM	105	1	1	1	69.34143829	16.40901566
09/05/2016 02:00:58	PM	106	1	1	1	69.35314178	16.40791893
09/05/2016 02:10:18	PM	107	1	1	1	69.36257935	16.43197441
09/05/2016 02:39:56	PM	108	1	1	1	69.3607254	16.35023689
09/05/2016 02:47:45	PM	109	1	1	1	69.36992645	16.35957718
09/05/2016 02:54:37	PM	110	1	1	1	69.35353088	16.37145042
09/05/2016 03:06:37	PM	111	1	1	1	69.35423279	16.40299416
09/05/2016 03:20:06	PM	112	1	1	1	69.36587524	16.45832253
09/05/2016 03:23:02	PM	113				69.36569977	16.41444016
09/05/2016 03:43:18	PM	115				69.32311249	16.36208534
09/05/2016 04:40:05	PM	117		1		69.39682007	16.36335945
09/05/2016 04:54:39	PM	119	1	1	1	69.42095184	16.39105988
09/05/2016 05:01:50	PM	120	1	1	1	69.42438507	16.4473114
09/05/2016 05:05:35	PM	121		1		69.42401123	16.4388237
09/05/2016 05:08:37	PM	122		1		69.39737701	16.47519112
09/05/2016 05:39:50	PM	123		1		69.42037964	16.45593071
09/05/2016 05:44:24	PM	124	1	1	1	69.43292999	16.43932152
09/05/2016 05:55:42	PM	125		1		69.45785522	16.48201752
09/05/2016 06:14:19	PM	126	1	1	1	69.48963928	16.4532299
09/05/2016 06:46:16	PM	128				69.48671722	16.38519096
09/05/2016 07:19:00	PM	129	1	1	1	69.46840668	16.36881447
09/05/2016 07:46:37	PM	130	1	1	1	69.48947144	16.43118286
09/05/2016 09:09:52	PM	131		1		69.49098969	16.28096771
09/05/2016 09:23:29	PM	132		1		69.46334076	16.37636185
09/05/2016 09:47:51	PM	133		1		69.45695496	16.33664894
09/05/2016 10:53:22	PM	134	1	1	1	69.44956207	16.33529282
09/05/2016 11:19:32	PM	135	1	2	2	69.43479156	16.36447144
09/05/2016 11:49:48	PM	136	1	1	1	69.42210388	16.13363266
09/05/2016 12:17:47	PM	139	1	1	1	69.42063141	16.23367882
09/05/2016 12:20:56	PM	140	1	1	1	69.41140747	16.22685051
09/05/2016 13:00:08	PM	142	1	1	1	69.39627838	16.41923714
09/05/2016 13:03:02	PM	143				69.39733124	16.47206688
09/05/2016 13:05:19	PM	144	1	1	1	69.40171814	16.48413086
09/05/2016 13:09:18	PM	145	1	1	1	69.40007782	16.50058365

GpsTime	Species	Sighting number	Group size			Position	
09/05/2016 13:21:49	PM	146	1	1	1	69.3875351	16.36860275
09/05/2016 13:24:37	PM	147	1	1	1	69.39211273	16.37277794
09/05/2016 13:33:27	PM	148	1	1	1	69.38121033	16.38143349
09/05/2016 13:37:10	PM	149	2	2	2	69.39389801	16.29841042
09/05/2016 13:41:51	PM	150		1		69.38999176	16.28451157
09/05/2016 13:50:17	PM	151		1		69.38699341	16.28610229
09/05/2016 13:51:26	PM	152		1		69.3846283	16.23015594
09/05/2016 13:56:51	PM	153		1		69.40003967	16.22135353
09/05/2016 14:01:01	PM	154		1		69.38074493	16.24650002
09/05/2016 14:04:43	PM	155	1	1	1	69.3870697	16.24726677
09/05/2016 14:23:15	PM	156	1	1	1	69.40943909	16.273592
09/05/2016 14:27:59	PM	157	1	1	1	69.41727448	16.28274155
09/05/2016 14:30:10	PM	158	1	1	1	69.40309906	16.28111649
09/05/2016 14:40:04	PM	159	1	1	1	69.42783356	16.22701645
09/05/2016 14:44:41	PM	160	1	1	1	69.45957184	16.33584785
09/05/2016 14:51:05	PM	161	1	1	1	69.46279144	16.2618618
09/05/2016 14:58:17	PM	162	1	1	1	69.47174072	16.39628601
09/05/2016 15:13:18	PM	163	1	1	1	69.51501465	16.34981918
09/05/2016 15:19:05	PM	164	1	1	1	69.47714996	16.31061554
09/05/2016 15:20:26	PM	165	1	1	1	69.46764374	16.35035324
09/05/2016 15:21:45	PM	166				69.48845673	16.50894547
09/05/2016 15:22:32	PM	167	1	1	1	69.48786163	16.33047104
09/05/2016 15:26:46	PM	168	1	1	1	69.4779129	16.30573082
09/05/2016 15:35:22	PM	169	1	1	1	69.45380402	16.33504295
09/05/2016 15:39:20	PM	170	1	1	1	69.47344208	16.36192703
09/05/2016 15:43:29	PM	171	1	1	1	69.4588089	16.19573212
09/05/2016 15:50:02	PM	172	1	1	1	69.42882538	16.22685623
09/05/2016 16:00:21	PM	173	1	1	1	69.44148254	16.13400078
09/05/2016 16:19:37	PM	174	1	1	1	69.44216156	16.12802505
09/05/2016 16:20:53	PM	175	1	1	1	69.45029449	16.21804428
09/05/2016 16:39:35	PM	177	1	1	1	69.42549133	16.08779716
09/05/2016 16:55:50	PM	178	1	1	1	69.44776917	15.94536209
09/05/2016 16:56:29	PM	179	1	1	1	69.43769073	16.02580261
09/05/2016 21:13:11	PM	180		1		69.31787109	15.00767803
09/05/2016 21:45:12	PM	181		1		69.34549713	14.99492168
09/05/2016 22:39:21	PM	183	1			69.36145782	15.04177761
09/05/2016 22:45:33	PM	184				69.36065674	15.02142239
09/05/2016 23:17:48	PM	185	1	1	1	69.37722778	15.04935741
09/05/2016 23:40:53	PM	186	1	1	1	69.36617279	14.97274685

GpsTime	Species	Sighting number	Group size			Position	
09/05/2016 23:45:22	PM	187	1	1	1	69.37230682	14.98595524
10/05/2016 00:16:12	PM	191	1	1	1	69.3600235	14.95291328
10/05/2016 00:22:22	PM	193		1		69.3743515	15.04230785
10/05/2016 00:25:49	PM	194				69.37873077	15.05736065
10/05/2016 02:29:05	PM	195	1	1	1	69.30157471	14.86163044
10/05/2016 02:59:58	PM	196	1	1	1	69.30454254	14.76727486
10/05/2016 03:18:55	PM	197	1	1	1	69.30809784	14.69102573
10/05/2016 04:02:13	PM	198	1	1	1	69.31194305	14.63876343
10/05/2016 04:22:30	PM	199	1	1	1	69.30548859	14.57327557
10/05/2016 05:39:38	PM	200	1	1	1	69.31204224	14.45187569
10/05/2016 06:37:45	PM	201	1	1	1	69.33560944	14.29978371
10/05/2016 07:05:54	PM	202	1	1	1	69.32927704	14.26385307
10/05/2016 07:37:59	PM	204	1	1	1	69.31128693	14.20803738
10/05/2016 11:52:13	PM	208	1	1	1	69.34710693	13.89009762
10/05/2016 13:08:03	PM	209	1	1	1	69.28282928	14.02510929
10/05/2016 13:12:09	PM	210	1	1	1	69.33086395	14.08681965
10/05/2016 13:14:55	PM	211	1	1	1	69.3044281	14.02425766
10/05/2016 13:18:14	PM	212	1	1	1	69.3391037	14.13942909
10/05/2016 13:27:16	PM	213	1	1	1	69.29360962	14.10966682
10/05/2016 13:33:27	PM	214	1	1	1	69.32556152	14.15043259
10/05/2016 13:38:38	PM	215	1	1	1	69.32086182	14.16126537
10/05/2016 14:34:02	PM	216		1		69.35137177	14.28751659
10/05/2016 14:37:56	PM	217		1		69.33079529	14.26414394
10/05/2016 15:02:38	PM	218		1		69.29779053	14.12687016
10/05/2016 15:21:14	OO	219	4	6	8	69.28245544	14.07036686
10/05/2016 15:39:54	PM	220		1		69.19760132	14.03806782
10/05/2016 16:21:39	OO	221	2	2	3	69.30522919	14.13856411
10/05/2016 16:30:28	OO	222	2	3	5	69.31900024	14.12774467
10/05/2016 16:40:04	PM	223	1	1	1	69.30330658	14.13780117
10/05/2016 19:26:25	PM	224	1	1	1	69.2049942	14.17433739
10/05/2016 19:32:28	PM	225	1	1	1	69.22943115	14.18766785
10/05/2016 22:33:27	PM	226	1	1	1	69.20235443	13.7356472
12/05/2016 10:25:58	GM	227				69.1439209	16.34844589
12/05/2016 12:01:56	GM	229	4	5	10	69.14156342	16.21662903
12/05/2016 12:44:37	GM	230	6	8	10	69.13027954	16.25105858
12/05/2016 15:12:19	LAc	231		3		69.13039398	16.3524704
12/05/2016 17:41:20	GM	232				69.12199402	16.33441544
12/05/2016 19:45:33	PM	234	1	1	2	69.22861481	16.42267609
12/05/2016 19:50:32	GM	235		8		69.24650574	16.44579887
12/05/2016 20:01:35	GM	236				69.21813202	16.37996292

GpsTime	Species	Sighting number	Group size			Position	
12/05/2016 20:10:03	GM	237				69.19609833	16.37438202
12/05/2016 20:14:08	GM	238				69.19477844	16.36078835
12/05/2016 20:58:26	GM	239				69.23458862	16.43688965
12/05/2016 21:26:57	GM	240				69.24061584	16.42929268
13/05/2016 12:11:11	PM	242		1		69.80337524	17.37851906
13/05/2016 12:39:28	PM	243		1		69.80874634	17.35744095
13/05/2016 13:58:15	PM	244	1	1	1	69.84077454	17.41794014
13/05/2016 15:11:01	PM	245	1	1	1	69.82169342	17.44840431
13/05/2016 16:16:05	PM	246	1	1	1	69.80038452	17.63101196
13/05/2016 17:22:21	PM	247	1	1	1	69.77320862	17.58446884
13/05/2016 18:55:54	PM	248	1	1	1	69.77706909	17.7612915
13/05/2016 19:11:29	PM	249	1	1	1	69.78045654	17.61674309
13/05/2016 19:40:15	PM	250	1	1	1	69.79276276	17.63634491
13/05/2016 20:06:06	PM	251	1	1	1	69.78338623	17.61902046
13/05/2016 20:46:19	PM	252	1	1	1	69.80056	17.62068176
13/05/2016 21:19:48	PM	253	1	1	1	69.79221344	17.63569069
13/05/2016 21:45:46	PM	254	1	1	1	69.78137207	17.65362549
13/05/2016 22:20:04	PM	255	1	1	1	69.76121521	17.65395927
14/05/2016 00:22:03	PM	256	1	1	1	69.76873779	17.48713112
14/05/2016 01:20:02	PM	257	1	1	1	69.76119232	17.53101921
14/05/2016 01:50:36	PM	258	1	1	1	69.76677704	17.54317856
14/05/2016 02:22:06	PM	259	1	1	1	69.7718277	17.56541634
14/05/2016 02:45:57	PM	260	1	1	1	69.77470398	17.54206085
14/05/2016 03:37:49	PM	261	1	1	1	69.78839111	17.57913399
14/05/2016 04:35:39	PM	262	1	1	1	69.77773285	17.80331039
14/05/2016 06:33:51	PM	263		1		69.75112152	17.80865097
14/05/2016 07:23:06	PM	264		1		69.79140472	17.51639938
14/05/2016 08:01:17	PM	265	1	1	1	69.77620697	17.60778809
14/05/2016 08:12:55	PM	266	1		1	69.76177216	17.52345276
14/05/2016 08:19:41	PM	267	1	1	1	69.77838135	17.66327667
14/05/2016 09:15:22	PM	268	1	1	1	69.81561279	17.62592506
14/05/2016 09:43:47	PM	270	1	1	1	69.82724762	17.57134819
14/05/2016 10:19:04	PM	271	1	1	1	69.84938049	17.51383591
14/05/2016 11:34:46	PM	274		1		69.85746765	17.45115662
14/05/2016 11:37:16	PM	275		1		69.84722137	17.45844078
14/05/2016 12:02:55	PM	276	1	1	1	69.84178162	17.47024155
14/05/2016 12:42:37	PM	277	1	1	1	69.8354187	17.44750023
14/05/2016 12:45:21	PM	278	1	1	1	69.84635925	17.42344284
14/05/2016 13:03:55	PM	279	1	1	1	69.85725403	17.33768272

