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TNO report

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Behavioral response study on the effects of continuous sonar and the effects of source proximity on sperm whales in Norwegian waters

The 3S-2017 Cruise report

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Contents

1 Introduction

Modern long range anti-submarine warfare sonars transmit powerful sound pulses which might have a negative impact on marine mammals. Behavioral response studies (BRS) conducted by research groups in the US (the AUTEC project 2006-2009 (Tyack et al. 2011) and the SOCAL project 2010-2016 (Southall et al. 2012)) and in Norway (the Sea Mammals and Sonar Safety (3S) projects: 3S1 2006-2010 (Miller et al. 2011) and 3S2 2011-2015 (Kvadsheim et al. 2015)) over the past 10 years have shown large variation in responsiveness between different species, but also variation within a species depending on the behavioral context of the animals and probably also other factors. Behavioral responses such as avoidance of the sonar source, cessation of feeding, changes in dive behavior and changes in vocal and social behavior have been observed, and response thresholds determined threshold close xxx relationships.
Results from BRS have helped navies to comply with international guidelines for stewardship of the environment, as well as rules and resolutions within Europe and the USA.

The third phase of the Sea Mammals and Sonar Safety project was initiated in 2016 ($3S^3$), and two successful sea trials have already been conducted to collect data on sperm whales and pilot whales (Lam et al. 2018) and on northern bottlenose whales (Miller et al. 2017).
In the first two phases, $3S^1$ (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 signals, we addressed specific questions such as frequency specificity of behavioral responses (Miller et al. 2014) and the efficacy of ramp-up (Wensveen et al. 2017).
Another key output from these studies was a set of species-specific 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 (Miller et al. 2014), pilot whales (Antunes et al. 2015), sperm whales (Harris et al. 2015) and humpback whales (Sivle et al. 2015) have been established and compared (Harris et al. 2015, Sivle et al. 2015). Such functions can be used to define an affected area around a source and estimate cumulative effects of operations on marine mammal populations. However, it is not obvious what the best measure of exposure or sonar dose is. The received RMS sound pressure level (SPL) is the most commonly used metric, but accumulated Sound Exposure Level (SEL) has also been used. However, 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 therefore implies that there is no effect of distance, i.e., that whales respond only to sound levels rather than to how far away the whale judges the source to be. Recent studies indicate that response to sonar may be influenced by the distance from the source (DeRuiter et al. 2013; Moretti et al. 2014). However, more empirical data 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, but also avoiding unnecessary restrictions on naval training activity. Furthermore, all BRS research so far has been conducted using pulsed active sonars (PAS), typically transmitting only 5-10% of the time (a short pulse followed by a much longer period of listening).

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 more continuous illumination of a target and therefore more detection opportunities (van Vossen 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 navies to implement this technology in operational use. This raises imminent questions about the environmental impact of such future sonar systems.

1.1 Objectives of the 3S3-project

In the third phase of the 3S project, which started in 2016, we address the following specific research questions:

1) Does exposure to continuous-active-sonar (CAS) lead to:

   a. different types or severity of behavioral responses than exposure to traditional pulsed active sonar (PAS) signals?

   b. acoustic responses that indicate masking due to the CAS high duty cycle?

2) How does the distance to the source affect behavioral responses?

1.2 Task and priority of the 3S-2017 trial

This report summarizes the outcome of the 3S-2017 trial conducted along the coast of Northern Norway between 22nd June and 13th July 2017. The trial had the following specific tasks:

Primary tasks:

1. Tag sperm whales with DTAGv3 or mixed-DTAG and record vocal-, movement- and dive behavior, and thereafter carry out no-sonar control-, pulsed sonar- and continuous active sonar exposures.
2. Prepare the ground for future studies using operational sonar sources, including testing mixed-DTAG on sperm whales and protocols and procedures for parallel exposures of multiple tagged animals.

Secondary tasks:

3. Tag pilot whales and killer whales with DTAGv3s and do CAS and PAS experiments on them following the same protocol as with sperm whales.
4. Collect baseline data of target species.
5. Collect information about the environment in the study area (CTD and XBT).
6. Re-approach tagged animal after experimental cycle to collect biopsy sample.
7. Collect acoustic data using towed arrays.
8. Test the use of moored passive acoustic sensors in the study area, to address the range of effects of sonar on whales.
9. Collect sightings of marine mammals in the study area.

The primary tasks had a higher priority than the secondary tasks. We tried to accomplish as much of the secondary tasks as possible, and some of them are incorporated in our regular experimental protocol (see also Chapter 2 and Appendix D: cruise plan). However, secondary tasks were given a lower priority if they interfered with our ability to accomplish the primary tasks. Since we already had collected some data on pilot whales last year, it was a higher priority to replicate the CAS-vs-PAS experiment on pilot whales than to tag killer whales.

The trial was split in two separate efforts. In the period just before the main trial a smaller shore-based team worked to tag sperm whales to collect baseline data, test the mixed-DTAG on sperm whales and train the taggers. Immediately following this, the larger team embarked the RV HU Sverdrup II for the main trial, which also included controlled exposure experiments.

2 Method

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 FFI's 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-2017 cruise plan (Appendix D) as well as in the cruise report from last year's trial (Lam et al. 2018). Below follows a short description of the basic experimental design of the experiments.

2.2 Basic experimental design

Our target species were 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 along and off the shelf edge between Harstad and Tromsø (from Langnesegga to Fugløy deep), or 69.0-70.5° northern latitude and 12.5-19.5° eastern longitude. 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 standard DTAGv3 or a mixed-DTAG was deployed using the cantilever pole or ARTS system with sperm wales, and hand held pole or ARTS system with pilot whales. The mixed-DTAG contained a GPS sensor and an Argos SPOT transmitter in addition to the regular DTAG sensors (triaxial accelerometer sensor, triaxial magnetometer sensor, stereo acoustic sensors and pressure sensor). We aimed to deploy two tags on two separate animals, of which at least 1 tag had to be a mixed-DTAG (with GPS sensor) so that the whale did not require visual tracking. Tag release time was set to 15-16 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.

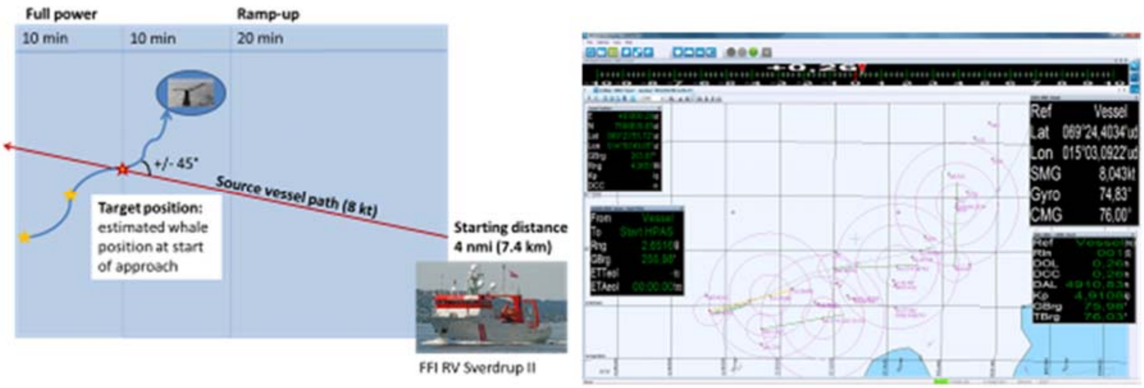


Figure 2.1. Planned geometry of controlled exposure experiment (CEE) approaches (left) and example of the sailed tracks during an experiment on two sperm whales on 1-2 July (right). The second tagged whale ended up 30 nmi north of the focal whale

From tag on to tag off the focal whale was tracked by visual observers on HUS, aided by radio tracking of the VHF-beacon on the tag and acoustic tracking of vocalizing whales under water. If we had tagged two animals, the non-focal whale with a mixed-DTAG was not tracked visually because the GPS sensor on the tag was expected to collect enough fixes for a track reconstruction. During tracking HUS sailed in boxes of 2-3nmi by 2-3 nmi, aiming to keep the focal whale inside the box. This sailing pattern seemed to be the optimal compromise between the visual effort, the acoustic tracking, the VHF tracking range and the desire to not affect the behavior of the focal animal by the close presence of the ship. Good communication between the sonar operators tracking the whale acoustically and the marine mammal 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 system where the MMOs could see the geographical display of the acoustic tracks at the MMO platform. MMOs recorded position of the focal whale and other animals in the area at each surfacing using the software Logger.