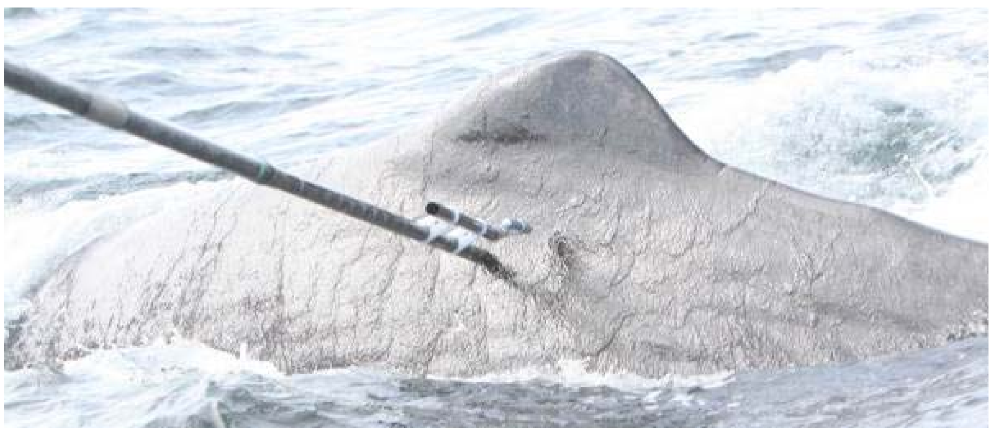
GpsTime	Species	Sighting number	Group size			Position	
14/05/2016 13:12:43	PM	280	1	1	1	69.85791779	17.42815018
14/05/2016 13:18:17	PM	281	1	1	1	69.8536377	17.34608269
14/05/2016 13:51:24	PM	282	1	1	1	69.87394714	17.42967033
14/05/2016 13:58:06	PM	283	1	1	1	69.85474396	17.4484005
14/05/2016 20:04:12	PM	293				69.71089935	15.95147896
14/05/2016 20:29:22	PM	294	1	1	1	69.69328308	15.86155987
14/05/2016 21:29:38	PM	296	1	1	1	69.70737457	15.85393429
14/05/2016 23:39:56	PM	298	1	1	1	69.63594055	15.73199177
15/05/2016 00:32:33	PM	299	1	1	1	69.6160965	15.67339039
15/05/2016 00:46:19	PM	300	1	1	1	69.61229706	15.64710903
15/05/2016 01:42:03	PM	302		1		69.58919525	15.55713654
15/05/2016 02:52:52	PM	303	1	1	1	69.60031128	15.51152611
15/05/2016 03:02:00	PM	304	1	1	1	69.55917358	15.52958012
15/05/2016 03:03:58	PM	305	1	1	1	69.61634064	15.53212261
15/05/2016 03:06:21	PM	306	1	1	1	69.61862183	15.55294514
15/05/2016 03:15:41	PM	307	1	1	1	69.61877441	15.67167377
15/05/2016 03:48:08	PM	309	1	1	1	69.63591003	15.58932495
15/05/2016 04:00:27	PM	310	1	1	1	69.62411499	15.57411289
15/05/2016 04:06:47	PM	311	1	1	1	69.64011383	15.58038044
15/05/2016 04:11:46	PM	312	1	1	1	69.6519165	15.57014751
15/05/2016 04:39:14	PM	313	1	1	1	69.69022369	15.69734097
15/05/2016 04:49:42	PM	314	1	1	1	69.70056152	15.65432358
15/05/2016 04:52:19	OO	315	4	6	8	69.71870422	15.69331455
15/05/2016 05:06:09	PM	316	1	1	1	69.693367	15.63935852
15/05/2016 05:09:54	OO	317	10	15	20	69.72677612	15.79902935
15/05/2016 05:20:50	OO	318	6	8	12	69.75340271	15.75125599
15/05/2016 05:34:04	PM	319	1	1	1	69.75286102	15.78757191
15/05/2016 05:40:05	PM	320	1	1	1	69.72028351	15.67872143
15/05/2016 05:46:10	PM	321	1	1	1	69.70539093	15.75891781
15/05/2016 05:47:23	PM	322	1	1	1	69.70204163	15.7027626
15/05/2016 05:55:09	PM	324	1	1	1	69.68199921	15.61767292
15/05/2016 05:59:34	PM	325	1	1	1	69.66430664	15.52087593
15/05/2016 06:39:35	PM	326	2	2	2	69.70722198	15.81268978
15/05/2016 07:00:48	PM	327	1	1	1	69.70462799	15.87061977
15/05/2016 07:16:04	PM	328	1	1	1	69.69035339	15.92131042
15/05/2016 07:21:01	PM	329	1	1	1	69.70298004	15.90769768
15/05/2016 08:29:03	PM	332	2	2	2	69.71886444	16.04245186
15/05/2016 08:30:41	PM	333	1	1	1	69.72214508	16.05527115
15/05/2016 08:33:13	PM	334	1	1	1	69.71057129	16.0390892
15/05/2016 09:00:15	PM	335	1	1	1	69.74077606	16.02028465

GpsTime	Species	Sighting number	Group size			Position	
15/05/2016 09:00:33	PM	336	1	1	1	69.71656799	16.00569534
15/05/2016 09:02:36	PM	337	1	1	1	69.73789978	16.03227997
15/05/2016 09:23:33	PM	338	1	1	1	69.7536087	16.03286934
15/05/2016 09:39:01	PM	339	1	1	1	69.76207733	15.99287701
15/05/2016 10:41:32	PM	340	1	2	2	69.79154968	16.00414658
15/05/2016 10:43:41	PM	341	1	4	4	69.78419495	16.07260895
15/05/2016 11:29:31	PM	342				69.81552887	16.0753746
15/05/2016 11:53:04	PM	343	1	1	1	69.82868958	16.08562469
15/05/2016 12:19:21	PM	344	1	1	1	69.82292175	16.08156395
15/05/2016 12:28:34	PM	345	1	1	1	69.81481934	16.09014511
15/05/2016 12:33:32	PM	346	1	1	1	69.81077576	16.08148384
15/05/2016 12:34:14	PM	347	1	1	1	69.80919647	16.07856178
15/05/2016 12:43:38	PM	348	1	1	1	69.81777191	16.03899765
15/05/2016 12:46:01	PM	349	1	1	1	69.82293701	16.04190826
15/05/2016 13:28:00	PM	355	1	1	1	69.80657959	16.01598549
15/05/2016 19:46:16	PM	362	1	1	1	69.37916565	16.32699776
15/05/2016 20:07:56	PM	363	1	1	1	69.39168549	16.3987751
15/05/2016 20:16:19	PM	364	1	1	1	69.38507843	16.43486595
15/05/2016 20:51:17	PM	367				69.38397217	16.44794655
15/05/2016 21:01:06	PM	368				69.3971405	16.5004673
15/05/2016 21:23:44	PM	369				69.41158295	16.43880653
15/05/2016 21:42:21	PM	370				69.36557007	16.43833542
15/05/2016 22:06:54	PM	371				69.36952972	16.49482155
16/05/2016 00:34:52	PM	372		1		69.3690567	16.4435482
16/05/2016 01:01:02	PM	373		1		69.3586731	16.4255352
16/05/2016 02:13:39	PM	375	1	1	1	69.36966705	16.42588806
16/05/2016 02:44:41	PM	376	1	1	1	69.38710022	16.43608093
16/05/2016 03:18:01	PM	377	1	1	1	69.43693542	16.25384712
16/05/2016 03:23:46	PM	378		1		69.41468811	16.23228073
16/05/2016 03:37:13	PM	379	1	1	1	69.44171143	16.2151165
16/05/2016 03:46:20	PM	380	1	1	1	69.41618347	16.32294464
16/05/2016 04:07:11	PM	381	1	1	1	69.38850403	16.37049294
16/05/2016 04:27:51	PM	382	1	1	1	69.40274811	16.42771912
16/05/2016 05:26:51	PM	383	1	1	1	69.4855423	16.30587196
16/05/2016 06:05:40	PM	385		1		69.41426849	16.42090225
16/05/2016 06:38:55	PM	386	1	1	1	69.41117859	16.37656212
16/05/2016 07:27:15	PM	387	1	1	1	69.40116882	16.33737373
16/05/2016 07:28:29	PM	388	1	1	1	69.38549805	16.34549713
16/05/2016 07:30:01	PM	389	1	1	1	69.39897919	16.31881905

GpsTime	Species	Sighting number	Group size			Position	
16/05/2016 07:46:23	PM	390	1	1	1	69.44275665	16.33472824
16/05/2016 08:19:29	PM	391	1	1	1	69.52529907	16.31712341
16/05/2016 08:43:05	PM	392	1	1	1	69.47315216	16.37148285
16/05/2016 09:15:39	PM	393	1	1	1	69.43082428	16.37068176
16/05/2016 10:21:56	PM	394	1	1	1	69.52419281	16.25802231
16/05/2016 11:00:47	BA	395	1	1	1	69.56562042	16.15334702
16/05/2016 12:26:28	PM	397	1	1	1	69.53846741	16.23228645
16/05/2016 13:10:00	PM	398	1	1	1	69.56931305	16.31908798

D Tagged Whale Photos

sw16_126a



sw16_130a

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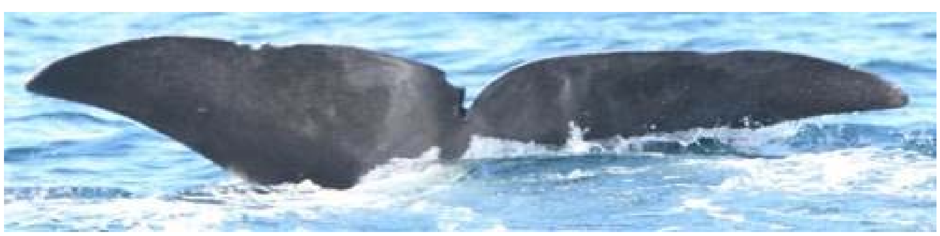

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E 3S-2016-CAS Trial – Risk assessment and management plan

Introduction

This document describes the risk identified for the 3S-2016-CAS research trial. The trial will primarily take place along the shelf break between Andenes and Tromsø in Norwegian territorial waters and EEZ between May 3rd and May 17th 2016.
The objective of the trial is to test if exposure to continuous-active-sonar (CAS) leads to different types or severity of behavioural responses than exposure to typical pulsed sonar signals.
The primary task is to tag sperm whales with digital tags which records vocal-, movement- and dive behavior, and thereafter carry out no-sonar control-, pulsed sonar- and continuous active sonar exposures.
The operation is described in detail in the 3S-2016-CAS cruise plan (Appendix F).

Risk Inventory

5 types of risk are identified and mitigation measure and responsibility specified:

1) Risk to the environment (injury to marine mammals)
2) Risk to third party human divers
3) Risk of impact on commercial activity (whale safari, whaling and fishery).
4) Risk of damaging expensive equipment (Socrates and Delphinus systems)
5) Risk to humans involved in the operation

Risk to the environment (marine mammals)

Risk of direct injury to marine mammals is determined by the accumulated acoustic energy rather than peak pressure levels. A widely accepted acoustic criteria for hearing injury for these multiple sounds for cetaceans is a received level of 230 dB re 1 μPa (sound pressure level, SPL), or 198 dB re 1 μPa^2 s (accumulated sound exposure level, SEL) (Southall et al. 2007[1]). However, recent studies indicate that in some particularly sensitive species hearing might be affected also at lower levels (e.g. Kastelein *et al.* 2014[2]), but risk seems to be negligible at sound exposure levels below 180 dB (re 1μPa·s). The distance from sonar source to animal required to stay below this level depends on the transmitted source level, duty cycle and speeds of the sonar and animal. At source levels below 200 dB re 1 μPa m, the risk of direct injury is negligible. Since the operation includes animal experimentation, we will operate under permits from the Norwegian Animal Research Authority (permit no 2015/223222) acquired by Petter Kvadsheim at FFI. Ethical aspects of the experiments and animal welfare issues, including direct risk to experimental or other marine mammals are dealt with in the permit documents. The permits include tagging and acoustic exposure of minke whales, bottlenose whales, sperm whales, pilot whales and killer whales according to the protocol described in the cruise plan. Permits also allow for biopsy sampling of target species. The exposure experiments are permitted under the condition that maximum received sound pressure level

(SPL) does not exceed 175 dB re 1 µPa, and that project participants are skilled in handling the animals.

1 Southall, B. L., Bowles, A. E., Ellison, W. T., Finneran, J. J., Gentry, R. L., Greene, C. R., . . . Tyack, P. (2007). Marine mammal noise exposure criteria: Initial scientific recommendations. Aquatic Mammals, 33(4), 411-521.
2 Kastelein, R.A., Hoek, L., Gransier, R., Rambags, M. and Claeys, N. (2014). Effect of level, duration, and inter-pulse interval of 1-2 kHz sonar signal exposures on harbour porpoise hearing. Journal of the Acoustical Society of America, 136:412-422.

Risk Mitigation measures

- During active transmissions from the Socrates source, marine mammal observers on Sverdrup will assure that no whales are closer to the source than 100m. If any animals are approaching this safety zone an emergency shut-down of sonar transmission will be ordered.
- Exposure sessions will commence using a 5-20 min ramp-up (gradual increase of source level) starting 60 dB below maximum level.
- Transmission will also be ceased immediately if any animal shows any signs of pathological effects, disorientation, severe behavioral reactions, or if any animals swim too close to the shore or enter confined areas that might limit escape routes.
- The decision to stop transmission outside the protocol is made by cruise leader Kvadsheim or by someone he appoints to be responsible for permit compliance. In addition to Kvadsheim, Patrick Miller and Lars Kleivane will be field operators responsible for permit compliance in the field.

Responsibility

Permit compliance and management of environmental risk is ultimately the responsibility of the permit holder Petter Kvadsheim at FFI.

Risk to third party human divers

We will primarily operate off shore and in deep water and therefore don’t expect to encounter human divers. Human divers are a marine mammal and can be injured by exposure to high levels of acoustic energy. The main concern with exposure of divers is however, that divers might experience a high stress level during the exposure because they are unacquainted with the sonar sounds. NATO guidelines[3] therefore differentiate between risk to naval divers and commercial and recreational divers. The guidelines are based on psychological aversion testing, and for commercial and recreational divers a maximum received sound pressure level (SPL) of 154 dB re 1µPa is established for the relevant frequency band. Based on the source level of 214 dB re 1µPa @ 1m and the maximum received sound pressure level of 154 dB re 1µPa and expected propagation conditions during the trial, the stand-off range from divers will be 2000 m. This number includes a factor 2 safety margin.

3 NATO Undersea Research Centre Human Diver and Marine Mammal Risk Mitigation Rules and Procedures. NURC-SP-2006-008 (http://ftp.rta.nato.int/public//PubFullText/RTO/TR/NURC-SP-2006-008///NURC-SP-2006-008.pdf)

Risk mitigation measures

- We will stay away from known diving sites.
- During transmission there will be visual observers on the source boat.
  Any observed diving activity should be reported to the cruise leader instantly, if any diver comes within the 2000 m stand-off range, transmission will be stopped.
- The 3S-16-CAS operation does not involve any diving activity by our own crew.

Responsibility

Management of risk to human divers is a shared responsibility of the cruise leader Petter Kvadsheim and the captain of the ship.

Risk of impact on commercial activity (whale safari, whaling and fishery)

Sonar activity in an area can result in avoidance responses of marine mammals. Threshold of avoidance varies between species and the context the animal is in (Sivle et al. 2015[4]). The focal species of the trial is sperm whales. Studies of sperm whales have shown that they might stop feeding and change their activity pattern, but we have not observed sperm whales to leave the area during short term exposure to naval sonar (Isojunno et al. 2016[5]). Our experimental protocol involves 40 min sonar exposures, and even though this is repeated up to 3 times, we don't expect any long term behavioral effects such as habitat avoidance. Minke whales are subjected to whaling in the operation area, and are also identified to be a particularly sensitive species, responding to sonar at relatively low levels[4]. Typically such responses involve rapid avoidance of the source. Such avoidance responses might occur as much as 20 nmi from the exposure location. However, it is very early in the whaling season and we are targeting different species. We will primarily operate in very deep water, whereas whaling is often located to shallower waters.

Research has shown that naval sonar has little or no impact on fish populations (Sivle et al. 2014[6]). However, in the area closest to a sonar source, it is still uncertain if some fish species might respond to sonar transmissions. Such short responses are unlikely to affect the vital rates of the fish, but might affect fishery catch rates. Safety distances known to not trigger any escape responses in fish are established by the Norwegian Navy[7] to avoid negative impact on fishery. Such safety distances will vary with the transmitted source level, duty cycle and speed of the source. Fish in fish farms might be stressed by a sonar source passing closer than the safety distance, but the duration of this stress response will be very short, and is primarily triggered by the ship not the sonar.

1 Sivle, L, PH Kvadsheim, C Curé, S Isojunno, PJ Wensveen, FPA Lam, F Visser, L Kleivane, PL Tyack, C Harris, PJO Miller (2015). Severity of expert-identified behavioural responses of humpback whale, minke whale and northern bottlenose whale to naval sonar. Aquatic Mammals41(4): 469-502 DOI 10.1578/AM.41.4.2015.469

2 Isojunno, S, C. Curé, P. H. Kvadsheim, F. P. A. Lam, P. L. Tyack, P. J. Wensveen, P. J. O. Miller (2016). Sperm whales reduce foraging effort during exposure to 1-2 kHz sonar and killer whale sounds. Ecological Applications 26(1): 77-93.