Table 2.1. During the 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 $1\mu Pa^2 \cdot s$)	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. The SOCRATES source was deployed and HUS positioned to approach the focal whale from a distance of 4nmi (7.4 km) (Figure 2.1). The course and speed of the tagged whale was estimated based on the track using the NaviPac tool and a future position of the whale at the start of the approach was estimated. 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 (dose escalation). Four different transmission schemes were conducted: no-sonar, continuous active sonar and pulsed sonar at two different source levels (Table 2.1). Between each approach the focal animal had to be relocated to estimate the start position and course of the next approach. The approaches were always separated in time by at least 1 hour and 20 min from the 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. Sometimes the tag released prematurely or the track of the whale was lost and the experiment had to be terminated before all four approaches were achieved.

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, by contrasting the response to MPAS and HPAS we can look at effect of range, because these two experiments give us the same received levels at different ranges. With the multiple tag deployment design the focal whale was subject to a very strict dose escalation experiment, whereas the position of the non-focal whale relative to the source was more random, and expected to be further away. This was expected to give us a wider range versus received level interval. However, since the animals were exposed several times to different signals, we also have to account for any potential exposure order effects. Therefore the order of the three different sonar exposure runs was alternated, except that the no-sonar runs was always conducted first to avoid any potential sensitization to the ship before any effect of the approaching ship was tested.

After the final exposure run, we collected post exposure data. About 1 hrs before the tag was expected to come off, we deployed the tagboat to collect a biopsy sample. 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 20nmi away from 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’s 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. To minimize risk to the environment a separate risk assessment and management plan was developed for the trial (Appendix D). This document also specifies suitable mitigation measures, endpoints and responsibilities.

2.4 Preparing the ground for future studies using operational sonar sources

In future trials we are planning to use a real naval ship with an operational source as the source ship, as an addition to the experimental Socrates source deployed from the research vessel. The reason is that operational sources have significantly higher source levels. When looking at received level versus range as the response driver, we can get the same received level at much longer ranges with an operational source and this will give us more data coverage and statistical power in our received level versus range analysis. There are two main things we need to prepare before we are ready to do this experiment with operational sources.
We can’t expect to have a naval frigate available for extended periods and therefore we need to collect data more efficiently. In addition we also need to monitor for larger scale effects, when we are using such high powered sonars.

A primary task for this trial was therefore to prepare the ground for some adaptations of our protocol to meet these requirements. One of the changes was to replace the regular DTAG with mixed-DTAGs, which basically track themselves, and thereby be able to deploy multiple tags on several animals in parallel, thus collecting data from more than just one animal per exposure. During this trial, the design was to deploy up to two tags, where at least one should be a mixed tag. One of the two animals would then be the focal whale, which was approached by the source ship as explained above, and the other one would be a non-focal animal – having a mixed tag on it. The position of the non-focal whale would then be more random relative to the source, but the expectation was this this would give us more data coverage at greater distances from the source.

The other new element in our design is the use of moored acoustic buoys. Two Loggerhead Instruments DSG-ST Ocean Acoustic Datalogger (sampling at 144 kHz) with an aluminium housing were deployed using an IXSEA Oceano 2500S universal acoustic release. The two buoys were placed 27 nmi apart at 1200-1500 m depth in known hot spots for sperm whales within our operation area (Figure2.2.). The idea was that they would monitor the vocal activity of sperm whales along a gradient from any exposure site.

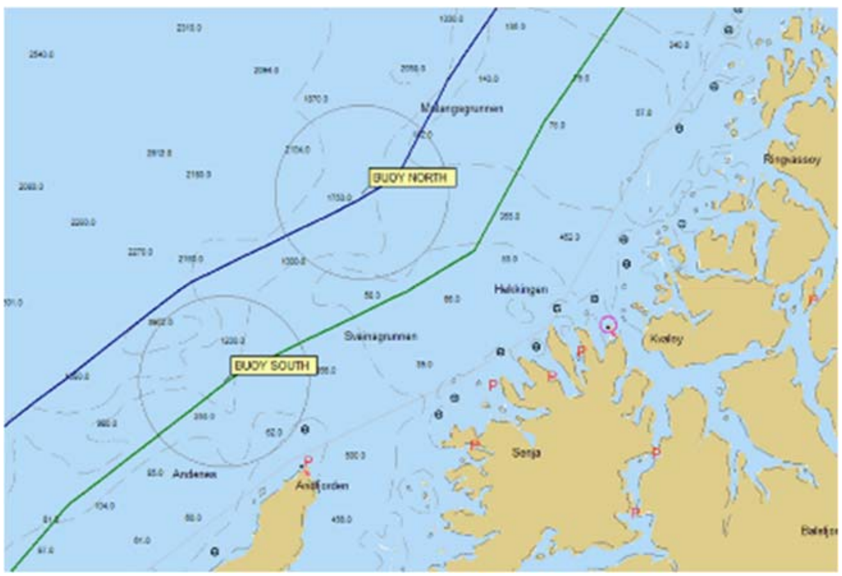


Figure 2.2. Position of moored acoustic buoys during the 3S-2017 experiments with 10 nmi range rings. The two positions were chosen because they were expected to be hot spots for sperm whales. This was confirmed during the trial.

3 Results

3.1 Overview of achievements

Despite quite challenging weather conditions during the trial (Table 3.1) we managed to tag 13 animals in 18 days. We collected 56 hours of baseline data, and conducted 7 successful sonar exposure experiments (Table 3.2). In 4 of these 7 experiments we deployed 2 tags on separate animals. In total we conducted 26 sonar or control runs (Figure 3.1).

Table 3.1. Overview of weather and overall activity during the 3S-2017 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
June 21.	Tromsø	Rendezvous, joint briefing				
June 22.	Tromsø	In port			Embarkment, Mobilization	No regular watches
June 23.	Tromsø-Malangen	Clear sky	NE 4-5	1	Training and testing Socrates	No regular watches
June 24.	Malangen channel	Clear sky	NE 3-7	1-5	Testing tracking equipment. Started acoustic survey through operation area	green, green, yellow, yellow
June 25.	Bleik canyon – Andfjord	Rain showers	NE 4-6	4	Continue survey through operation area. Tagging pilot whales in Andfjord.	yellow, green, green, green
June 26.	Vågsfjord-Harstad	Sun and rain	NE 3-4	2-3	Survey for pilot whales in protected waters. Short technical port call to Harstad	green, red, green, red
June 27.	Bleik-Malangen canyon	Clouded	NNW 3-5	4-5	Moored buoys deployed in Bleik and Mala-ngen. Tracking and tagging sperm whales.	yellow, green, green, green
June 28.	Malangen canyon	Partly clouded	SW 3-5	4	CEE I on two tagged sperm whales. Transit north to Fugløy deep.	green, green, green, green
June 29.	Fugløy deep	Partly clouded	SW 3-5	1-4	Tagging sperm whales, CEE II on one tagged sperm whale.	green, green, green, green
June 30.	Andfjord – Harstad	Partly clouded	NE 2-5	2-4	Survey south from Fugløy deep. Transit to Harstad for crew change.	yellow, yellow, red, red
July 1.	Malangen- Bleik canyon	Partly clouded	NE 0-3	1-3	Tagged 2 sperm whales between Malangen and Bleik. CEE III	yellow, green, green, green
July 2.	Bleik – Malangen	Clouded, rain	SW 2-4	3-4	Recovered tags. Survey northwards to Malangen channel, tagging sperm whales	yellow, green, green, green
July 3.	Off Fugløy deep	Partly clouded	WSW 4	3-4	Tagging killer whales and sperm whales. CEE IV on one sperm whale	green, green, green, yellow
July 4.	Malangen channel	Partly clouded	W 3-5	4-5	Survey through the channel, tagging sperm whales off shore	green, green, green, yellow
July 5.	Andfjord-Langnesegga	Partly clouded	NW 3-4	3-4	Surveyed through Andfjord, transitted to Langnesegga, tagging sperm whales.	red, green, green, green
July 6.	Langnesegga-Bleik	Partly clouded	SW 3-6	3-4	CEE V on sperm whales. Transit to Bleik to recover M-DTAG and southern buoy.	green, green, red, yellow
July 7.	Malangen	Rain, fog, sun	NWSW 2-5	3-4	Tagging sperm whales CEE VI	green, green, green, green
July 8.	Malangen channel	Clear sky	NE 3-5	2-3	Searching for lost mixed dtag. Transit north and start tagging.	yellow, yellow, yellow, green
July 9.	Fugløy channel – Malangen off shore	Partly clouded	E 2-3	2-3	Tagged a pilot whale. Bad tag placement, tag search and rescue.	green, green, red, green
July 10.	Malangen channel	Sun and rain	NSEW 2-4	2	Searching for lost M-DTAG, tagging sperm whales. CEE VII	green, green, green, green
July 11.	Malangen channel	Light clouds	SW 2-4	1-2	Recover buoy in Malangen. Searching for pilot whales.	yellow, green, green, red
July 12.	Tromsø	In port			De-brief, de-mobilization, celebration	No regular watches
July 13.	Tromsø	In port			Dissembarkment	No regular watches

Compared to the condition in 2016 there was a marked change in animal distribution. In 2016 we tagged and conducted many experiments in the Malangen channel and in the outer Andfjord (Lam et al. 2018). This year animals were not found in these coastal areas (Figure 3.2), and we therefore had to operate further offshore. The reason for this change is not known. It could be related to changes in the prey distribution, or it could be related to the conspicuous presence of killer whales and/or pilot whales in much higher numbers than in 2016 (Figure 3.2).