3 Sivle, L.D., Kvadsheim, P.H. and Ainslie, M.A. (2014). Potential for population-level disturbance by active sonar in herring. ICES J. Mar. Sci. doi: 10.1093/icesjms/fsu154
4 Instruction for use of active sonar in Norwegian waters. In: Nordlund and Kvadsheim - SONATE 2015 – a decision aid tool to mitigate the impact of sonar operations on marine life (https://www.ffi.no/no/Rapporter/14-02200.pdf)

Risk mitigation measures

- Prior to the operation we will contact the whale watching companies operating in the area and inform them about our planned activity.
- Prior to the operation we will investigate where the whale watching activity primarily happen, and during the operation we will monitor their activity and as much as possible stay away from their core area. This is also important to minimize risk that vessel traffic close to the focal whales compromises the controlled sonar exposure experiments.
- To minimize risk of accumulated effects active sonar transmissions will not be conducted within 20 nmi of the previous exposures experiment within 24 hours. This is also important to avoid habituation or sensitization of the experimental animals.
- During the operation we will monitor the area for whaling ships. If we suspect that our activities may influence whaling activity we will inform the vessel concerned.
- During active transmission, we will implement a stand-off range of 500m from fishing vessel actively involved in fishing and from aquaculture installations containing fish to avoid potential negative effects.

Responsibility

Management of risk of impact on commercial activities is the responsibility of the cruise leader Petter Kvadsheim.

Risk of damaging expensive equipment (Socrates and Delphinus systems)

During the operation both the SOCRATES source and the DELPHINUS array will be deployed and towed by the Sverdrup. SOCRATES is a multi-purpose sophisticated versatile towed source that is developed by TNO for performing underwater acoustic research. The Delphinus array is a single line array, 74 meters long used to detect and track whales. Risk of damage to these systems includes risk of hitting the sea floor, risk of cavitation during high power transmission and risk of entanglement while towing both systems simultaneously (dual tow). A separate chapter of the cruise plan (Appendix F) contains specifications of the equipment as well as procedures for safe deployment, operation and recovery.

Risk mitigation measures

- When deploying or recovering the Socrates and Delphinus systems the ship should maintain a constant speed (4-5 knots) and course. The systems should not be handled above sea state 4.
- When preparing to tow both systems simultaneously, the deploying sequence will be first Delphinus and then Socrates. The retrieval sequence will be first Socrates and then Delphinus.
- A minimum and maximum tow speed (4-12 knots) and maximum turn angle (20-30 degrees/min) is specified, depending on turn (port or starboard) and on single or double tow.
- A minimum water depth is specified for both systems depending on cable scope (e.g. for a cable scope of 260m, the minimum water depth when towing Socrates is 200m, and the minimum water depth when towing Delphinus is 150m).
- A minimum tow depth is specified for the Socrates source, depending on the transmitted pulse (frequency band) and source level (e.g. when using the full band (1000-200 Hz) and maximum source level (214 dB re 1μPa·m) the minimum tow depth is 100m).

Responsibility

Management of risk of damaging Socrates and Delphinus is the ultimate responsibility of chief scientist of the TNO team Frans-Peter Lam. However, the captain of the ship, his first officer, and cruise leader Petter Kvadsheim are responsible for assuring that the equipment is used in accordance with the instruction given by TNO.

Risk to humans involved in the operation (EHS)

Being on a ship in motion constitute some elevated level of risk (e.g. tripping, falling over board etc). The Sverdrup is certified according to the ISM-code (International Safety Management) approved by IMO (International Maritime Organisation).
This is a comprehensive safety regime to minimize risk of accidents. An instruction to the scientific crew during the trial will be handed out as part of the safety briefing before departure. This document summarizes the safety regime, and responsibilities. For the 3S-2016-CAS trial the following operations requires special attention:

a) Deployment and recovery of the SOCRATES system. This involves lifting of heavy equipment with A-crane over head with an open aft deck.
b) Deployment and recovery of work boats and operations at sea.

Risk mitigation measures

- During deployment/recovery of Socrates all personnel involved in the operation on the aft deck should wear helmet, life vest and steel toe shoes. Support ropes will be used to prevent the hoisted equipment (Socrates) from swinging during ship movements. Personnel who operate winches, cranes, A-frame etc must take care and keep other personnel out of the way.

- Any personnel who are going in the work boats (Tag boats) should be briefed on how to operate the hooks, and the deployment and recovery procedure should be exercised in calm water. Personnel should wear floatation suits at all times during operation in the work boats. Personnel in the work boats should wear helmets during deployment and recovery. Work boats should not operate more then 4 nmi from the mother ship and always within VHF range. Work boats must report in to Sverdrup to confirm communication lines every hour. Use of work boats is limited to sea states 3 and below.

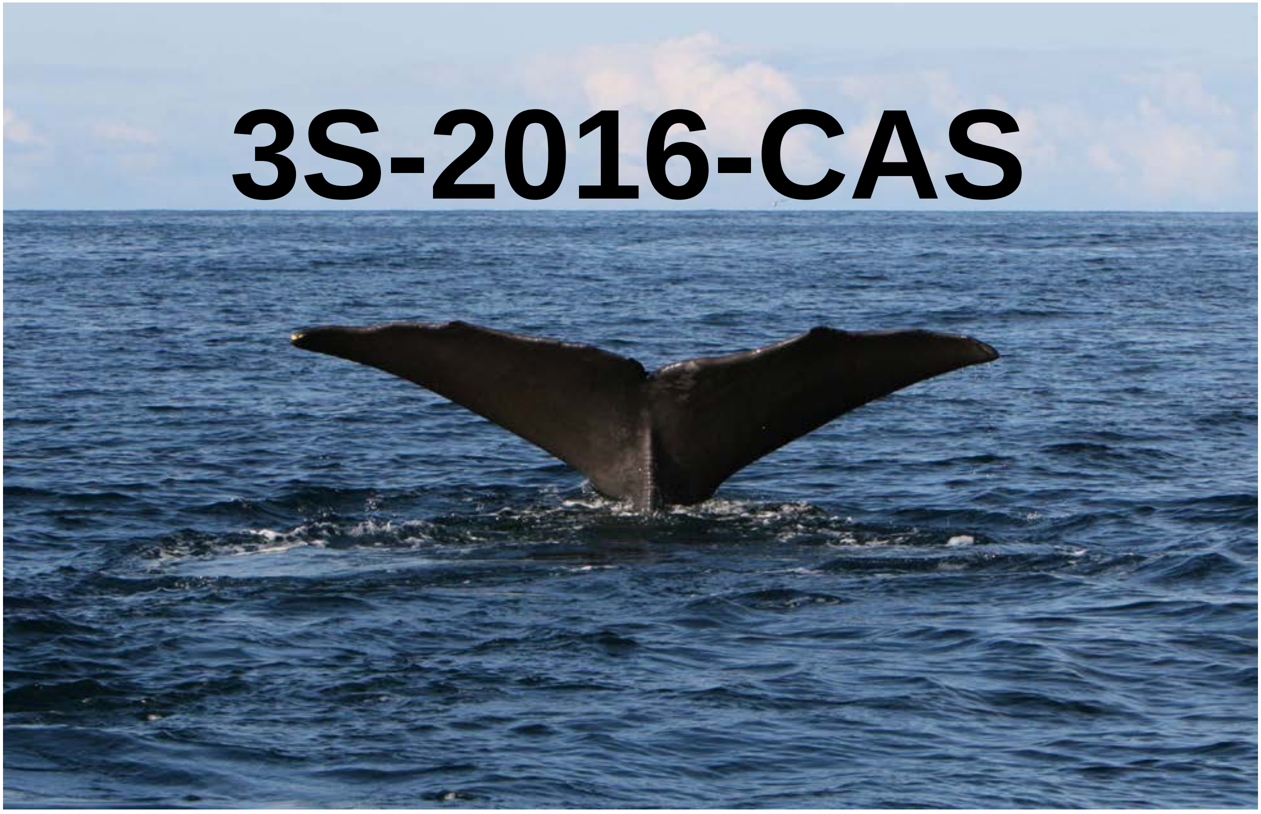
Responsibility

The shipping company (FFI) and the ship's contracted operator (Remøys shipping) are responsible for implementation of the safety regime. The ship's captain, and in his absence the first officer, is the chief authority with regards to safety of all personnel. He is responsible for the comprehension and complying of all safety instructions. The party chief (cruise leader) is responsible for making current instructions known to and comprehended by the survey participants and the crew.

F 3S-2016-CAS Cruise Plan

Cruise Plan

3S-2016-CAS



Sanna Kuningas

Final version

The 3S-16-CAS research trial is conducted by the 3S-consortium as part of the 3S^3-project.

CONTENT

PROJECT OBJECTIVE

Test whether exposure to continuous-active-sonar (CAS) leads to different types or severity of behavioural responses than exposure to traditional pulsed sonar signals, or if the CAS feature of high duty cycle leads to indications that use of sound by cetaceans is masked or interfered with.

CRUISE TASKS AND PRIORITY

Primary tasks:

1. Test the CAS-performance of the Socrates source to assure that it can transmit the scheme needed for the CAS-experiment, and to measure the presence of harmonics in the different transmission modes.
2. Test the mixed-GPS-DTAG3 in DTAG2 housing concept, and start using that tag in the CAS experiments as soon as we are comfortable that it works.
3. Tag sperm whales with DTAG and record vocal-, movement- and dive Behaviour, and thereafter carry out no-sonar control-, pulsed sonar- and continuous active sonar exposures.

Secondary tasks:

4. Tag killer whales or pilot whales with DTAG3 and do CAS experiment on them following the same protocol as with sperm whales
5. Tag minke whales with DTAG3 and replicate the pulsed sonar experiment from 2011.
6. Test ARTS launching of the mixed-DTAG
7. Collect baseline data of target species.
8. Collect information about the environment in the study area (CTD and XBT measurements).
9. Re-approach of tagged animal after experimental cycle to collect biopsy sample.
10. Collection of bio-acoustic data using towed arrays.
11. Collect sightings of marine mammals in study area.

Priority:

The primary tasks have a higher priority than the secondary tasks. We will try to accomplish as much as possible also with the secondary tasks, and some of them are incorporated in our regular experimental protocol. However, secondary tasks will be given a lower priority if they interfere with our ability to accomplish the primary tasks.

3S-CONSORTIUM

The main partners of the 3S[3]-project conducting the 3S-16-CAS trial are:

- The Netherlands Organization for Applied Scientific Research (TNO), The Netherlands
- Sea Mammal Research Unit (SMRU), Scotland
- The Norwegian Defense Research Establishment (FFI), Norway

In addition the following organizations are contributing to the project through their association with one or several of the 3S-partners:

- Institute of Marine Research (IMR), Norway
- CEREMA Dter Est, Acoustics Group, Laboratoire de Strasbourg, France

The 3S[3] research project is sponsored by;

- The Royal Netherlands Navy and the Netherlands Ministry of Defence
- Office of Naval Research, USA
- DGA, French Ministry of Defense.
- DSTL (Defense Science and Technology Lab), UK Ministry of Defense .

The 3S-16-CAS trial is sponsored by;

- The Royal Netherlands Navy and the Netherlands Ministry of Defence
- DGA, French Ministry of Defense.
- DSTL (Defense Science and Technology Lab), UK Ministry of Defense .

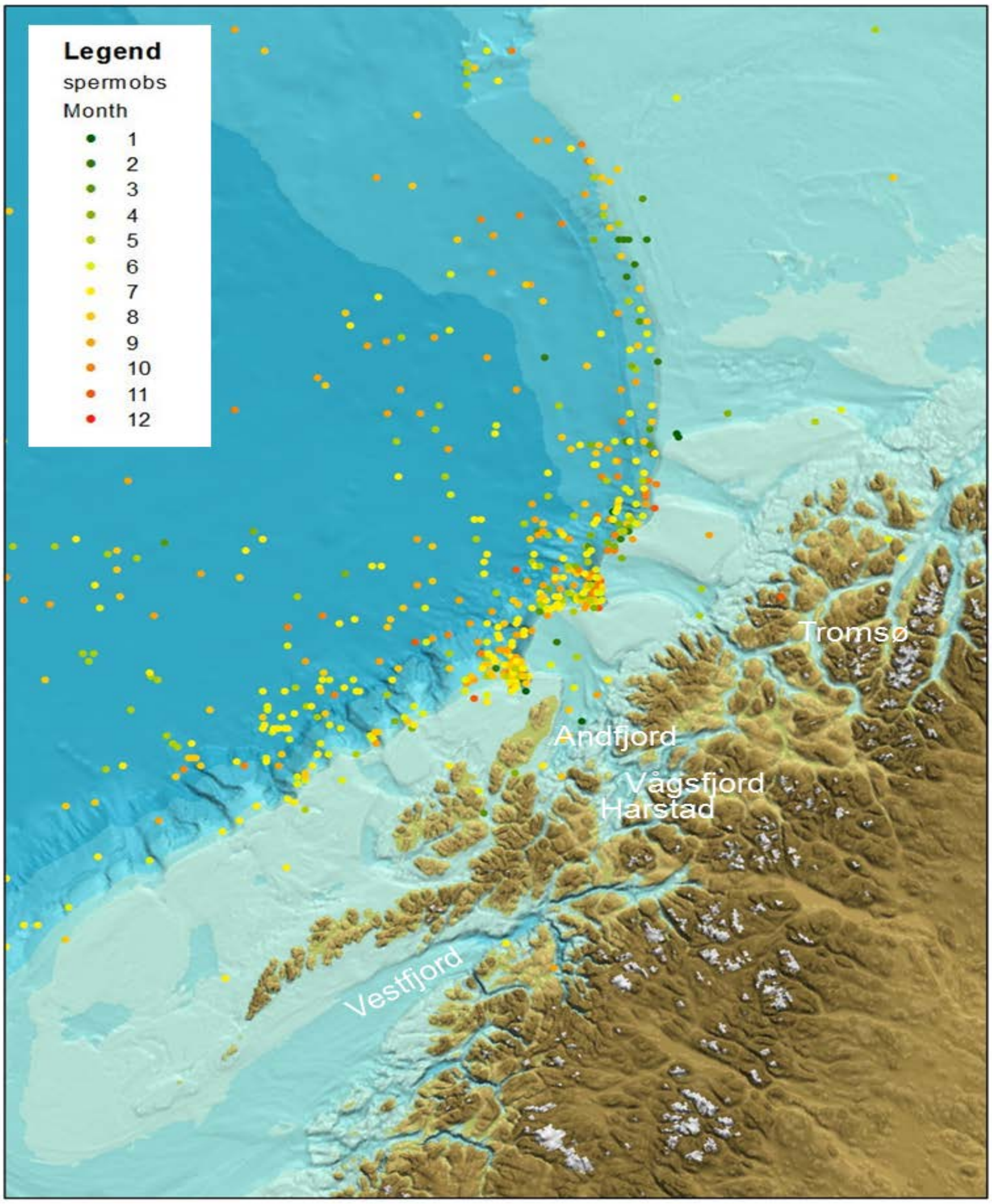
SAILING SCHEDULE

Date	
Mon May 2nd	17:00 General brief of science crew at Scandic Hotel Harstad. 19:30 Joint no-host dinner.
Tues May 3rd	08:00 - 3S science crew embarks RV HU Sverdrup II in Harstad. Loading of equipment, fuel and food for 15 days at sea without any port calls. Technical installation commences
Wed May 4th.	Finalize technical installation and testing of equipment. Training of science crew. Brief of ship's crew. Safety briefing and exercise 14:00 Sail off. Engineering test of source in Vågsfjorden, training/calibration of observers, drill of operation. 20:00 Regular watch schedule – transit to operation area.
May 5-16th	Regular operation, no scheduled port calls.
Mon May 16th	Transit to Tromsø over night.
Tues May 17th	ETA Tromsø at 08:00. Packing and de-brief.
Tues May 18th	08:00 Off loading 12:00 Dissembarkment

OPERATION AREA

The primary target for the trial is to work with sperm whales. We will therefore primarily operate in deep water off the shelf break northwards and southwards from Harstad. The initial engineering test will be carried out in Vågsfjord just outside Harstad. This is because we don't want to transmit any sonar sound into the main operation area and pre-expose the target animals. Within this fjord there is a 10 by 2nmi basin which is deeper than 200m and therefore suitable for testing the Socrates source.

Sperm whales are generally found throughout the deep water basin of the Norwegian sea, but tend to concentrate along the steeper part of the shelf break and in canyons. However, we might want also to seek out areas with lower concentrations. In case of windy conditions we can also look for sperm whales in Andfjord and Vestfjord. Sperm whales are sighted in both these fjords, and quite regularly in Andfjord, and depending on the wind direction these fjords might offer some protection from the wind. If we can't find sperm whales, or the weather does not allow us to search for them where we can expect to find them, we can choose to work with secondary species, minke whales, killer whales and pilot whales. They can often be found in the more protected waters in Vestfjorden.



The operation area for 3S-2016-CAS with positions of sperm whale sightings

MAIN LOGISTICAL COMPONENTS

R/V H.U. Sverdrup II (HUS)
Length: 180 feet
Max speed 13 knots
Crew: 7
Scientific crew: 15

Sverdrup will be outfitted with the Socrates source and operating software, Delphinus towed array system, Digital Direction Finder VHF tracking system, two tag boats with cradle for loading/off-loading. Fuel for the tag-boats. In addition Sverdrup will also carry equipment to measure sound speed profiles.

Visual and acoustic search for marine mammals, VHF- and visual tracking of tagged animals, recording of Behavioural observations of tagged animals, operation of sonar source and preparation of the tags will be done from the Sverdrup. Sverdrup will also lodge the entire research team and be the command center for the operation.

Tagging boats

Two tag boats can be deployed from HUS. Tag Boat 1 (TB1) is a four stroke outboard engine fibre glass work boat, and Tag Boat 2 (TB2) is a water jet propulsion Man Over Board boat. TB1 is deployed using the ships derrick crane, and TB2 is deployed using a dedicated davit. Tb1 can be deployed and operated at sea conditions up to sea state 2, while TB2 is a heavier more robust system which can be deployed and operated up to sea state 3. The tag boats will be launched when whales are sighted and weather permits tagging attempts. In the tagging phase they will carry tagging gear (ARTS, pole, tags with necessary accessories), documentation sheets, GPS and camera. Both tag boats are installed with navigation system, VHF and AIS. The tag team will usually consist of three people; a driver, a tagger and someone in charge of photo id/documentation.

Tag Boat 1 (top) and Tag Boat 2 (bottom). TB1 will be equipped with a swivel in the bow for the cantilever pole. TB2 can be installed with a 2 person elevated MMO-station behind the driver for tracking whales, and an elevated shooting platform in the bow for the tagging.

The primary tagging tool for sperm whales is the long cantilever pole, and therefore TB1 will primarily be used. TB2 will be used to test ARTS-tagging with a new tag, the mixed-DTAG with GPS. TB2 will also be used if we choose to work with secondary species.

We may decide to use TB2 to track the tagged whales, even though the primary modus operandi is to track the whale from the source ship. If we decide to use TB2 for tracking it will be outfitted with an observation platform in the aft with space for two observers. It will also be equipped with VHF-tracking antennas and DDF receiver in addition to compass, binoculars, range finders and a data recording system which consist of a fully ruggedized laptop running the Logger software. During tracking the crew will consist of 4 people, a driver, a data recorder and 2 marine mammal observers.

Sonar source – SOCRATES

The multi-purpose towed acoustic source, called SOCRATES II (Sonar CalibRAtion and TESting), will be used and operated from the Sverdrup. This source is a sophisticated versatile source that is developed by TNO for performing underwater acoustic research and has been used as a prototype LFAS source on board of the M-frigates of the Royal Netherlands Navy. Socrates has two free flooded ring transducers, one ring for the frequency band between 0.95 kHz and 2.35 kHz (source level 214 dB re 1 µPa @ 1m), and the other between 3.5 kHz and 8.5 kHz (source level 199 dB re 1 µPa @ 1m). It also contains one hydrophone, depth, pitch, roll, and temperature sensor. All these sensors can be recorded. Because of risk of cavitation and damage to the source, it must stay below cavitation depth during operation. A minimum of 200 m water depth is required if the source transmits at full power with low frequency transducer ring. Appendix A describes further details of SOCRATES and gives detailed operational instruction.


The sonar source SOCRATES (left) and acoustic array Delphinus (right) safely recovered on the Sverdrup during a previous trial (3S-12).

Acoustic array – Delphinus

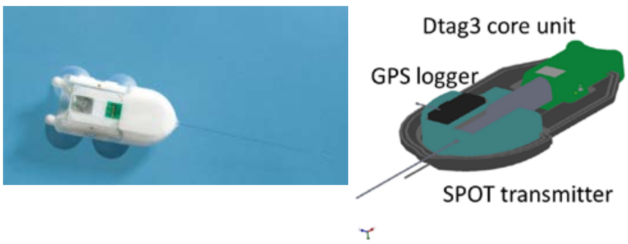
During the trial, the TNO developed Delphinus array system will be used. It will be deployed from the Sverdrup to primarily acoustically search for marine mammals and track sperm whales before and during experiments. The Delphinus is a 74 m long single line array containing 18 LF hydrophones used for the detection and classification of marine mammal vocalization up to 20 kHz. Three UHF hydrophones with total baseline of 20m are used for the detection, classification and localization of marine mammal vocalizations up to 160 kHz. Additionally there is a single triplet (consisting of 3 UHF hydrophones), which will be used to solve the left-right ambiguity for the localization. The array is also equipped with depth and roll sensors.

During exposure experiments we will have to tow both the Socrates source and the Delphinus system simultaneously. Delphinus needs to be deployed before Socrates and Socrates will be recovered out of the water before Delphinus. When a CTD sensor is being used the Socrates and Delphinus need to be out of the water. More information about sailing and deployment restrictions can be found in Appendix A.

Whale tag – DTAG3 and M-DTAG

The version 3 DTAG (DTAG3) built at the University of Michigan is the main tool used to record the behaviour of the whales. The DTAG, is a miniature sound and orientation recording tag developed by Woods Hole Oceanographic Institution. The tag is attached to the whale using a cantilever operated carbon fiber pole, or a pneumatic remote deployment system (ARTS). Using the tags with the ARTS system has to be finally approved by University of Michigan. The tag is attached to the animals with four suction cups. At a pre-set time of 16 hrs the vacuum is released from the suction cups and the tag floats to the surface.

The tag contains a VHF transmitter used to track the tagged whale during deployment and to retrieve the tag after release. All sensor data are stored on board the tag and the tag therefore has to be retrieved in order to obtain the data. DTAGs record sound at the whale as well as depth, 3-dimensional acceleration, and 3-dimensional magnetometer information. DTAG audio will be sampled at 96 kHz and other sensors at 50 Hz, allowing a fine reconstruction of whale behaviour before, during, and after sonar transmissions.



DTAG3 with suction cups (left) and model of the new mixed DTAG (right) with GPS logger and SPOT transmitter in addition to the DTAG3 electronic.

In addition to the DTAG3 we will also test the performance of a new tag developed primarily for the bottlenose whale experiments, being another but separate effort under 3S3. However, the CAS project will also benefit if we test and approve this new tag and start using it, because it collects a more detailed track of the whale. The mixed DTAG (M-DTAG) consists of the electronic package of the regular DTAG3, but built into a version-2 housing. This housing is bigger than the current v3 housing therefore allowing us to add a GPS-logger and/or a SPOT satellite transmitter. These two additional sensors helps record a more detailed track of the whale (GPS) and help us to find the tag when it has released from the whale.

Responsibilities:

FFI

Personnel: Cruise leadership, marine mammal observers, Tag Boat drivers, local knowledge, oceanographic measurements, ARTS tagging.

Equipment: Research vessels with crew, Tag Boat 1 with gas, Tag Boat 2 with ARTS and MMO platforms, CTD’s, 2 VHF DDF, 1 VHF receiver (219MHz), 2 sets of VHF Coax cables, VHF-communication equipment, Ruggedized computer, Maria PC.

Permits: NARA permit, FOH military permit

SMRU

Personnel: PI, pole taggers, marine mammal observers, photo id/documentation.

Equipment: DTAG3, M-DTAG, DTAG accessories, cantilever pole, 2 VHF DDF, 2 VHF receivers (219 MHz), 1 set of VHF yagi antennas, Handheld VHF-tracking, Logger laptop, Directional hydrophone, Tracking equipment for 2 platforms (laser range finders, compass, protractor etc), 2 digital cameras for photo id, biopsy kit, 2 mini big eyes, 2 binoculars.

Permits: SMRU ethics approval

TNO/RNLN

Personnel: Software and hardware technicians for Socrates and Delphinus, marine mammal observer, acoustic operators, deputy cruise leader (XO).

Equipment: Shipment of heavy equipment from the Netherlands to Norway, Socrates source, Delphinus array including processing, real-time displays and recording, Acoustic tablet for MMO station, XBTs, XBT-launcher, GPS recorder, AISrecorder, calibrated hydrophone, ruggedized computer, wireless network and data server.

LK-ARTS

Personnel: Tagger and marine mammal observer

Equipment: 2 ARTS, ARTS dart (biopsy carrier), ARTS M-DTAG carrier (DTAG2 carrier), ARTS DTAG3 carrier, 1 set of VHF yagi-antennas, 1 set of VHF coax cables, 1 VHF Receiver (219 MHz), Ruggedized computer.

DGA

Personnel: Marine mammal observer/acoustic operator

DSTL

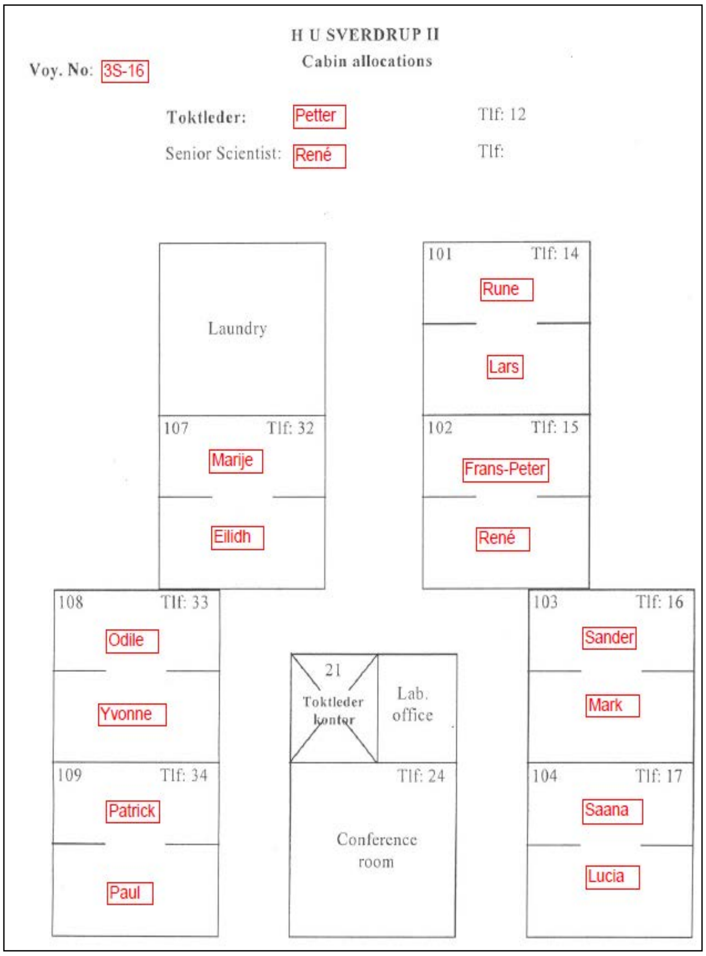
Personnel: Marine mammal observer/acoustic operator

CREW PLAN

The total number of scientific crew is 15 people. There will be no scheduled port calls and therefore no crew changes during the trial.

Crew list

Name	Main role	Secondary roles	Affiliation	Nationality
Petter Kvadsheim	CO	MMO	FFI	NOR
René Dekeling	XO	SOC/MMO	RNLN	NL
Patrick Milller	PI	TB	SMRU	US
Frans-Peter Lam	SOC	MMO	TNO	NL
Mark van Spellen	SOC	MMO	TNO	NL
Sander van Ijsselmuide	SOC	Data management/MMO	TNO	NL
Lars Kleivane	MMO	TB	FFI	NOR
Rune Roland Hansen	MMO	TB	FFI	NOR
Paul Wensveen	MMO	Data management/TB	SMRU	NL
Saana Isojunno	Tag technician	TB, MMO	SMRU	FIN
Lucia Martin Lopez	Tag technician	MMO	SMRU	SPA
Odile Gerard	SOC	MMO	DGA	FR
Marije Siemensma	MMO	Data management	TNO	NL
Yvonne Mather	MMO trainee	SOC trainee	DSTL	UK
Eilidh Siegal	MMO	MMO	SMRU	UK



Cabin plan

DAILY WORK PLAN

The 3S-2016-CAS trial is a complicated operation which requires different teams to work together in a highly coordinated manner. The different teams include: visual teams, acoustic teams, tagging teams, cruise management and the ship's crew. In addition, the crew is divided between different platforms (Sverdrup, TB1 and TB2) and on Sverdrup on different locations/decks, depending on which phase of the operation we are in. The operation goes through different phases which require very different staffing from the different teams. The main phases are (see picture below): search phase, tagging phase, pre-exposure phase, exposure phase and post exposure phase. Finally, the operation is conducted in an area and at a time with fulltime daylight, which enables us to operate 24 around the clock. This is a challenge but also a great opportunity we have to make the most of the time available.

The complexity of all this requires a structured watch plan, which considers a minimum staffing requirement from the different teams, but we also have to be flexible when the operation moves into the more labor demanding experimental phases. It also requires a well-defined chain of command and communication plan.

Main phases of the operation. The tracking phase includes pre-exposure, exposure and post-exposure

Planning meetings

Every morning before breakfast (0700), the chief scientists from the main 3S partners (Kvadsheim, Lam, Miller) and the XO (Dekeling) will convene to plan the activities for that day. Search areas and patterns, species priority, logistical constraints, crew dispositions etc. will be discussed and implemented in the daily plan. The plan for the day will be announced on a poster board on board before 09:00. Every evening at 2030, the chief scientists will meet again to make adjustments to the daily plan, and plan activities for the coming night. If you have an idea or would like to bring something to the attention of the cruise management team, you might address one of the chief scientists at any time. Occasionally, the cruise leader may call for a plenum meeting with the entire scientific crew.

Watch plan in search, tagging and tracking phases

The entire crew, with the exception of Miller who is on 24 hrs stand by for tagging, will follow a basic regular seamen's watch plan of 6 hrs on and 6 hrs off, with change of watch at 8 and 2 am and pm, coordinated with the meals on-board and following the schedule of ship's crew. This will cover the basic staffing requirement during the search, tagging, and tracking phases, with the exception of the experimental phase (exposure), which requires some additional staffing due to exposures. Around midnight (01:00 local time) it might be a bit dusky, at least in the first week of the trial. If in the search phase visibility drops to levels where efficient observations can't be made, the lead MMO can reduce staffing to 1 person on watch (coordinate with CO/XO). However, we will keep the basic watch structure, because in tracking phases all personnel is needed, and in the last week of the trial we expect good visibility through the night. Secondary MMO's might be instructed to also support the visual search during part of their watch, depending on their other tasks. At the start of the watch the CO/XO and lead MMO will organize the watch and make a watch plan for the MMO's which also includes the secondary MMO's.