Table 3.2. Overview of tag deployments and controlled exposure experiments. NS=no sonar runs, CAS= Continuos active sonar runs, MPAS=Moderate power (201 dB max) pulsed sonar runs, HPAS=High power (214 dB re 1μPa^{2}m^2) pulsed sonar runs.

CEE #	DTAG ID	Species	Date/Area	Block/Runs
	Gm17_176-MDTAG	Pilot whale	June 25 / Andfjord	Baseline
CEE I	Sw17_179a-MDTAG Sw17_179b-MDTAG	Sperm whales	June 28. Malangen deep	5: Baseline, MPAS, HPAS, CAS
CEE II	Sw17_180-MDTAG	Sperm whale	June 29. Fugløy deep	6: Baseline, NS, HPAS, MPAS, CAS
CEE III	Sw17_182a-MDTAG Sw17_182b-DTAGv3	Sperm whales	July 1-2. Malangen-Bleik	2: Baseline, NS, MPAS, CAS, HPAS
CEE IV	Sw17_184-MDTAG	Sperm whale	July 3. Fugløy deep	3:Baseline, NS, CAS, HPAS
CEE V	Sw17_186a-MDTAG Sw17_186b-DTAG3	Sperm whales	July 6. Langnesegga	4: Baseline, NS, HPAS, CAS, MPAS
CEE VI	Sw17_188a-DTAGv3 Sw17_188b-MDTAG	Sperm whales	July 7. Malangen deep	5: Baseline, NS, MPAS, HPAS, CAS, CAS
	Gm17_190-MDTAG	Pilot whales	July 9. Fugløy deep	“Baseline” Tag rescue
CEE VII	Sw17_191-DTAGv3	Sperm whale	July 11. Malangen deep	6: Baseline, NS, HPAS, MPAS

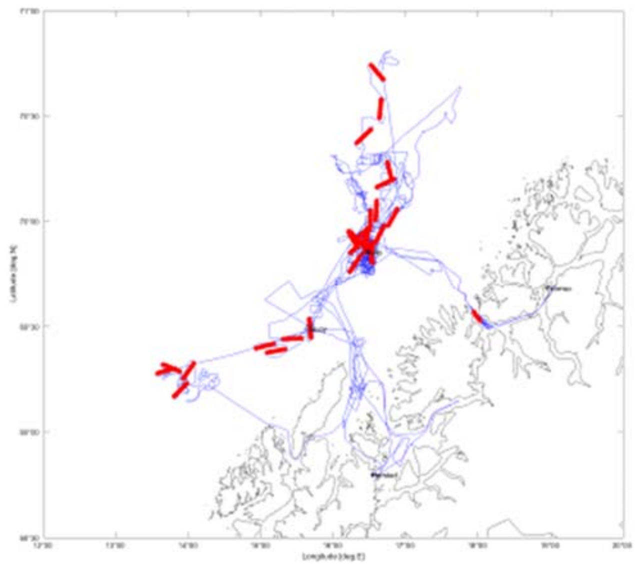


Figure 3.1. Overview of the sailed tracks between June 23rd and July 11th 2017 and the exposure runs executed (red tracks).

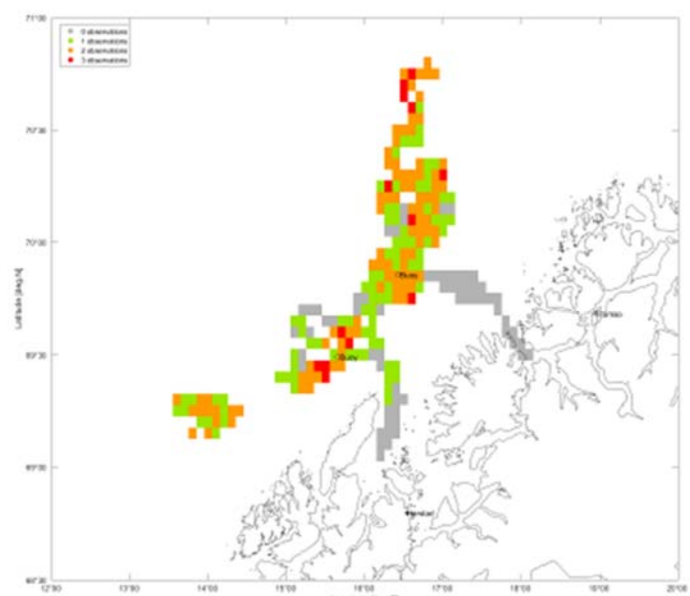


Figure 3.2. Average density of acoustically detected sperm whales between June 23rd and July 11th 2017. Colors are depicting: effort without observations (gray), 1 (green), 2 (yellow) and 3 or more (red) sperm whale observations within each grid cell. An observation is consisting of the average number of sperm whale tracks as logged every 15 minutes. All observations are averaged within each grid cell, also when the ship was in a grid cell multiple times.

3.2 Visual effort and visual-acoustic interactions

A total of 214 hours of visual effort was achieved during the cruise. This could be subdivided into 48 h of searching for animals, 37 h tagging animals and 129 h tracking animals during experiments (from tag on to tag off). On average, we spent 4 h and 22 min searching before the tag boat was launched. 427 sightings were recorded in logger (excluding 336 re-sightings) (Figure 3.3). Sightings included 5 species: sperm whales (N=332 sightings), minke whales (N=28), pilot whales (N=29), killer whales (N=8) and harbour porpoises (N=9). Sperm whales and minke whale sightings were almost always of single animals, with only 7 of the sperm whale sightings (2%) and 2 of the minke whale sightings (7%) involving more than one animal. Harbour porpoises were recorded both as single animals (N=5) and in groups of 2-3 animals (N=4). In contrast, the average group sizes for pilot whale and killer whale sightings were 9.0 and 10.0, respectively. All species were encountered along the continental slope (Figure 3.3).

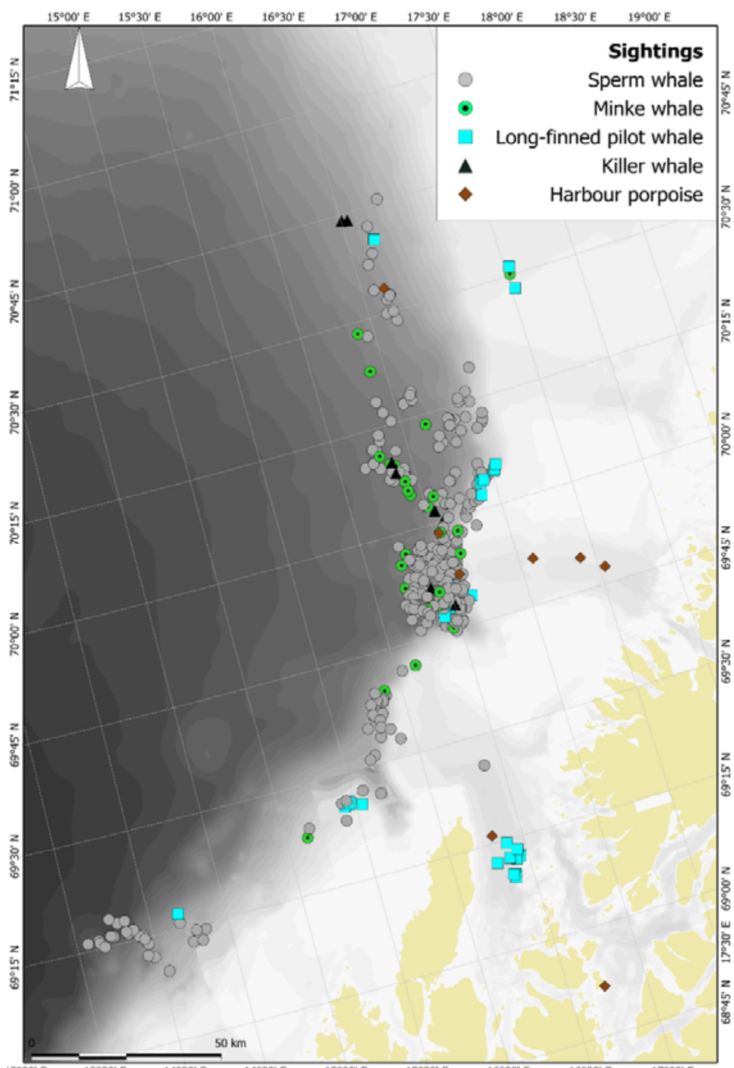


Figure 3.3. A GIS plot of the marine mammal sightings. Locations are based on the recorded bearing and range values recorded in Logger.