	Watch			
Name	**08 - 14**	**14 - 20**	**20 - 02**	**02 - 08**
Petter Kvadsheim				
René Dekeling				
Patrick Milller	24-hr stand by			
Frans-Peter Lam				
Mark van Spellen				
Sander van IJsselmuide				
Lars Kleivane				
Rune Roland Hansen				
Paul Wensveen				
Saana Isojunno				
Lucia Martin Lopez				
Odile Gerard				
Marije Siemensma				
Yvonne Mather				
Eilidh Siegal				

Basic watch plan used in the survey, tagging and tracking phases. The entire crew will follow a regular 6 hrs on and 6 hrs off seamen's watch plan. This watch plan implies that there are at least 7 people on watch at any time, 3 dedicated MMOs and 4 secondary MMOs. Secondary MMOs should support the primary MMOs as much as possible!

It is part of our 3S-culture that the full team is expected to arrive on its post 10 min prior to the start of your watch. This is to avoid any gaps in the effort, and to allow for organized information exchange between teams. The new team will be ready and the retiring team is dismissed in time.

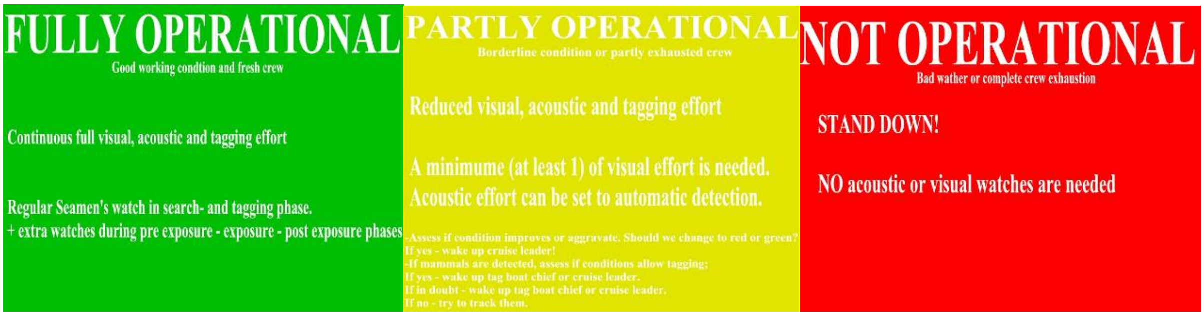
Watch plan in experimental phases

During the exposures we will generally follow the same schedule as we use in the rest of the tracking period. However, the number of MMOs will be maximized to assure that there is enough effort to track the focal whales and monitor the safety zone around the ship (mitigation) at the same time. The MMO station should be manned with a minimum of 5 MMOs during the exposures. Playback coordinators Kvadsheim and Miller will both be on watch during the exposures. XO/CO will make ad-hoc adjustments to the watch plan prior to the exposures if needed to fill these requirements.

As the default procedure we will track the focal animals from the source boat (HUS). After the first 1-2 experiments we will assess if this work satisfactory. Meaning that we are able to track the whale from a distance of 1-2nmi, which does not raise concern about the whale being affected by the presence of the ship, and that we are able to predict the position of the whale and approach the whale as intended during the exposures. If this does not work out well, we will consider to switch to a mode where there is an independent boat tracking he whale. From tag on and in the 15-16 hrs until the tag is recovered we will track the whale from TB2 (MOBHUS). If this happens, extra manpower is needed, and therefore a separate watch plan will be implemented. Two MMO-teams of 3-4 people, which take turns and rotate every third to fourth hour between MOBHUS and resting "duty" will be established. In addition a separate watch plans for the remaining MMOs, who will stay on the Sverdrup as well as for the acoustic team will also be established.

Operational status

In extended periods of good weather, and if we are successful in finding animals and tagging them, there is a risk that the work load on the team will be very high, and that eventually we will all suffer from collective exhaustion. In these periods, the basic watch plan has to be considered to be normative. It is better to have some level of search effort all the time than periods with no effort at all.



Operational status green – we are fully operational with continuous full visual, acoustic and tagging effort.
Operational status yellow – we are partly operational with reduced effort on visual, acoustic and tagging effort.
Operational status red – we are not operational, everyone can and should rest!

On the other hand, increased risk to personnel in some phases of the operation, and increased risk of reduction in the quality of the data collected in other phases are factors which also have to be considered carefully in these periods of intense work load. Thus, the cruise leader may decide to reduce effort during search and tagging phase to rest the crew. Because of this risk of crew exhaustion, the cruise leader may also reduce effort in periods of bad weather. To make sure everyone is aware of the operational status a traffic light system will be implemented. The operational status will be clearly indicated in the main operation room and the bridge of the ship.

DATA COLLECTION

Overview of experimental cycle

Each tagged whale will be subject to a controlled exposure experiment (CEE). To avoid habituation or sensitization from previous experiments, CEEs will not be conducted within 20nmi of the previous exposure within 24 hours. This is based on expected response threshold and propagation loss.

The standard protocol is developed to test differenced in responses to continuous sonar signal compared to pulsed sonar signals. This protocol will be used with sperm whales, killer whales and pilot whales. If a minke whale is successfully tagged a separate protocol is specified below.

We aim to attach two tags on the subject whale in order to ensure successful recording of the full experimental protocol. A minimum of 4 hours of baseline data will be recorded after all tagging effort is ceased, and before the experimental phase starts. The experimental phase (~8 hours) consists of a no-sonar control approach first, followed by three approaches with sonar transmissions. Tag release time will be 16 hours, thus we expect 17-18 hour tag deployments. Sperm whales are the primary target species. When sperm whales are not available, such as due to poor weather conditions offshore, tagging and CEE effort may be switched to secondary species (killer whales and pilot whales). The protocol will be the same.

Experimental phases. The second tagging period should be 1 hr max. The pre-exposure baseline period should be 4 hrs minimum. The experimental phase consists of 4 different exposure sessions lasting 40min, with 1 hr 20 min of post exposure between each. Biopsy sampling starts 16 hrs after tag on. The tag is expected to come off after 17-18 hrs.

Search phase

The Marine Mammal Observer (MMO) and the acoustic team (SOC) will collaborate to locate target species at sea visually or acoustically. During the search phase, the MMOs and SOC operators will rotate between four roles: 1) data entry to logger, 2) visual search with big eyes, 3) visual search with binoculars, 4) acoustic monitoring with towed hydrophone array.
All marine mammal sightings should be recorded for survey and mitigation purposes. Non-target species should be recorded as individual sighting events, and no re-sightings should be recorded. The Logger re-sighting form may be used to record target species during the search phase, and must be used for tracking the tagged whale during the pre-exposure baseline and experimental phase. At the MMO station geographical displays of both visual and acoustic detections are available to the MMO and cruise leader, but on separate displays.

Tagging phase

When a decision has been made to attempt tagging on target species, TB1 will be launched from the Sverdrup with tagging and photo-id capability (team: driver, tagger, photographer/tagger trainee). During tagging, the MMO team should provide tracking support to the tag boat, or search for new animals depending on the situation.
Dtag3 technicians will ensure that a minimum of two DTAG3s are armed and ready for deployment prior to tagging. Release time will be set to 16 hours, and release-by time can be set depending on weather and other logistical limitations.
The tag boat will have two different methods to attach the DTAG3: cantilevered pole and ARTS system. The primary attachment method for standard DTAG3 will be the pole, with ARTS primarily used for test deployment of the mixed DTAG (M-DTAG), and for tagging secondary species.

Once a tag is attached, the tag boat may re-approach the tagged whale for a second tag deployment if the whale did not show moderate or strong reactions to tagging attempts (2-3 in table below). Hand-held GPS is required on the tag boat to record the exact tag-on location and time. Secondary tagging attempts should not exceed 1 hour from the tag-on time (TOT) of the first deployment.

Severity of reactions to tagging attempts.

0	No reaction	Whale continued to show the same behaviour as before the biopsy or tagging attempt
1	Low-level	Whale modified its behaviour slightly, e.g. dived rapidly or flinched
2	Moderate	Whale modified its behaviour in a more forceful manner but gave no prolonged evidence of behavioural disturbance, e.g. tail slap, acceleration, and rapid dive
3	Strong	Whale modified its behaviour in a succession of forceful activities, e.g. successive percussive behaviours (breaches, tail slaps)

Mixed DTAG test protocol:

Testing the M-DTAG is an important primary task of the trial, because if we can use it to collect data during the CAS experiment it increases the quality of the data collected. During initial approaches of sperm whales we will try to double tag with DTAG3 and the M-DTAG. The DTAG3 will be deployed first using the cantilever pole, but at the second approach of the same whale we will try to deploy the M-DTAG still using the pole. The M-DTAG will have the same release time as the regular DTAG3s. After 1-2 deployments of the M-DTAG we will assess it's performance and if we are comfortable that it works fine, we will start using the M-DTAG as the primary tag deployed first, or if we are not happy with it, we might stop using it altogether.

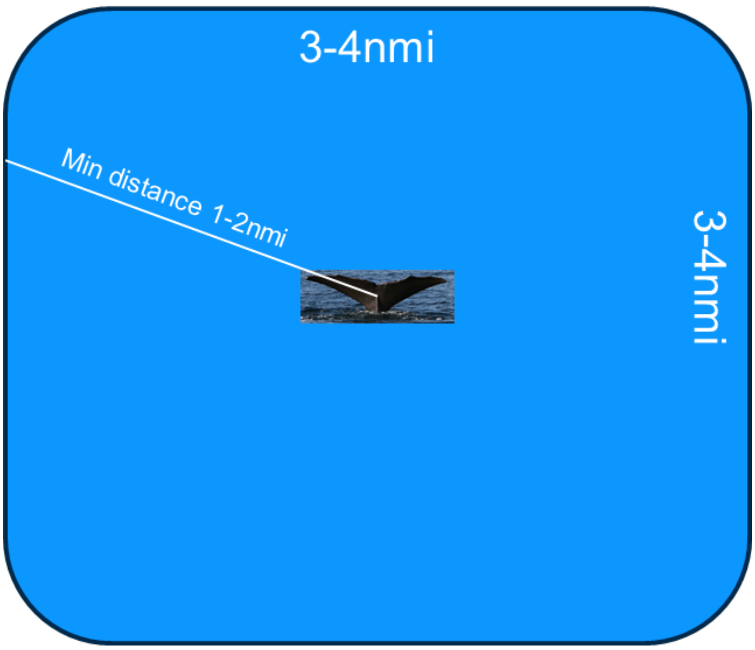
The second test which needs to be done with the M-DTAG is to test its launching with ARTS. However, this secondary task will have less priority than tagging the primary species. We will primarily try to test this on secondary species (killer whales, pilot whales or minke whales). If the M-DTAG has not been tested before on sperm whales, we will use a short (4 hr) deployment the first time, and thus not conduct any exposure experiment.

Tracking of the tagged whale

Tracking of the tagged whale should be commenced as soon as the first tag is deployed. The exact tag-on position and time should be transmitted from the tag boat to Sverdrup and recorded in Logger. From now on the MMO team has to also start using the VHF tracking (DDF) system to support them in tracking the tagged whale.

During tracking, the MMO and acoustic team (SOC) will be split into dedicated visual and acoustic teams. Re-sightings should be recorded at 2-min intervals when the whale is at surface, and at the time of a fluke-up. For every re-sighting, it is important to record range, bearing, group size, and distance to the closest other conspecific whale/group of whales. Recording of non-tagged whale sightings should continue throughout, until the tag is off. Where sighting effort needs to be prioritized, the first priority is the re-sightings of the tagged whale(s), second priority is non-tagged conspecific sightings, and third priority is non-tagged heterospecific whale sightings. During sonar exposures, recording and communicating any sightings of marine mammals around the mitigation zone is highest priority.
The visual MMO team should communicate the location and timing of the fluke up to the acoustic MMO team. Conversely, when the whale is not available to visual observation during diving, the acoustic MMOs should provide feedback to the visual team about the estimated range and direction to the tagged whale.

Sverdrup will aim to navigate around the tagged whale in large rectangles around the animal at a constant speed of 6 knots to optimize acoustic performance. Based on acoustic localization of the animals from the SOC-team and sightings of the focal animal reported by the MMO-team, the experimental coordinators (CO/XO) will place the box to keep the animal inside of it. Thus, the box will constantly move with the focal animal. To minimize research vessel effects while tracking, Sverdrup will aim to keep a distance of 1-2nmi from the tagged whale, thus sailing in 3-4nmi by 3-4nmi boxes with the animal is the center. The navigator (CO/XO) will coordinate closely with the MMO's to keep them oriented about the expected relative position of the tagged whale. The exact size of the tracking boxes will depend on the MMOs ability to make visual fixes and the VHF tracking range.



Idealized navigation pattern of HUS during tracking

Pre-exposure baseline period

Pre-exposure baseline phase starts once the tag boat has returned back to Sverdrup. The end of tag boat effort should be recorded in Logger by the MMO responsible for data entry. Four hours of baseline data will be collected before the start of the experimental phase.
The pre-exposure data collection is important because it is our best estimate of "undisturbed" whale behaviour before the experimental phase starts. Logger "Comments" field should be

used to take notes on the quality of this baseline data, such as extended avoidance of the tag boat. Also any other vessel (e.g. recreational, whale-watching boats) approaches of the tagged whale will be recorded in Logger.

Exposure phase

The full experimental phase will consist of a sequence of four CEE approaches of 40 min each, with a minimum of 1h 20min of post/pre-exposure time in between them. The post/pre-exposure time may be extended if the whale does not appear to recover to post-exposure baseline level after exposure.

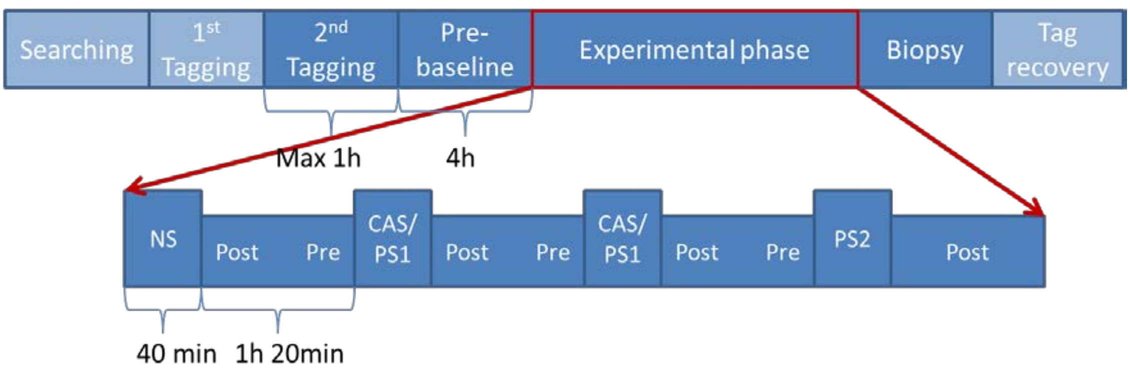
The first CEE approach will be a no-sonar control approach where the source is towed, but not transmitting. Each sonar transmission will include 20min of dose-escalation and 20 min of full SL transmission. To ensure equivalent speed of dose-escalation, all signals will be started -60 dB below the full SL.