Visual effort normally included 3-5 observers rotating between different observation stations and recordings. During the search phase, a minimum of 3 observers were always present. During the tagging phase, 2 of the observer team members were also on the tag team, thus reducing the available staffing for visual effort. However, other available scientific personnel also helped out with visual observations during this phase, ensuring a minimum of 2 observers present at all times during this phase. In the experimental phase (from baseline start until tag off) the entire observation team was available, thus ensuring a staffing of minimum 3 persons present at all times. During sonar transmissions, a minimum of 5 observers were present to conduct mitigation observations that were required of other animals (other than focal) in vicinity of the ship.

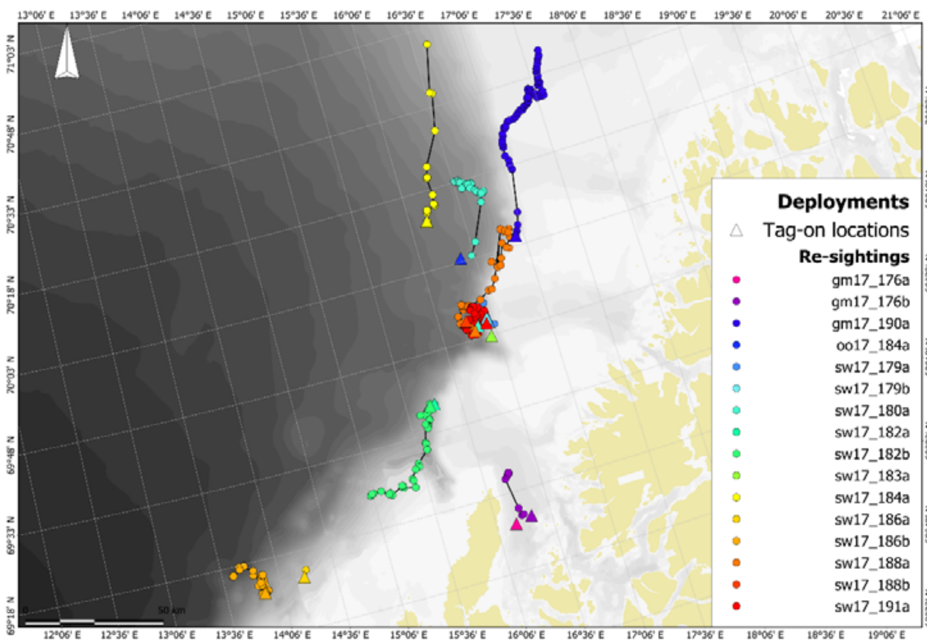


Figure 3.4. A GIS plot of all re-sightings of focal whales.

Efficient tracking of focal animals (Figure 3.4 and 3.5) was a result of good cooperation between the visual and acoustic observation stations. A shared screen showing the latest acoustic and visual detections on a map was very helpful (Figure 3.10). During the searching and tracking, the acoustic team always reported when a focal animal became silent, thus indicating it was ascending to surface, and their placement of the last acoustic detection on the shared screen was helpful to guide the visual observers of where to look for the animal. During the tagging phase, the acoustic station guided the tag boat into a position where the focal whale was likely to surface, and when the animal surfaced, the visual station guided the tag boat until the tag boat themselves established visual contact with the whale.

Once a tag was on a whale, the VHF signal from the DTAG was used together with the visual sightings to confirm that the animal sighted was actually the focal animal. As a back up to the automatic direction finder, we always used a person with a pair of Yagi antennas in addition ("human direction finder"). One person was hence dedicated to listen to the VHF signals and was placed in a higher tower at the observation platform to increase detection distance. This person listened for signals throughout the entire tracking period. We normally rotated every 30 min, to avoid exhaustion and to keep warm, as the tower was quite windy, as well as to maintain concentration and a sharp ear at all times. When hearing the tag signal, this person would shout to the observers for them to look out, as well as indicate the direction from where the signal sounded the strongest. The observer on Logger would coordinate between the person in the tower, other observers and keep radio contact with the acoustic station. The person in the tower shouted “beep” each time when hearing the tag signal, so that the visual observers could relate this to observed surfacings. This was especially important when multiple animals were present in the area, to make sure we tracked the tagged animal. The perhaps most important task in terms of tracking the correct animal was to combine the silencing of the tag VHF-signal with the fluke-up of the visually observed animal, as this was an indication that the animal started a new dive. Such combined fluke-ups/silencing of tag signal was immediately communicated to the acoustic team along with bearing and range information, so that when they picked up a new clicking signal matching the time and location, it was likely the focal whale.

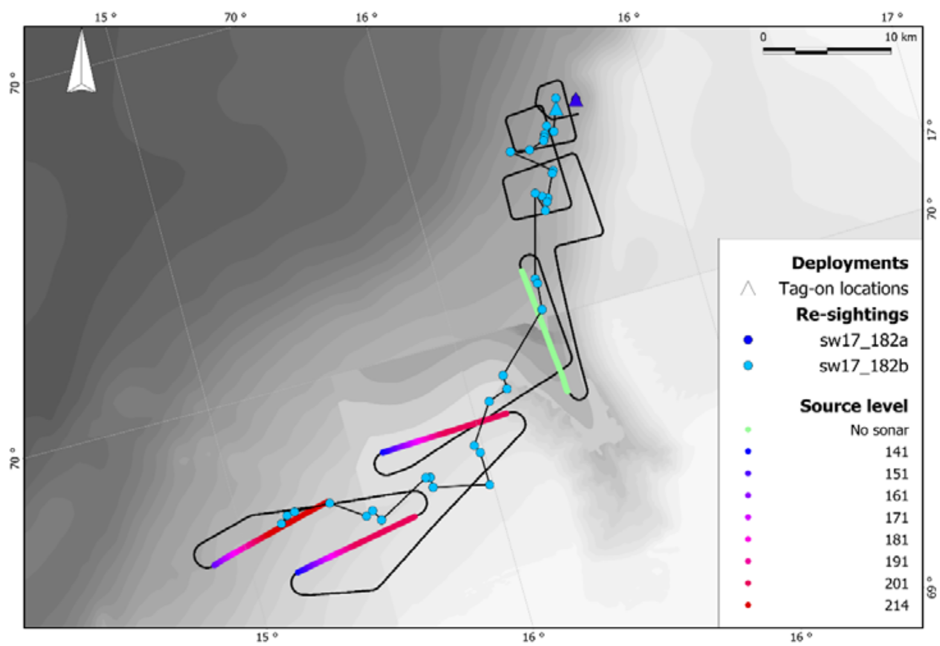


Figure 3.5. Example of focal follow of tagged whales sw17_182a and sw17_182b. The observation vessel is sailing in boxes around the focal to optimize for alternating visual and acoustic tracking. During the four exposure experiments the observation vessel position 4nmi from the whale and approach it at constant speed and course while increasing transmitted source level.

During previous years, the human direction finder has been used mainly as a back-up if we lost contact with the tagged whale. This year, we used this during all experiments. This was a result of the relatively short range of the DDF Horten system, and/or the weaker VHF signal of the mixed DTAG. During a signal test in the first day of the survey, the maximum detection range on the DF-Horten system was estimated at about 4 nautical miles. However, depending on the placement of the tag on the animal, the range during actual experiments could be less than this.

3.3 Passive acoustic detection and tracking

This year the Delphinus array was towed extensively while searching, tagging and tracking sperm whales (see Table 3.3. for an overview of the recordings made). In total 270 hours of data have been recorded, collecting almost 2 terabytes of acoustic data. This year the Ultra High Frequency (UHF) data suffered from significant electronic interference, resulting in degraded performance.
Together with the already limited added value of the UHF data when tracking sperm whales the UHF data was only sparsely recorded and used during the trial.
The Mid Frequency (MF) data also suffered from the same electronic interference, but for the MF data the effect was much less significant. 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 (Figure 3.6 and 3.7).

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 3.8). Sperm whale detections could be passed on to Carcharodon for localization using the Target Motion Analysis (TMA) tools.

3. GIS: Used to combine and visualize the track of HU Sverdrup, the tracks of the tag boats and other boats using AIS, acoustic detections and bathymetry (Figure 3.9). 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 3.10).

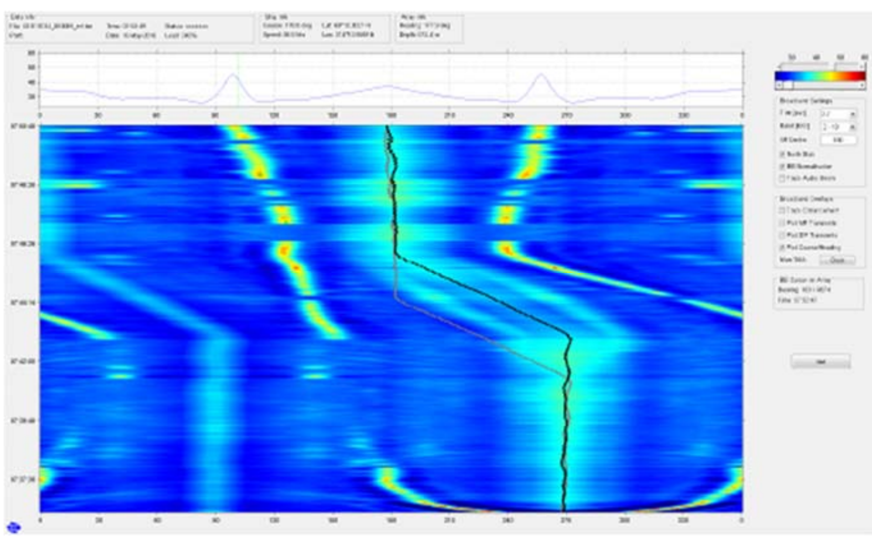


Figure 3.6 Screenshot of the Carcharodon broadband display showing an Amplitude-Bearing plot (top) and Bearing-Time plot (bottom). This display was mainly used to determine the bearing of the sperm whale vocalizations. The main beam is the track of Sverdrup, making a 90-degree turn around 07:44. Dots 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 3.8 below).

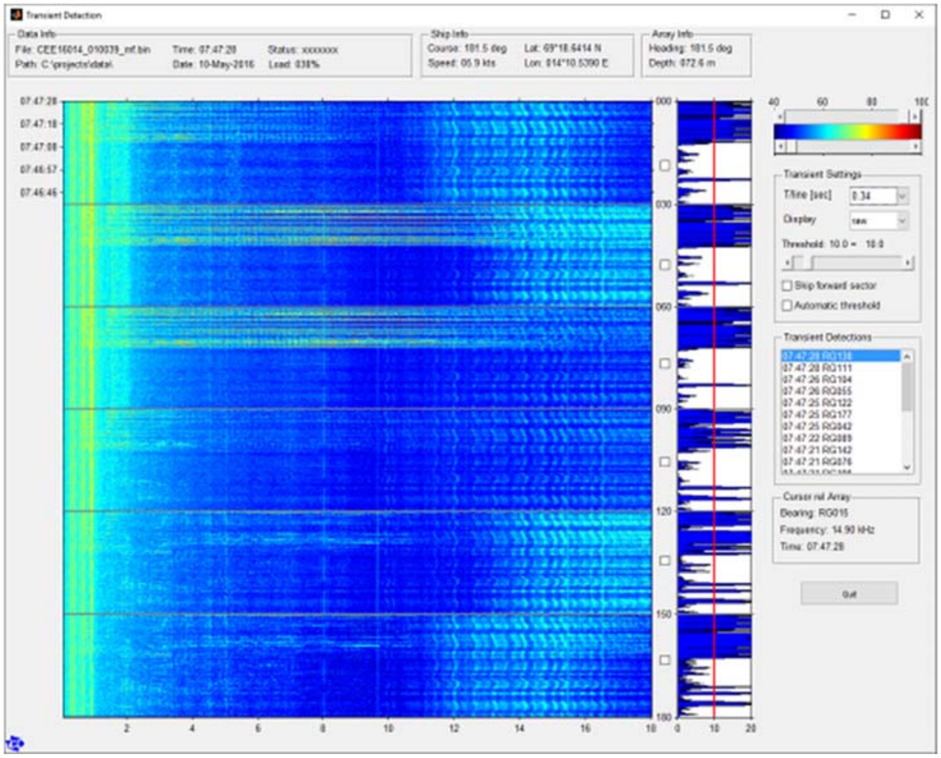


Figure 3.7 Screenshot of the Carcharodon transient detection display showing six time-frequency plots for six horizontal bearing sectors. This screen was mainly used for the initial detection and classification of sperm whale vocalizations.

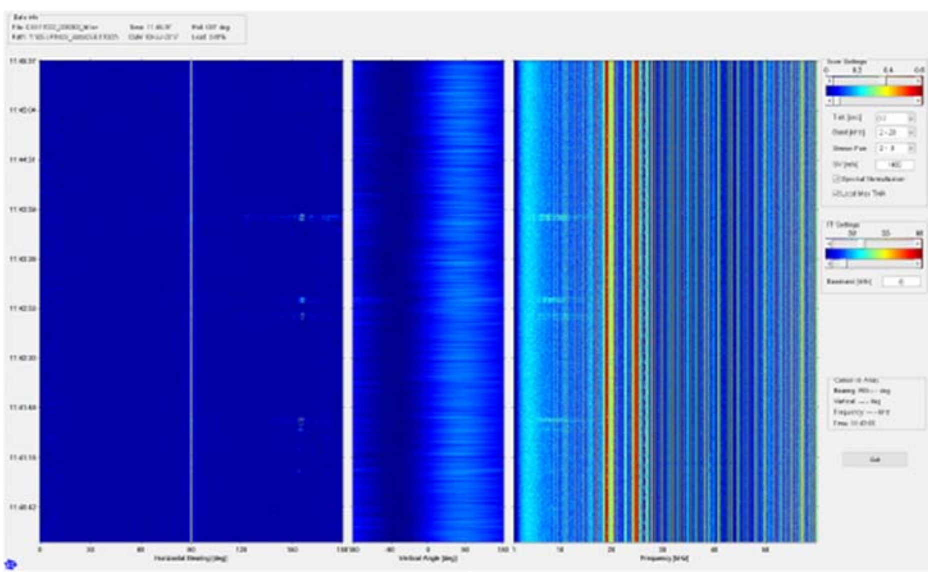


Figure 3.8 Screenshot of Thetis showing a horizontal bearing-time plot (left), vertical angle-time plot (middle) and time-frequency plot (right). The right panel shows serious electronic interference in the UHF data.

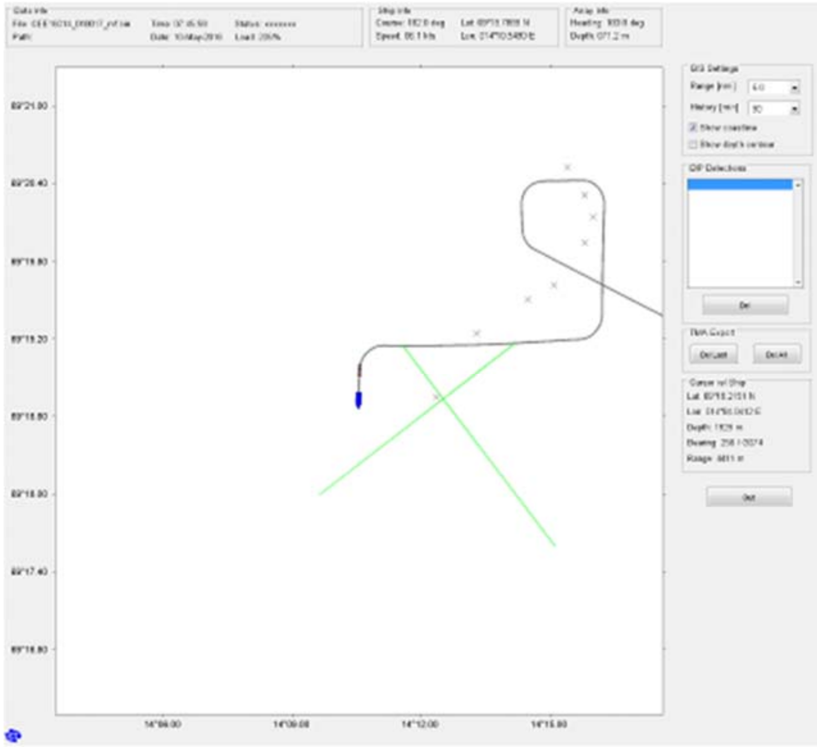


Figure 3.9. Screenshot of the Carcharodon GIS or TMA display. Own ship (track) and array (track) are depicted by the blue ship symbol and red box on the grey line. Bearings of the detected sperm whale vocalizations are shown in green (Carcharodon). The estimated sperm whale location is marked by the cross (x), which is then exported to the second GIS display at the marine mammal observer station (Figure 3.10).