The order of the four exposure sessions is determined to maximize the contrast between the different signals with minimum amount of data. No-sonar control approach (NS) is always conducted first to test the effect of ship on whale behaviour, before any sensitization by sonar can take place. After that CAS has highest priority because we don't have any data with CAS exposure, whereas we have some data for pulsed sonar. CAS exposures are therefore never conducted last. Similarly, the MPS have higher priority than HPS as we already have behavioural response data on HPS (see tables below for abbreviations). These criteria give us the following experimental sequence:

Order of exposures during experiment 1-4, after that the cycle is repeated . The different signals are defined in the table below.

Experiment	1st Signal	2nd Signal	3rd Signal	4th Signal
1	NS	CAS	MPS	HPS
2	NS	MPS	CAS	HPS
3	NS	CAS	HPS	MPS
4	NS	HPS	CAS	MPS
5. Repeat Cycle				

If the tag falls off before all exposures are completed, the rest of the exposures need to be cancelled. However, if 2 treatments or more are completed, we will move on to the next step of the cycle in the next experiment.

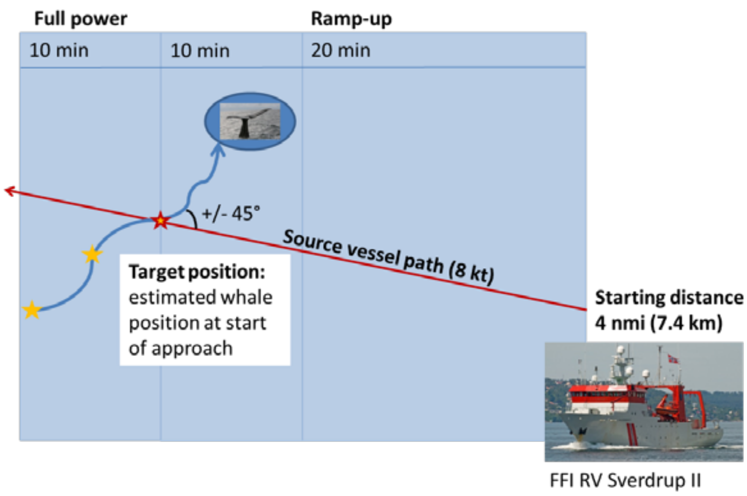


CEE approaches during the experimental phase: NS = no sonar control; CAS = continuous active sonar, PS1/PS2 = pulsed sonar transmitted first or second in the experimental order.

At the start of each CEE approach, Sverdrup will be positioned at 4nmi range from the estimated tagged whale position, at +/- 45 degrees to the side of the whale's direction of travel Approach course will be fixed towards the estimated whale position at the start of the approach. The speed of the vessel should aim to maintain 8kt over ground. The final decision on when to start the approach will be made by the cruise leader.

During the CEE approaches, one of four different sonar signals will be transmitted. No-sonar (NS), Continous active sonar (CAS), Moderate source level pulsed sonar (MPS), and high source level pulsed sonar (HPS)

SIGNAL	NS	CAS	MPS	HPS
Start and end source level dB re 1µPa·m	No-signal	141-201	141-201	154-214
Ramp-up duration [min]	20	20	20	20
SL increase	No-signal	Linear, 1dB/pulse	Linear, 1dB/pulse	Linear, 1dB/pulse
Full power period (min)	20	20	20	20
SEL_{19s} dB re 1µPa·s	No-signal	154-214	141-201	154-214
Signal duration (s)	No-signal	19	1	1
Signal interval (s)	No-signal	20	20	20
Duty cycle	No-signal	95%	5%	5%
Frequency	No-signal	1-2 kHz	1-2 kHz	1-2 kHz
Signal shape	No-signal	HFM Upsweep	HFM Upsweep	HFM Upsweep
Pulse Shading/Signal rise time	No-signal	Cosine envelope with duration of 0.05 sec at start and end of pulse.		



Geometry of all CEE approaches

Post exposure phase

After each 40min exposure session there is a post exposure phase of minimum 1 hr, 20 min. During this period Sverdrup will again maneuver to track the whale as we did on the pre-exposure phase. After the end of the fourth exposure session, the final post exposure phase should be at least 1 hr, 20 min, but preferably longer. Around the time of tag release (TOT+16hrs), MOBHUS (TB2) will be deployed with a tag team to collect a biopsy of the tagged whale, and ultimately pick up the tag when it releases.

Exposure protocol for minke whales

Tagging minke whales is extremely difficult and during this year's trial it is a secondary objective. We there don't expect to tag minkes, but we will opportunistically try, and if successful we will assure to make good use of the opportunity. The goal of any exposure experiments to minke whale will be to replicate the exposure executed during the 3S-11 trial, with the slight modification established in the protocol for the 3S-13 trial, and some additional modification necessary for practical purposes.

The tag release time will be set to 10 hrs. If we tag a minke whale we have to track the tagged whale from the MOBHUS (TB2). Thus if MOBHUS is not prepared for tracking, we will not tag and expose any minke whale. After 4 hrs of baseline data collection, and a change of the MOBHUS crew, the Sverdrup will first do a no-sonar control approach from 5nmi distance at 8 knots speed. After 1 hr, we will then approach the whale again while transmitting a 20 min ramp-up and 20 min of full power using the same transmission scheme as during the sperm whale exposures (High Pulsed Sonar HPS), except that the bandwith of the pulses will be limited to 1300-2000 Hz. We only expect to be able to do two sessions.

The detailed of the protocol for minke whale experiments might be subject to changes.

Mitigation during transmission

During transmissions, MMOs on Sverdrup will assure that no whales are too close to the source that they might be exposed to received SPLs over 175 dB re 1μPa as required by the permit. The stand-off range between source and animals during full power transmission is 100m. If any animals are approaching this safety zone an emergency shut-down of sonar transmission will be ordered. Transmission will also be ceased immediately if any animal shows any signs of pathological effects, disorientation, severe behavioural reactions, or if any animals swim too close to the shore or enter confined areas that might limit escape routes. The decision to stop transmission outside the protocol is made by Kvadsheim or by someone he appoints to be responsible for permit compliance (Miller or Kleivane).

Sound speed profiles (CTD and XBT)

A temperature profile (XBT) should be taken during or as soon as possible after end of transmission during all animal approaches of the source ship, including no-sonar approaches. CTD profiles will be taken form the Sverdrup after the end of the full experimental cycle. However, Sverdrup cannot reduce speed beyond 3 knots when towing Socrates or Delphinus. After an exposure experiment, Socrates and Delphinus are usually recovered on the Sverdrup, which allows Sverdrup to collect CTD profiles along the exposure path (close to CPA) using the CTD probe. CTD profiles should preferably also be collected on a routine basis to monitor the acoustic propagation conditions in the operation area. This will enable us to plan the acoustic experiments using transmission loss models (e.g. LYBIN or Bellhop).

Testing the SOCRATES source

Before we can start any experiment on any whales we need to confirm that the Socrates source perform as expected when transmitting the defined transmission scheme. In particular, we need to measure the harmonics of the source during the different transmissions. The main goal of this test is to measure the spectral side lobe level of the Socrates 2 source when transmitting high power sonar signals.

The test will take place in Vågsfjorden close to Harstad before we transit to the operation area. This fjord is preferred over Andfjord to avoid un-intended exposure of sperm whales. Within Vågsfjord there is a 10 by 2nmi basin which is deeper than 200m and therefore suitable for testing the Socrates source. We will find an area of at least 1 by 1nmi with water depths of >300m for the test.

Indication of tag-boat location (red marker) and track of H.U. Sverdrup II around tag-boat (yellow circle) for Socrates 2 harmonics test. Actual location of experiment has to be defined on site based on local conditions such as water depth and ship traffic.

Test procedure:

- Sverdrup: Socrates 2 source deployed in single tow (no Delphinus) at depth 100m (i.e. cable scope of 200m @ 4 kts).
- Tag-boat: hydrophone @ 50m + recorder + handheld GPS deployed at stationary position.
- Sverdrup sails circles around tag-boat with turn-rate of 15°/min and speed of 4-5 kts. This would result in circle with radius of ≈ 0.3 nmi.
- Sverdrup transmits pulse schedule as listed below and tag-boat records transmitted pulses.
- The test is then repeated using a deeper source depth (200m) to investigate possible source depth influence on harmonics level. This requires cable scope of 400m and water depth of at least 300m.

Pulse schedule:

- CW pulses (with 5% envelope shading)
- Frequency: 1000, 1500, 2000 Hz
- Pulse length: (0.01, 0.1, 1 sec) combined in one 3 second wav file.
- Pulse repetition time: 10 sec (to reduce reverberation)
- Source Level: 214, 208, 201 dB

Recorder:

- TNO will bring OWID recorder which has dynamic range of ≈ 90dB (16bit).
- TNO will look into possibility of using B&K Pulse recorder with higher dynamic range (>120dB).

Note on dynamic range: with 90dB dynamic range we can measure harmonic side-lobe levels down to:

- Source Level = 214dB: -90 + 6 = -84 dB
- Source Level = 201dB: -90 + 6 +13 = -71 dB

The 6 dB margin is to make sure we do not suffer from clipping when measuring the highest source level.

Detailed pulse schedule

Rel Time [mm:ss]	T_{pulse} [sec]	F_{pulse} [Hz]	SL [dB]
00:00	0.01	1000	201
00:01	0.10	1000	201
00:02	1.00	1000	201
00:10	0.01	1500	201
00:11	0.10	1500	201
00:12	1.00	1500	201
00:20	0.01	2000	201
00:21	0.10	2000	201
00:22	1.00	2000	201
00:30	0.01	1000	208
00:31	0.10	1000	208
00:32	1.00	1000	208
00:40	0.01	1500	208
00:41	0.10	1500	208
00:42	1.00	1500	208
00:50	0.01	2000	208
00:51	0.10	2000	208
00:52	1.00	2000	208
01:00	0.01	1000	214
01:01	0.10	1000	214
01:02	1.00	1000	214
01:10	0.01	1500	214
01:11	0.10	1500	214
01:12	1.00	1500	214
01:20	0.01	2000	214
01:21	0.10	2000	214
01:22	1.00	2000	214

After 90 seconds the schedule is repeated. For an experiment duration of 30 minutes this accounts for 20 transmissions of the above schedule. The cable scope is then extended to test the deeper source depth and the test cycle repeated.

As a final test we will run the entire CAS transmission scheme with 20 min ramp up and 20 min of full power (201 dB) CAS transmissions.

After completion of the test, the recorded data will be investigated. Only after the decision is made that no-further testing is required will we proceed to the operation area start searching for whales.

MANAGEMENT AND CHAIN OF COMMAND

Operational issues

Operational decisions such as decisions on sailing plan, decisions to deploy tag boats/Socrates/ Delphinus, crew dispositions etc are ultimately made by the cruise leader. The cruise leader is also the coordinator and leader of the exposure experiments. However, the cruise leader is obliged to consult with the chief scientists of the 3S-partners on decisions affecting their area of interest or responsibility.

Safety issues

The captain of the ship or the first officer, depending on who is on watch, makes final decisions on any safety issues.

Permit issues

The permit holder is Petter Kvadsheim. He makes final decisions on permit issues. However, Patrick Miller also has responsibility for permit compliance during tagging and exposure.

Sonar operation safety issues

A Risk Management Plan for the operation of Socrates and Delphinus is specified to minimize risk to this high value equipment (Appendix A). Final decisions on issues related to the safety of Socrates and Delphinus are made by the chief scientist of TNO (Lam).

Scientific issues

Final decisions regarding the protocol for execution of the exposure experiments lies with the PI.

DATA MANAGEMENT

A central server will be placed in the operation room and connected to the wireless network on-board. A file structure will be specified and all data should be uploaded to the server as soon as possible. Be aware that everyone can write to this disk, but everyone can also delete files, so pay attention when working on the master-disk. Data should always be backed up on local disks.

In the end of the trial the entire data record will be copied to all partners.

Folders in root:

Documents – DTAG – Calibration - Logger – Socrates test data - Socrates logs - Sound samples - Pics and videos - Software tools - Tagboat GPS - HUS GPS – SOC tracks – XBT/CTD.

COMMUNICATION PLAN

In all phases of this trial the crew will be split in different groups (acoustic teams – marine mammal observation teams – tag teams - coordination/management) and platforms (Sverdrup – TB1 – TB2). Coordination and thus clear communication between these units will be crucial, especially in critical phases. To ensure good communications there are VHF-communication equipment on all units. Tag boats must bring a spare handheld VHF. In Vestfjord cell phones can be used as back up, but at high seas there is no coverage.

The radio call signals for the different units will be:

“Sverdrup”	Sverdrup (HUS) bridge (HQ) (answered by CO/XO, or captain/first officer if CO/XO not on the bridge)
“Tag Boat I”	4 stroke outboard engine work boat
“Tag Boat II”	Water jet propulsion MOB (MOBHUS)
“SOCRATES”	Sonar operator on Sverdrup (Socrates and Delphinus)
“Obs deck ”	Marine mammal visual observation deck on Sverdrup

A main working channel (channel A), and an alternative channel (channel B) in case of interference, will be specified.

During the tagging phase, communication to and from the tagging teams must be limited as much as possible.

Tag boats must report in to “Sverdrup” to confirm communication lines every hour! We are mostly operating in open ocean, and this safety procedure is an invariable rule.

If not otherwise specified in the daily work plan the following channels should be used:

Main working channel	**Channel A**	**Maritime VHF channel 73**
Alternative channel	**Channel B**	**Maritime VHF channel 67**

RISK MANAGEMENT AND PERMITS

FFI has obtained necessary permits from appropriate civilian and military authorities for the operation described in this document. The operation area is entirely within Norwegian territorial waters or the exclusive economic zone of Norway. The operation is considered a military activity under the jurisdiction of Norwegian military authorities. RV HU Sverdrup II will carry a Royal Norwegian Navy Ensign and be placed under command of government official from The Norwegian Defense Research Establishment. Cruise leader Petter Kvadsheim is the commanding officer ultimately responsible for the operation.

A separate risk assessment and management plan has been made specifically for this trial. 5 types of risk are identified and mitigation measure and responsibility specified:

- Risk to the environment (injury to marine mammals)
- Risk to third party human divers
- Risk of impact on commercial activity (whale safari, whaling and fishery).
- Risk of damaging expensive equipment (Socrates and Delphinus systems)
- Risk to humans involved in the operation

Since the operation includes animal experimentation, we will operate under permits from the Norwegian Animal Research Authority (permit no 2015/223222) acquired by Petter Kvadsheim. The permits include tagging and acoustic exposure of minke whales, bottlenose whales, sperm whales, pilot whales and killer whales according to the protocol described here. Permits also allow biopsy sampling of target species. The exposure experiments are permitted under the condition that maximum exposure level does not exceed received SPL of 175 dB (re 1 μPa) (100 m stand-off range) and that project participants are skilled in handling the animals. In addition to Kvadsheim, Patrick Miller and Lars Kleivane will be field operators responsible for permit compliance in the field.