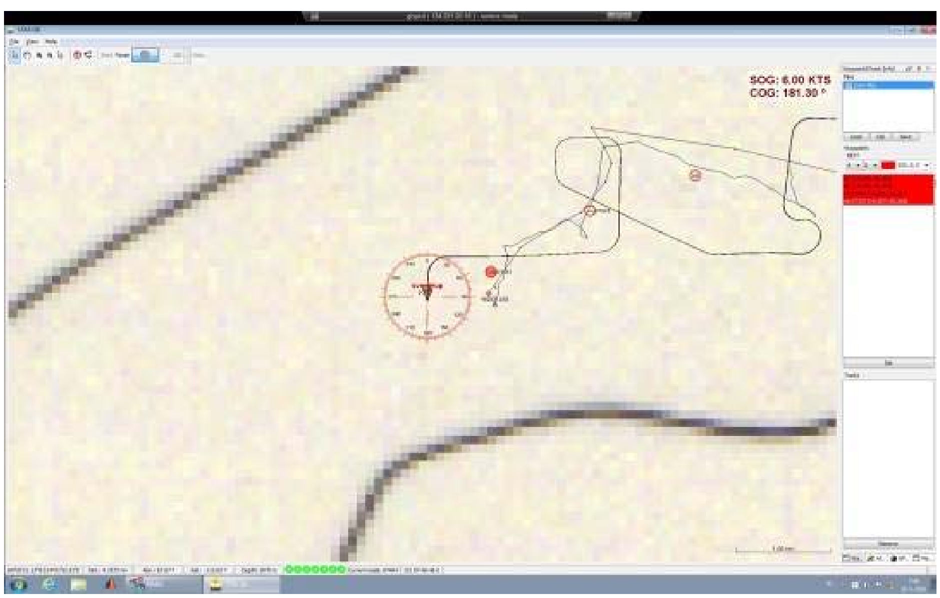


Figure 3.10 GIS display from the Delphinus system showing the estimated position of acoustic detections of sperm whales (pink dot). Black lines are the sailed track of the Sverdrup. The AIS position of the tag boat is also shown in this display (green dot)

Table 3.3. Overview of acoustic recordings and transmissions (Delphinus and SOC) during 3S-2017-CAS.

Exp Name	Sys	Date (start time)	Start Time (UTC)	Stop Time (UTC)	Duration [HH:MM]	Summary
Minky Dinky	Soc	23-06-2017	19:00	21:00	02:00	Test of Socrates
CEE17001	Delp	24-06-2017	13:00	16:11	03:11	Test of Delphinus
CEE17002	Delp	24-06-2017	16:28	20:15	03:45	Search for SW + tagging
CEE17003	Delp	24-06-2017	20:49	06:11	09:22	Search for SW, heading south to Andfjorden
CEE17004	Delp	25-06-2017	06:11	12:14	06:02	Survey Andfjorden
CEE17005	Delp	27-06-2017	02:35	05:25	02:49	Survey first bouy position
CEE17006	Delp	27-06-2017	11:55	17:58	06:02	Search for SW
CEE17007	Delp	27-06-2017	17:58	06:17	12:19	Search for SW, SW
CEE17008	Delp	28-06-2017	06:19	11:14	04:55	Tracking tagged sperm whale
CEE17009	Delp, Soc	28-06-2017	11:34	20:06	08:31	Exposure runs SW using MPAS, HPAS, CAS
CEE17010	-	-	-	-	-	Failed recording, GPS errors
CEE17011	-	-	-	-	-	Failed recording, GPS errors
CEE17012	-	-	-	-	-	Failed recording, GPS errors
CEE17013	Delp	29-06-2017	02:59	16:32	13:32	Transit to new area, tagged SW
CEE17014	Delp, Soc	29-06-2017	16:57	06:44	13:47	Exposure runs SW using HPAS, MPAS, CAS
CEE17015	Delp	30-06-2017	09:29	12:55	03:25	Transit out of exposure area, quiet area
CEE17016	Delp	01-07-2017	09:03	15:22	06:18	Survey out of Andfjorden, tagging attempt
CEE17017	Delp	01-07-2017	15:22	20:26	05:03	Search for SW, tagged SW
CEE17018	Delp, Soc	01-07-2017	20:47	07:36	10:48	Exposure runs SW using MPAS, CAS, HPAS
CEE17019	Delp	02-07-2017	10:00	17:56	07:56	Transit to pick up 2nd tag, tag recovered
CEE17020	Delp	02-07-2017	17:57	23:31	05:34	Tagging SW attempt
CEE17021	Delp	02-07-2017	23:32	05:01	05:28	Tagging SW attempt, tag fell off
CEE17022	Delp	03-07-2017	05:01	12:42	07:40	Search for SW, tagged SW
CEE17023	Delp, Soc	03-07-2017	13:06	00:22	11:16	Exposure runs SW using CAS, HPAS (2-3 pings missed with CAS). Seismic survey in background.
CEE17024	Delp	04-07-2017	06:38	16:20	09:42	Survey
CEE17025	Delp	04-07-2017	16:20	21:43	05:22	Tagging attempt SW
CEE17026	Delp	04-07-2017	21:50	02:30	04:40	Transit to Andfjord, bad weather
CEE17027	Delp	05-07-2017	02:45	05:54	03:09	Survey inside Andfjord for PW
CEE17028	Delp	05-07-2017	13:25	21:56	08:30	Search for SW, tagging attempt SW, seismic survey
CEE17029	Delp	05-07-2017	21:59	03:08	05:09	Search for SW, tagged SW, seismic survey
CEE17030	Delp, Soc	06-07-2017	04:02	14:44	10:41	Exposure runs SW using HPAS, CAS, MPAS (5-6 HPAS pings missed), seismic survey
CEE17031	Delp	07-07-2017	00:01	14:03	14:02	Search for SW, tagged SW
CEE17032	Delp	07-07-2017	14:03	16:58	02:54	Tracking tagged SW
CEE17033	Delp, Soc	07-07-2017	17:18	07:38	14:19	Exposure runs SW using MPAS, HPAS, CAS, CAS2. Lots of Gm
CEE17034	Delp	08-07-2017	07:38	09:02	01:23	Transit to recover MTAG
CEE17035	Delp	08-07-2017	17:44	00:58	07:14	Search for lost MTAG
CEE17036	Delp	09-07-2017	00:58	03:35	02:36	Tagged Gm?
CEE17037	Delp	10-07-2017	03:59	16:33	12:34	Search for SW, tagged SW
CEE17038	Delp, Soc	10-07-2017	16:52	07:05	14:12	Exposure runs SW using HPAS, MPAS
CEE17039	Delp	11-07-2017	10:42	16:55	06:13	Transit for buoy recovery, explosions?
Total					11 days 06:29	

Delp = Delphinus system. Soc = SOCRATES II sound source.

3.4 Acoustic moorings

New this year was the deployment of two acoustic recorders to assess the range at which sonar transmissions might affect whales and monitor possible large scale effects of sonar exposures. The deployment positions were chosen based on knowledge that there is high density of whales around, that we cover the main operation area, and such that we get different ranges from expected exposure sites (see Figure 2.2 for the intended mooring positions). The actual deployment positions were very close to these intended locations and are listed in Table 3.4. A schematic overview of the mooring set-up and an impression of the deployment are shown in Figure 3.11.

Table 3.4: Overview of deployment, recovery and recording settings for the two buoy position.

Recording Name	**CAS1-806121498**	**CAS2-1678020614**
Recorder s/n	806121498 (SMRU)	1678020614 (TNO3)
Deployment Time	27-06-2017 07:02Z	27-06-2017 11:23Z
Recovery Time	06-07-2017 22:11Z	11-07-2017 09:22Z
Deployment Position	Start: 69º28,9747N / 015º36,9369E End: 69º29,5120N / 015º39,3444E	Start: 69º50,8270N / 016º23,3602E Stop: 69º51,4497N / 016º25,6378E
Deployment Area & Depth	Southern Buoy (North-West of Andenes), water depth around 1600m (echo sounder).	Northern Buoy (West of Tromso) water depth around 1270m (echo sounder)
Deployment Set-up	Mooring, see Figure 2.1	Mooring, see Figure 2.1
Recording Start	26-06-2017 20:15Z	26-06-2017 20:23Z
Recording Stop	06-07-2017 23:39Z	11-07-2017 10:32Z
Recording Interval	Continuous	Continuous
Recording Settings	Fs=144kHz, Gain=high, X3compression=on	Fs=144kHz, Gain=high, X3compression=on
Remarks	Clock offset at recovery: DSG-ST = GPS - 00:00:10	Clock offset at recovery: DSG-ST = GPS - 00:00:07

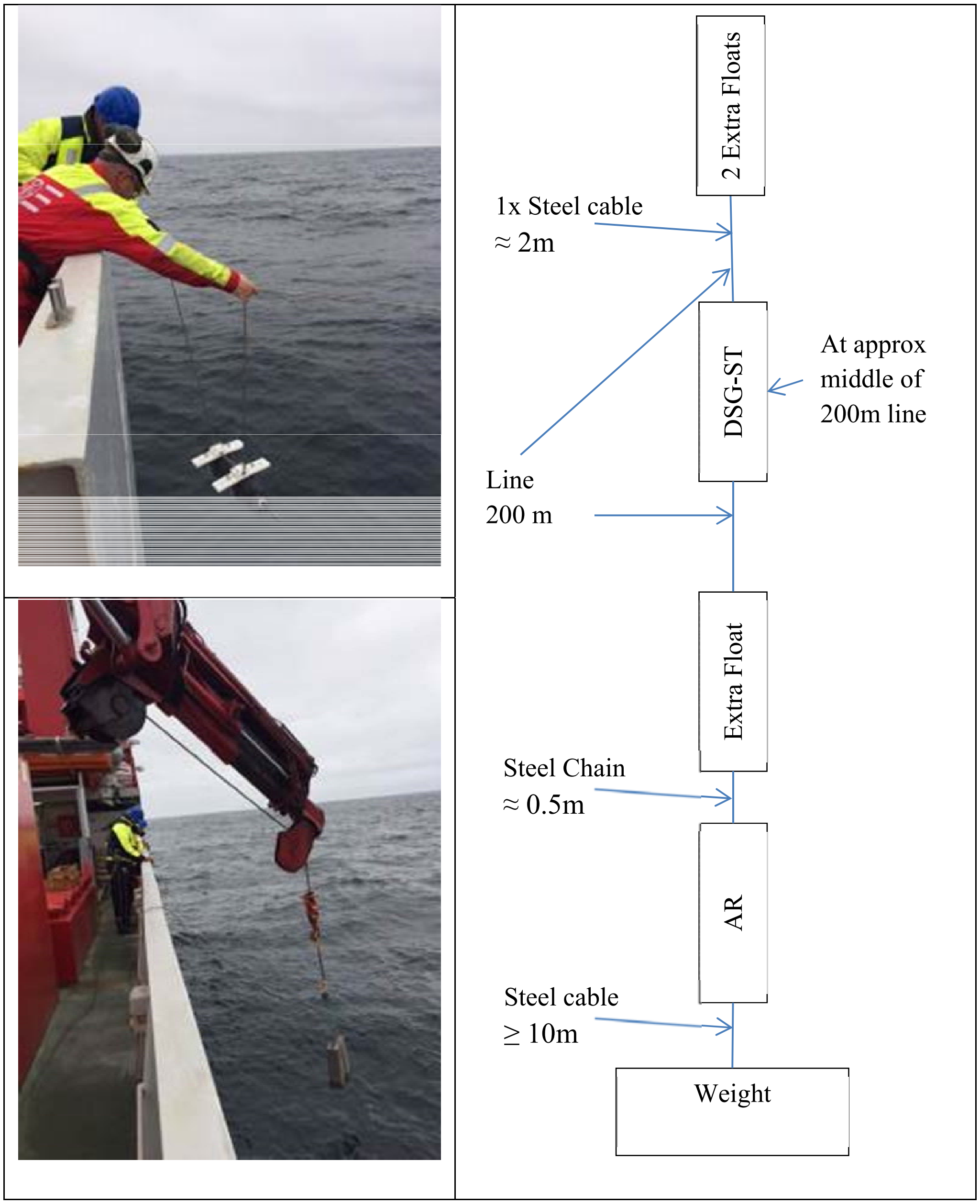


Figure 3.11. Overview of the mooring setup (right) used for the acoustic recorders (AR) during the 3S-CAS trial in 2017 and 2 pictures from the deployment of the northern mooring (pictures FPL).

Deployment from HU Sverdrup II was relative simple and could be done in less than 2 hours. Recovery of the two recorders was done using MOBHUS in order to avoid possible entanglement of the mooring ropes in the propeller of HU Sverdrup II. Recovery using MOBHUS was also an easy job that took less than 2 hours per recorder.

During the 3S-CAS 2017 trial both deployed recorders worked very well and provided us with continuous acoustic recording of the study area. For the southern buoy a total of 9 days and 14 hours of data was recorded and for the northern buoy this was 13 days and 20 hours. Figure 3.12 shows a spectral (time-frequency) overview of both recordings. In both recordings we can already detected several of the CEE sonar transmissions runs executed during the 3S-CAS 2017 trial. Furthermore, an unintended exposure by a 53C sonar and seismic survey activity is visible in both of the buoy recordings. Further analysis has to show if we can detect changes in the click rates of the present sperm whales and if the sonar buoy data is a helpful tool in determining long range effects of sonar exposures.

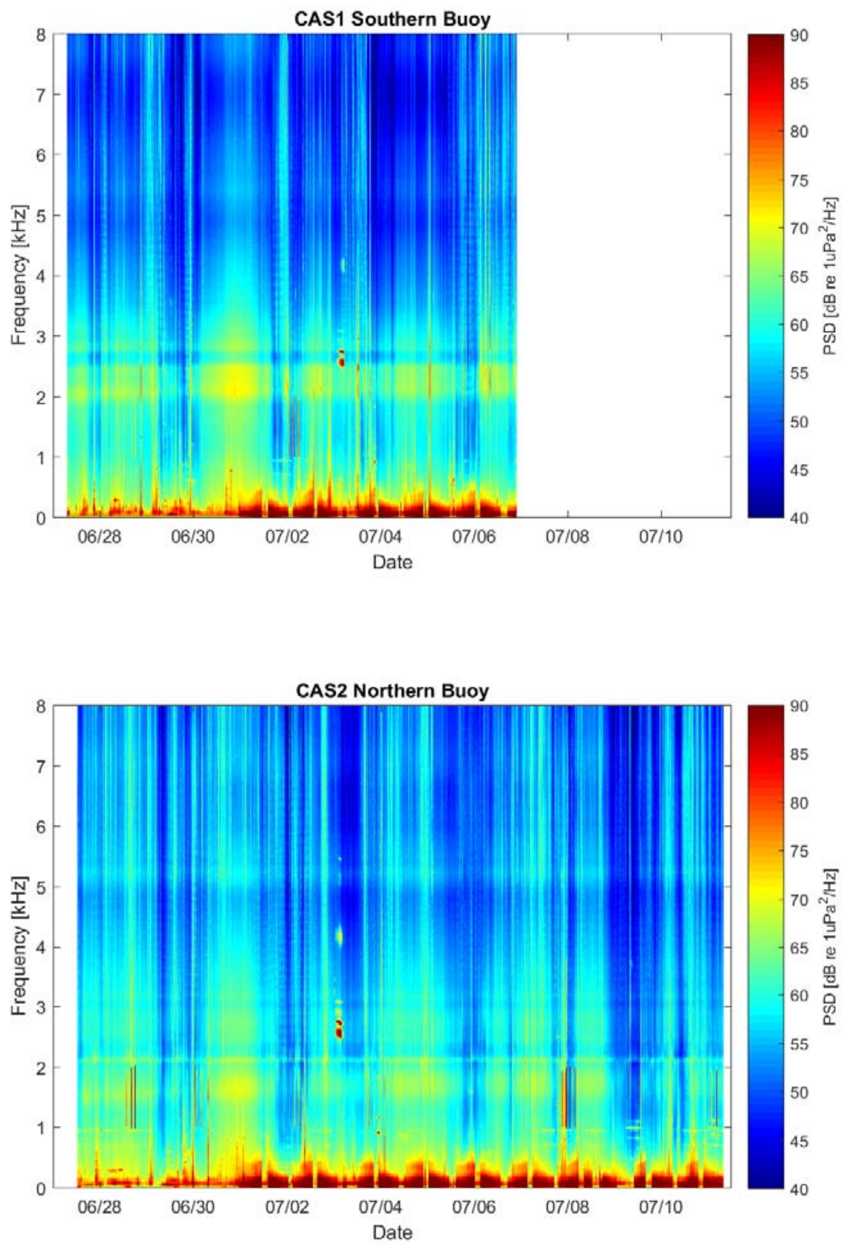


Figure 3.12. Long Term Spectral Average (LTSA) overviews of the Southern (top) and Northern (bottom) buoys. Visible are seismic survey activity starting around July 1st, several of the CEE sonar transmission runs and an unintended exposure from a 53C sonar around July 3rd .

3.5 Tagging

We deployed 16 tags on animals in total; of these 10 were Mixed-DTAGs and 6 regular DTAGv3. 12 tags were deployed on the primary species; sperm whales, while 3 and 1 tag were deployed on the respective secondary species, pilot and killer whales. Summaries of tag deployments are given in Tables 3.5-3.7.

Table 3.5. Number of tag deployments and mean deployment durations (excluding missed attempts and deployments of unknown duration).

	Mixed DTAG		DTAGv3	
	Number of on-animal deployments	Mean deployment duration (h)	Number of on-animal deployments	Mean deployment duration (h)
Sperm whale	7	19.18	5	12.34
Pilot whale	2	2.55	1	11.1
Killer whale	1	0.5	0	n.a.
Total number of tags	10		6	

The weather conditions experienced during tagging operations were generally suboptimal and often borderline for approaching animals. Wind conditions during tagging operations ranged from Beaufort 0-5 and swell heights from 1 to 5 meters (Sea state 1-3), with respective means of Beaufort 2.8 and 2 meters. In fact, 13 tags were deployed in wind of Beaufort 3 or greater. Table 3.6. lists all tag deployments, including missed attempts, with the respective duration of tagging effort and deployment duration. Although this might indicate that the quality and duration of tagging efforts were not influenced substantially by the sea conditions, it is difficult to appraise due to the few deployments in calm seas to compare with. All tagging operations (deployments and recoveries) were undertaken using MOBHUS, a water jet propulsion Man Over Board Boat, which is specifically designed for being safely launched and operated in rough seas. We worked within the safety limits ultimately set by the captain at all times.