Procedures to mitigate environmental risk will be implemented as described in this document, in the permit documents and in the risk management plan. Risk to humans should be minimized through the regular safety regime implemented for all relevant working operations on board. Appendix A of this document specifies procedures to mitigate risks to expensive equipment, such as the SOCRATES system and the towed Delphinus array. All personnel involved in handling this equipment, including navigators, must be aware of the content of this plan. Risk involved in the handling and operation of this equipment is the primary responsibility of the TNO chief scientist.

PUBLIC OUTREACH AND MEDIA

During the cruise, all media contact should be referred to the cruise leader (Kvadsheim) who will coordinate with the 3S-board members (Miller and Lam) and FFI's information office. An on-shore PR-contact will be appointed by FFI, and will serve as the POC for all inquiries from media.

There is some local concern about our operation from whale watching companies operating off Andenes. These companies have been informed about our operation, but if necessary we might do some public outreach meeting during the trial.

GENERAL ADVICE TO MEMBERS OF THE SCIENTIFIC CREW

The scientific trial you will be involved is a unique experience. Make it enjoyable for yourself and others. Be positive and constructive by finding solutions to problems before complaining.

Weather conditions will be the most limiting factor during the cruise. In May the air temperature will still be relatively cold at sea in these Arctic oceans (0-10 ºC). Make sure you bring high quality clothing for all layers. Floatation suit is mandatory for everybody working on the tag boats. However, it's what you wear under the suit which keeps you warm. A hat, gloves and shoes which keep you dry are your most important tools.

The entire cruise is north of the Arctic circle and it's almost midsummer, thus we will have 24 hours of daylight and working conditions, though it might get a little dusky around midnight. This is a big advantage to the operation and our chances of success, because we can work around the clock and don't have to consider retrieving tags before dark. However, make sure you get some sleep! A watch plan will be specified, it is your duty to work when on duty, but also to rest when off duty. We must maximise the time available with good conditions to attempt as many experiments as possible. You should expect long hours of hard work while these good weather windows happen. You will have long hours of rest when weather conditions deteriorate.

Cruise methods and procedures have been fixed in advance, and need to be kept standardized with previous cruises. There is very little that can be changed without affecting the data being collected. If you can think of improvements, discuss them with the cruise leader and principal investigator first before implementing.

This cruise is not a whale watching cruise, so whenever you are on duty keep focused on your tasks. If you are off duty use well your resting period and do not disturb/distract the ones that are on duty. It is probable that you will share a cabin with other people, so keep it tidy and pleasant for everyone. If you have any problems please speak to the cruise leader directly and openly as soon as possible. A delay may make matters worse or cause ill feeling between work colleagues.

The food on the Sverdrup is known to be good. However, it might be a good idea to bring you favourite food goodies (*e.g.* tea, coffee, chocolate, cookies, etc.), and let us know if you have any diet restrictions.

Prepare yourself mentally that we might be at high sea without even sight of land for a week at the time. We might be out of cell phone range most of time. Warn the people at home that you are still alive, even if you don't pick up their calls. You will be allowed to call home, but not unlimited, due to the limited number of satellite based phone lines. The ship has continuous satellite based internet connection and internal wireless network. However the bandwidth is limited so avoid downloading large files and switch off software updates. Do not use web based communication such as Skype. There are a few available computer stations on board, but these have to be shared. You are welcome to bring your laptop and connect to the network.

Be prepared! ENJOY! Good luck!

APPENDIX A

Specifications, deployment, operation and recovery of SOCRATES and DELPHINUS system

In this appendix, technical details and sailing restrictions are presented for SOCRATES and Delphinus systems, both to be towed by H.U. Sverdrup II. Sailing restrictions are driven by 3 factors: to avoid hitting the sea floor, to avoid cavitation during (high power) transmission and to avoid entanglement while towing both systems simultaneously (dual tow).

Bottom Avoidance SOCRATES II and Delphinus array

During the trials the SOC2 towed body will be operated with a minimum cable scope of 100 m. In the Table below the maximum cable scope is indicated for different water depths.

Water depth [m]	110	150	200	250	300	400	500
Max Cable scope SOC2 [m]	100	170	260	400	500	500	500(*)
Max Cable scope Delphinus [m]	170	270	400	500	600	660	660

(*) beyond 500m water depth, the maximum cable scope for SOC2 equals the water depth.

These values are based on the speed-depth diagrams at speed 3 kts with a safety margin of 20 m. When applied a minimum speed of 4 kts should be enforced.

The cable scope of the Delphinus array should be longer (≥ 20m) than the cable scope of the source in order to get both systems at the same operating depth. The array itself is neutrally buoyant. Therefore it will only sink by the weight of the cable. When H.U. Sverdrup II would need to come to an unplanned stop the array will slowly sink to the bottom. In this case there will be time to recover the array in order to minimize damage to the system.

Turn rate

During dual tow, turns of H.U. Sverdrup II are carried out with the following maximum turn rate:

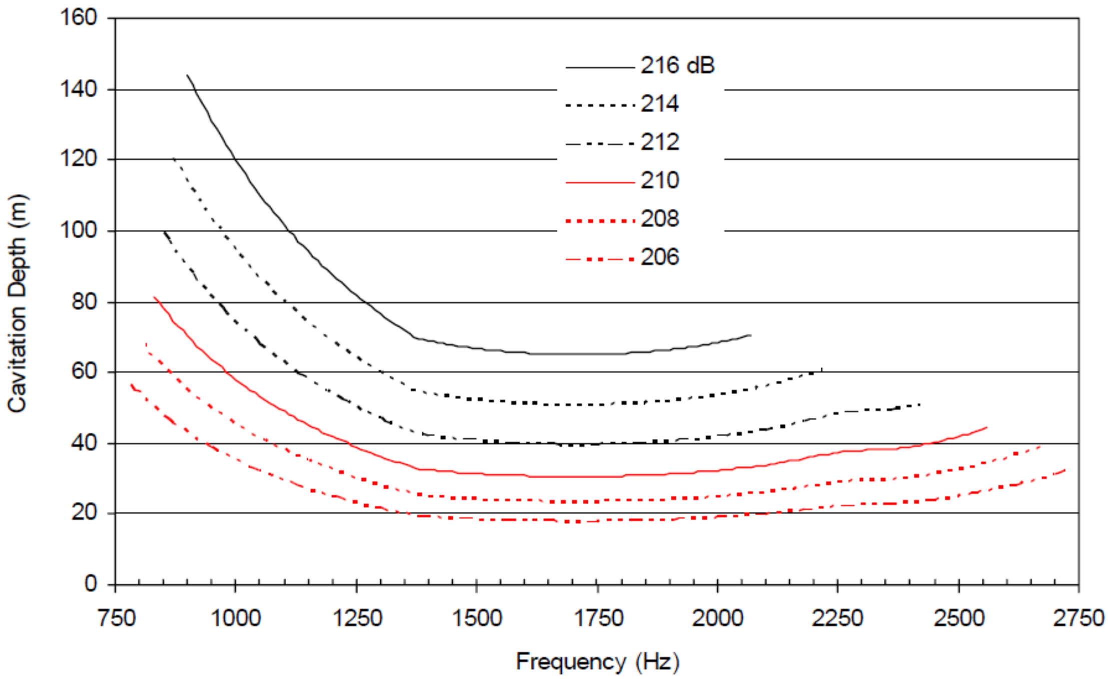
- Starboard turn for 3-12 kts with 20 deg/min.
- Port turn for 3-12 kts with 25 deg/min.
- While turning (and shortly before and after that (2min)) **speed should remain constant**

During single-tow operations the maximum turn rate is 30 degrees/minute.

Cavitation

Because of cavitation the source cannot be operated at full power at small depths. Cavitation depths depend on sonar frequency as shown in the Figure below (curves from Ultra Canada).

The maximum source level of SOC2 is 214 dB. At f = 1000 Hz this results in cavitation depth of 100m. In order to reduce cavitation “shallow tow pulses” are defined that have a minimum frequency of f = 1300 Hz. This reduces the cavitation depth to 60 m.



Full band pulses (1000-2000Hz)
In case other pulses (including frequencies *f* < 1300 Hz) are used and if the sonar depth is less than 100 m the source level should be adjusted with 1 dB per 10 m as shown in the table below.

Source level [dB]	214	213	212	211	210	208	206	204
SOC2 min depth [m]	100	90	80	70	60	50	40	30
SOC2 min cable scope [m] @ 6 kts	250	220	190	160	140	110	100	100
Min water depth [m] @ 6 kts	190	180	160	145	130	110	110	110
SOC2 min cable scope [m] @ 8 kts	470	410	350	290	230	180	140	100
Min water depth [m] @ 8 kts	280	260	240	210	180	160	130	110

Shallow tow pulses (1300-2000Hz)
In case special *shallow tow pulses* (*f* > 1300 Hz) are used and if the sonar depth is less than 60 m the source level should be adjusted with about 1 dB per 5 m as shown in the table below.

Source level [dB]	214	213	212	211	210	209	208	206
SOC2 depth [m]	60	55	50	45	40	35	30	25
SOC2 cable scope [m] @ 6 kts	140	120	110	100	100	100	100	100
Min water depth [m] @ 6 kts	130	120	110	110	110	110	110	110
SOC2 cable scope [m] @ 8 kts	230	200	180	160	140	120	100	100
Min water depth [m] @ 8 kts	180	170	160	140	130	120	110	110

Overall depth guidelines
The above information as stated above, can be summarized with the following table for exposure runs at 8 knots (and without turning):

Signal	***Bandwidth (Hz)***	***Modulation***	***Source level dB re 1µPa@1***	***Tow speed Kts***	***Min tow depth m***	***Min water depth m***	***Min cable scope m***	***Target species***
LFAS$_{deep}$	1000-2000	HFM up-sweep	214	8	100	280	470	Bottlenose whales
LFAS$_{shallow}$	1300-2000	HFM up-sweep	214	8	60	180	230	Minke whales Humpback whales

Depth limits for the two earlier defined types of signals, LFAS$_{deep}$ and LFAS$_{shallow}$ during straight exposure runs at 8 knots without turns. Sailing restrictions for BRS-type exposures are discussed below.

Dual tow

We aim to keep tracking acoustically in parallel with sonar exposures as much as possible, implying dual tow (SOC2 and Delphinus).

- Minimum speed is expected to be 4 kts (constant speed preferred). This is both for acoustic functionality, as well as for safety of system (to prevent entanglement)
- Turn rate for dual tow is 20 deg/minute (starboard) or 25 deg/minute (port), this results in the following turn durations:

Turn [deg]	Turn duration [mm:ss]	
	Starboard turn [max 20 deg/minute]	Port turn [max 25 deg/minute]
90	04:30	03:36
180	09:00	07:12
360	18:00	14:24

- With numbers as stated above, the minimum box is 1x1nmi at 4 knots.
- It takes about 5-10 minutes for the array to get stable after turning (or changing speed). During this stabilization time the acoustic functionality is ranging from poor to sub-optimal.
- Note that handling, like deploying and recovering SOC (see below), should take place during a straight course. Deploying SOC between two corners of a 1x1nmi box will be (too) tight.
- Note that during dual tow it is more challenging to launch and recover tagboats. Special attention is required at these moments.

We should evaluate how things are working out while testing. If needed, test again!

Deployment and Recovery of systems

Sea state

The SOCRATES source and Delphinus/CAPTAS arrays will be deployed to and including sea state 4. It will be recovered if sea state is forecasted to be higher than 5. The decision to recover will be taken by the chief scientist sonar and the responsible TNO technician, and communicated with the captain of H.U. Sverdrup II and the cruise leader.

Deployment and Recovery Speeds

Deployment and recovery time for the SOCRATES to/from a cable scope of 100 m takes approximately 30 minutes and similar for the towed array. Stabilization time of towed body and towed array is about 5 minutes. During deployment and recovery, the tow ship speed is approximately 4 – 5 kts. When the handling supervisor on the aft deck is comfortable with the actual circumstances (wind, currents and sea state) deployment speed could eventually be increased to max. 8 kts.

Sequence

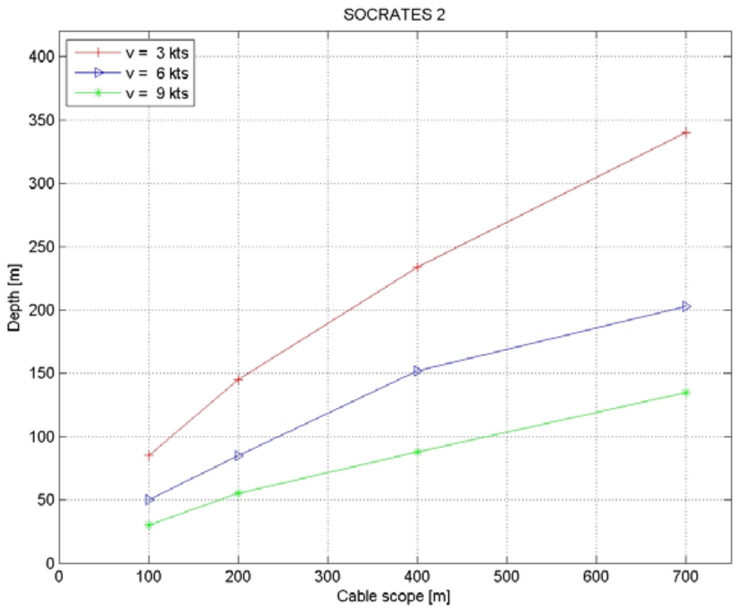
H.U. Sverdrup II can tow both the SOCRATES source and the Delphinus array simultaneously. The deploying sequence will be first the towed array and then the SOCRATES towed source. Consequently the retrieval sequence will be first SOCRATES and then the array.

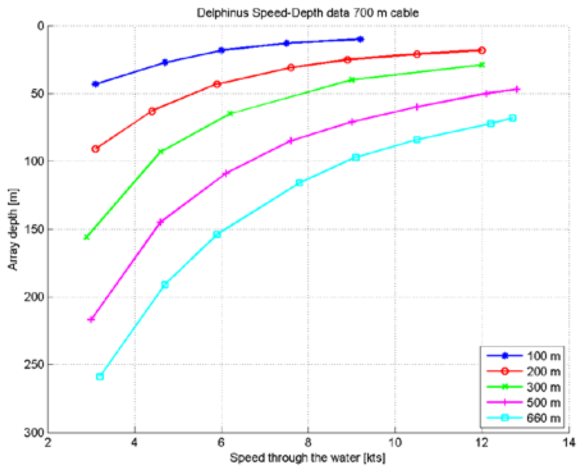
Data Sheet

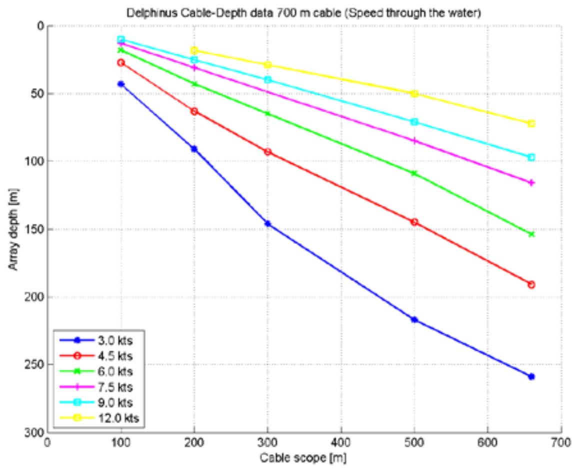
The operational limitations and additional information for H.U. Sverdrup II while towing are presented below:

Item	min	max	Remarks
SOCRATES 2 weight [kg (daN)]	430	750	Weight in water/air
SOCRATES 2 tow length [m]	100	950	
Bottom Vertical Safety Separation [m]	20		
Upper Vertical Safety Separation [m]	15		When not transmitting
Upper Vertical Safety Separation [m]	40		When transmitting
Array depth [m]	10	400	
Array tow length [m]	100	660	
Speed brackets [kts]	4	12	SOCRATES + array

Speed-Depth Graphs







APPENDIX B

A study of the effects of continuous active sonar (CAS) on cetaceans in Norway – Project outline

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Overall scientific goals of the project:

The planned experiments and associated data analyses will address the following specific research questions:

• Does exposure to continuous-active-sonar (CAS) lead to different types or severity of behavioural responses than exposure to typical pulsed sonar signals?

• Does the CAS feature of high duty cycle (proportion of time actively transmitting) lead to indications that use of acoustic media by cetaceans are masked or interfered with?

1.) Purpose of project and its academic rationale:

There has been a significant increase of underwater anthropogenic noise in recent decades, leading to increased background noise levels and more frequent exposure of marine animals to high intensity impulse sounds such as seismic signals and naval sonar. Modern long range anti-submarine warfare surveillance sonars transmit very powerful sound pulses in the 0.1-10 kHz band. Potential negative effects of sonars on marine mammals have received particular attention after several atypical mass strandings of cetaceans in connection with naval sonar activity (D'Amico et al. 2009). These events triggered significant research effort which initially was highly focused on direct effects of noise, such as hearing impairment or neurological injury. Based on this research, accepted noise criteria for injury have been established (Southall et al. 2007). These injury criteria imply that acute effects are limited to the immediate vicinity of the transmitting source. However, behavioural responses to anthropogenic noise can also lead to other negative effects, such as habitat exclusion or cessation of important activities such as feeding, migration or reproduction. Since cetaceans generally have sensitive hearing in the frequency range of naval sonars (Popper & Ketten 2008), behavioural responses might be triggered at much lower levels than acute effects, and the potential for population level effects cannot be ignored.

Behavioural response studies (BRS), in which animal borne tags are used to record behavioural responses of free ranging cetaceans during experimental and controlled sonar exposure experiments, have been conducted by research groups in the US (AUTEC project 2006-2009 (Tyack et al. 2011) and SOCAL project 2010-2016 (Southall et al. 2007)) and Norway (Sea Mammals and Sonar Safety (3S) projects 2006-2010 (Miller et al. 2011) and 3S2 2011-2015 (Kvadsheim et al. 2015)) over the past 10 years. Several species of toothed and baleen whales have been studied. These studies have shown large variation in responsiveness between different species, but also variation within a species depending on the behavioural context of the animals and probably also other unknown factors. Behavioural responses such as avoidance of the sonar source, cessation of feeding, changes in dive behaviour and changes in vocal and social behaviour have been observed, and response thresholds defined. Results from BRS, including the 3S-program, have helped navies to comply with international guidelines for stewardship of the environment, as well as rules and resolutions within Europe and the USA.

Recent technological developments imply that in the near future naval sonars will have the capability to transmit almost continuously (Continuous Active Sonar (CAS)) whereas all the research so far has been done on pulsed sonars typically transmitting only 5-10% of the time (a short pulse followed by a long period of listening). This raises questions about the environmental impact of future sonar systems. The proposed research is a comparative study of how cetaceans respond to CAS versus pulsed sonar.

2. Description of methods and measurements

We will conduct annual 2-week sea trials in May or September 2016 and 2017 using a research vessel (HU Sverdrup II) in the area offshore and inland waters of Lofoten and Vesterålen.

Animal instrumentation: Tags (version 3 DTAG, or 'mixed-Dtag': version 3 Dtag + GPS + ARGOS loggers)

The parameters recorded during the experiments are:
• Behaviour of the animals including social interaction with nearby animals using visual observations
• Horizontal movements of the animals (visual tracking and/or ARGOS or GPS tags)
• Vertical movements of the animals (Dive profiles)
• Vocalizations
• Acoustic exposure levels on the animals
• ID Photographs of tagged and non-tagged whales
• Sex, id, and body condition based on tissue samples

PROTOCOL:
For all species, subject animals will be chosen opportunistically from animals available in the study area. Individual whales will be approached for tagging, primarily using the established cantilevered pole method. Once a whale is tagged, efforts may be made for one hour to attach another tag to the same animal or another animal in its group. Post-tagging observations of 30-60 minutes will be made to collect photographic information, and to give the animal time to recover from any effects of tag attachment. Consistent observations of the study animals will begin at the start of the pre-exposure period, and will continue throughout the experiment phase, and the post-exposure period. While most behavioural recording will be done by the tag, visual observers will fix the location of tagged whales by measuring their range and bearing. Visual observers will monitor the social context of the tagged whale using established visual protocols (Visser et al., 2014). Biopsy samples will be collected near the end of the post-exposure phase.

For baseline data collection, no external exposure stimuli beyond the research activities themselves will be presented to the whales.

The specific exposure protocol will vary depending upon the specific species and goals, as detailed below. All experimental phases will only start after a minimum of 2 hrs of pre-exposure data has been collected.

CAS & pulsed sonar exposure sessions:
Sperm whales (primary species)
Minke whales, Killer whales, and long-finned pilot whales (secondary if sperm whales not available)

The goal of these treatments is to assess whether or not there is a difference in the severity and manner in which cetaceans respond to pulsed sonar versus more continuous sonar which are expected to be used to a greater extent in the future. A dedicated observation vessel (launched from the larger source vessel) will track the whale continuously throughout the tag-deployment period. During no-sonar control sessions, the source will be deployed, but no sound will be actively transmitted. At least one hour will pass after each session before starting the next session. The experimental design will be to conduct paired exposures to individual tagged whales of the two sonar signal types (Figure. 3) to control for individual variability in overall responsiveness.

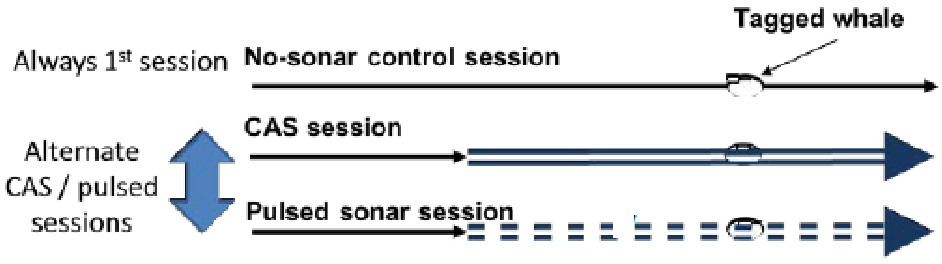

Figure 3. Schematic of sonar transmission schemes for the 3 exposure sessions. Arrowhead lines refer to vessel path toward the tagged whale. Solid single lines indicate vessel approach without any sonar signal transmission (No-Sonar control); Double solid lines indicate vessel approach while transmitting CAS sonar signals (CAS session); and double-dashed lines indicate vessel approach while transmitting pulsed sonar.

No-sonar control sessions will always be conducted as the first exposure session. Movements of the source vessel will be as similar as possible across the 3 different exposure sessions and procedures used in the previous field experiments with these species (Miller et al., 2011). The source vessel will start transmission at a range of 8-10km from the whale, and approach the estimated location of the whale to aim to conduct 45-60 min exposure sessions. No turns will be made during this initial approach phase once the vessel fixes its approach bearing. Transmissions will continue for five minutes after the closest-point of approach to the whale has been passed, or after one hour total of transmissions.

CAS source levels will be the maximum possible using Socrates to achieve a 90% duty cycle, expected to be ~203 dB re 1µPa @1m SPL. Since we don't know which feature of transmissions is the most important in triggering threshold and magnitude of responses (received SPL, received SEL, whale-source proximity, sonar source level), we intend to conduct two versions of 1s duration pulsed sonar exposure sessions: 1.) High source level in which the cumulative transmitted SEL is set to match the cumulative SEL expected under CAS. In that case, pulsed sonar exposure sessions will start at low source levels 150-160dB re 1µPa @1m, and will be gradually increased to the maximum-of 214dB re 1µPa @1m over a 20 minute period. Note this matches pulsed sonar treatments already conducted in the 3S project. 2.) Moderate source level in which a second pulsed treatment will set the maximum SL of the 1s duration pulses to be equivalent to the maximum SL for the expected CAS pulses (203 dB).

To take advantage of the previous 3S pulsed sonar exposures (Miller et al., 2012) to reduce the total number of exposures, CAS will be transmitted in the first session in the first three experiments. After those first three sessions, pulsed sonar will be presented first, and the order will alternate thereafter. Detailed plans for the balance of pulsed sonar treatment remain to be determined.

Secondary species: Killer whales, minke whales, long-finned pilot whales – control exposure sessions

No-sonar control sessions are conducted to separate potential effects of the approaching sonar-source-ship from the effects of the sonar itself. The sessions are conducted exactly as the sonar sessions, except that there are no active sonar transmissions.

Playback experiments as an additional control will only be conducted on a not-to-interfere basis with sonar or no-sonar control exposures, which will have priority on research trials conducted with R/V HU Sverdrup II. Some playback control experiments could be conducted under lower-cost trials.

These additional control sessions where natural occurring disturbance signals (the sound of predators or competitors) are played back to the animals are used to help us interpret the biological significance of any behavioural responses to sonar. The goal of these treatments is to obtain data on how these cetacean species behaviourally respond when they hear the sound of their potential predator, the killer whale (*Orcinus orca*). This treatment has been an effective positive control in previous 3S experiments, indicating what types of responses are made by cetaceans to a natural threat (Miller et al., 2012; Curé et al., 2012; 2013, 2015). We have already collected sufficient data on this treatment for sperm whales, but we have not conducted any of these exposures for the apparently sensitive minke whales. For long-finned pilot whales, initial tests employed sounds of herring-feeding killer whales (Curé et al., 2012), so additional data using playback of mammal-feeding killer whale sounds would benefit the study. When killer whales are the subject species for this treatment, we will playback the sounds of long-finned pilot whales as a relevant inter-specific control sound (De Stephanis et al., 2014).

In this treatment, the source vessel (RHIB) is positioned roughly 800m from the tagged whales, at a position roughly 45 degrees to one side of the whale's direction of movement. This position makes it possible to observe either avoidance or attraction (Curé et al., 2012; 2015). Killer whale (or pilot whale) sounds are played from a broad-band Lubell LL9642T underwater speaker at source levels that are naturally produced by killer whales (Miller, 2006), with maximum source levels of 160 dB re 1µPa @1m. Transmissions last for 15-30 minutes. A variety of different mammal-eating killer whale (or pilot whale) sound sequences will be used. Because the killer whale playback treatment uses a broadband signal and is placed relatively close to the whales, control sounds are presented as a negative control to that specific treatment. Vessel positioning and sound source levels are the same as are conducted for playback of killer whale sounds and only the specific sound stimulus is varied. Various control sounds can be used including broadband noise, tonal sweeps, or non-predatory biological sounds such as humpback whale song.

3. Animal species, number, age, gender

The species involved with each treatment are listed above. Details are presented in Table I, below. For all species, either sex will be tagged. Neonates will not be tagged. Detailed justification:

Sperm whales, killer whales, and long-finned pilot whales

These three species are the target species for this aspect of the study for three reasons:
1. They are relatively easy to find and tag. [more difficult for Killer whales]
2. We already have some data on responsiveness of these species to pulsed sonar, which helps reduce the required sample to address the study.
3. All three species produce click sounds and both killer whales and long-finned pilot whales vocalize with a wide-range of signals in the frequency band of the sonar, and therefore CAS signals might have a masking effect. A key aspect of our study is to compare effects on vocal behaviour of CAS and pulsed sonar.

Sperm whales are the primary target species for this study, and we will work with sperm whales when possible to assure that we gain a robust result for that species. Killer whales and long-finned pilot whales will be worked with when sperm whales are not available, or if analysis after the first field season indicates that we have obtained a conclusive result for sperm whales.

Data analysis approaches and expected sample sizes

Experimental groups include exposure sessions and control sessions for each species. Table 1, below, describes the details of each group.

The sample size needed to arrive at conclusive results depends on variation between and within individuals and the effect size. For killer whales (Miller et al. 2014), long-finned pilot whales (Antunes et al., 2014) and sperm whales (Isojunno et al. 2015), we have conducted similar experiments with pulsed sonar and therefore have reasonable estimates of both. Using state of the art statistical methods, in these cases state space modelling in combination with generalized linear models (GLM) and generalised estimating equations (GEE) in the sperm whale analysis (Isojunno et. al. 2015), and Mahalanobis distance change-point analysis in combination with Bayesian dose response functions in the killer whale and pilot whale analysis (Miller et al.2014; Antunes et al., 2014), we were able to arrive at statistically significant results with sample sizes as small as 4-6.

Conclusive statistical analyses of the outcome of experiments have been possible because of the powerful experimental design in which animals are their own control, with observations of rich multivariate observational data, and large effect sizes. However, the proposed research implies comparison between pulsed sonar and continuous active sonar, and even though individual variation can be expected to be similar, we have no means to estimate the effect size or even whether responses will increase or decrease when the animals are exposed to CAS compared to pulsed sonar. We are therefore planning to conduct 12 experiments with the primary target species (sperm whales). Killer whales and pilot whales are secondary target species for the CAS-study and the achievable number of experiments will therefore probably be lower.

At-sea field experiments like this have to be planned with a high uncertainty about the weather conditions and the availability of study animals. In addition we are restricted by logistic, time and economic limitations. Based on experience, we don't expect to be able to conduct more than 3-6 experiments per field season. However, based on previous outcomes, we do expect that this amount of data will be sufficient to draw conclusions. Nevertheless, research productivity is greater if we are able to study several of the relevant species expected to appear in the study area. The multi-species approach allows us to select the animals which we do find in the study area, and thereby optimize the field effort and success of the research project.

We will use established analytical approaches, led by named postdoctoral research assistant (PDRA) Saana Isojunno to contrast the effects of CAS and pulsed sonar on behavioural responses of the target species. Additionally, detailed analysis of sound production patterns will be carried out in two phases: 1.) standard acoustic audits of all tag records will score the recorded acoustic behaviour to enable computer analysis of the data, 2.) statistical analysis of the scored data will address whether the use of CAS led to acoustic responses that indicate a potential that biologically relevant signals were masked. We already have the analysis framework set up using existing approaches. Data analysis between field seasons will assess the need for more data and based on this prioritize between the different research goals before the next field trial. We expect to be able to collect enough data to arrive at firm conclusions within the two planned field seasons (2016, 2017), and more intensive data analysis effort after the second trial will be carried out leading to published papers addressing the two primary questions of the research project.

Outline the benefits of the project.

Results from BRS, including the 3S-program have helped navies to comply with international guidelines for stewardship of the environment, as well as rules and resolutions within Europe and the USA. This leads to more effective protection of the species from anthropogenic noise disturbance in their environment. This research will inform MOD and Navy about the anticipated environmental impact of CAS as compared to traditional pulsed sonar signals. At present no other (published) information is available to support any assessment on this.

The key benefit of this project from an animal welfare perspective is that a small sample of animals are approached, tagged and biopsied, which may involve short term responses and possibly acute pain, and then some of these are exposed to sonar or control stimuli. Their responses to the anthropogenic sounds will inform policy that will be used to protect marine mammals from adverse effects of exposure. We have reduced the adverse effects of our experimental work to the minimum required to achieve results that will have the intended effect protecting wildlife populations.

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