MOBHUS has been proven, during multiple previous 3S cruises, to be a robust and efficient platform from which to deploy tags, using either pole or tag launching systems. MOBHUS was rigged with the cantilever system, the primary tool for deploying Mixed DTAGs and DTAGv3s on sperm whales, in a similar fashion as during last year's trial (Lam et al. 2018). Our previous experiences have shown the cantilever pole to be a particularly efficient system for tagging sperm whales; approaching from behind and extending the pole over the tailstock, or parts of it, to slap the tag down high on the animal's back. During our tagging approaches on sperm whales this year, we noticed more evasive behaviors in some of the animals than we had previously observed. Typically, these evasive individuals made shallow or partial submergences, while moving in the range of tens to several hundreds of meters away from the tag boat. However, even with the cantilever pole fully mounted, we still managed to catch up and make successful tagging approaches on many of these animals. Thus, the cantilever proved once more to be an efficient deployment system; 11 tag deployments on sperm whales, achieved by two new and fairly inexperienced taggers (Figure 3.12). Pilot whales were tagged primarily using the handheld pole, while killer whales were only tagged with the ARTS system. Moreover, the ARTS functioned as backup system on sperm and pilot whales. However, since it was merely considered a backup system, little effort went into ARTS test launching's and system calibrations, which may have affected the quality of some of the deployments.

Table 3.6. Summary of tag deployments including missed attempts, with the respective sea conditions during the tagging operation.

Deployment	UTC time	Wind (Beaufort)	Swell height (m)	Duration of tagging effort (hrs)	Tag deployment duration (hrs)	Deployment system
gm17_176a	25.06.2017 13:52	3	3	2.0	<0.5	Hand-held pole, MDTAG
Attempt	25.06.2017 17:47	3	2	n.a.	0.0	ARTS, MDTAG
gm17_176b	25.06.2017 17:52	3	2	2.1	4.6	ARTS, MDTAG
sw17_179a	28.06.2017 02:58	4	1	2.5	~21	Cantilever, MDTAG
sw17_179b	28.06.2017 04:08	5	1	1.4	Unknown	Cantilever, MDTAG
sw17_180a	29.06.2017 11:13	2.5	1	3.9	18.9	Cantilever, MDTAG
Attempt	01.07.2017 09:03	3	1	n.a.	0.0	Cantilever, MDTAG
sw17_182a	01.07.2017 17:00	3	3	0.8	20.8	Cantilever, MDTAG
sw17_182b	01.07.2017 17:17	3	3	0.6	12.7	Cantilever, DTAGv3
sw17_183a	02.07.2017 16:07	3	3	0.8	<0.5	Cantilever, DTAGv3
oo17_184a	03.07.2017 01:11	3	3	3.3	<0.5	ARTS, MDTAG
Attempt	03.07.2017 06:10	2.5	1	n.a.	0.0	Cantilever, MDTAG
sw17_184a	03.07.2017 07:50	2	4	not noted	16.5	Cantilever, MDTAG
Attempt	04.07.2017 19:26	3	5	n.a.	0.0	Cantilever, MDTAG
sw17_186a	05.07.2017 17:03	3	4	2.7	18.7	ARTS, MDTAG
sw17_186b	05.07.2017 23:08	2	2	3.7	14.4	Cantilever, DTAGv3
sw17_188a	07.07.2017 13:56	3	3	1.2	17.2	Cantilever, DTAGv3
sw17_188b	07.07.2017 15:51	3	3	2.5	unknown	Cantilever, MDTAG
gm17_190a	09.07.2017 04:05	2.5	1	11.6	11.1	Hand-held pole, DTAGv3
Attempt	09.07.2017 09:48	1	1	n.a.	0.0	ARTS, dummy
sw17_191a	10.07.2017 13:04	0.5	1	1.5	16.9	Cantilever, DTAGv3

We can only speculate on why a number of the sperm whales tended to evade the tag boat this year. One hypothesis is that the whales were sensitized to small boats, due to encounters with whale watching operations that utilize fast moving small boats, possibly making aggressive, close proximity maneuvers around the animals. Since this year's trial was later in the whale watching prime season than the previous trial, the whales may have experienced more speedboats and possibly stronger sensitization. Secondly, sperm whale behavior may have been affected by the presence of killer whales, as we observed substantially more and larger groups of killer whales this year, compared to 2016. However, we did not observe any prominent behavioral changes (such as spyhops or grouping with other sperm whales) that could be attributed to the killer whales in an obvious way.

During the trial we discovered several technical issues with the Mixed-DTAG. These issues included problems with the magnetometer sensors, problems with the Fastlock GPS sensor, problems with the VHF sensor and damage to one core Mixed-DTAG unit. These issues were worked on substantially during the trial, but needs to be followed up further before the next trial. The problems and the tests done on the tags are summarized in Appendix C.

Table 3.7 Tagging table of 3S-2017. The tag deployment (dataset) nomenclature is a two letter abbreviation of the latin name of the species followed by the year and the julian day.

Data set	Species	DTAG data	Tag ID				Sighting number	Focal whale (yes/no)	Tag-on		Tag-off time (UTC)	On-animal time (hrs)	Tag recovery		Tagging method	Reaction
			DTAG	VHF	Argos	GPS			UTC time	Lat/Long			UTC time	Lat/Long		
gm17_176a	Pilot whale	1	303	219.1650	161597	65370		yes	25.06.2017 13:5200	69.2005 16.274		<0.5	25.06.2017 13:52:00	69.2005 16.274	Hand-held pole	1
Attempt	Pilot whale	0	302	218.8204	161596	65361		no	25.06.2017 17:4700			0.0			ARTS	0
gm17_176b	Pilot whale	1	302	218.8204	161596	65361	25	yes	25.06.2017 17:5259	69.2127 16.4241	25.06.2017 22:30:40	4.6	25.06.2017 23:03:00	69.3637 16.3237	ARTS	1
sw17_179a	Sperm whale	1	303	219.1650	161597	65370	70	yes	28.06.2017 02:5834	69.8456 16.5551		~21	29.06.2017 00:25:00	69.8174 16.4373	Cantilever	1
sw17_179b	Sperm whale	0	302	218.8204	161596	65361	68	no	28.06.2017 04:0800	69.85527 16.54235		Unknown	28.06.2017 22:30:00	69.94625 16.33336	Cantilever	1
sw17_180a	Sperm whale	1	303	218.8204	161597	65370	99	yes	29.06.2017 11:1300	69.8392 16.4448	30.06.2017 06:07:52	18.9	30.06.2017 07:10:00	70.1243 16.366	Cantilever	1
Attempt	Sperm whale	0	303	218.8204	161596	65361		no	01.07.2017 09:0300			0.0			Cantilever	1
sw17_182a	Sperm whale	1	303	218.8204	161596	65361	142	no	01.07.2017 17:0035	69.639 15.8604	02.07.2017 13:46:00	20.8	02.07.2017 14:11:00	69.8231 16.2271	Cantilever	1
sw17_182b	Sperm whale	1	310	219.0845			144	yes	01.07.2017 17:1716	69.6368 15.818	02.07.2017 06:00:52	12.7	02.07.2017 07:06:00	69.4266 15.0681	Cantilever	1
sw17_183a	Sperm whale	1	311	219.1650			176	yes	02.07.2017 16:0700	69.7976 16.5391	02.07.2017 16:12:03	<0.5	02.07.2017 17:07:00	69.7929 16.9613	Cantilever	1
oo17_184a	Killer whale	1	303	218.8204	161596	65361	208	yes	03.07.2017 01:1158	70.06185 16.46815	03.07.2017 01:15:12	<0.5	03.07.2017 01:19:06		ARTS	0
Attempt	Sperm whale	0	303	218.8204	161596	65361		no	03.07.2017 06:1000			0.0			Cantilever	1
sw17_184a	Sperm whale	1	303	218.8204	161596	65361	219	yes	03.07.2017 07:5000	70.2055 16.2617	04.07.2017 00:18:05	16.5	04.07.2017 00:53:00	70.8038 16.7510	Cantilever	0
Attempt	Sperm whale	0	303	218.8204	161596	65361		no	04.07.2017 19:2600			0.0			Cantilever	0

Data set	Species	DTAG data	Tag ID				Sighting number	Focal whale (yes/no)	Tag-on		Tag-off time (UTC)	On-animal time (hrs)	Tag recovery		Tagging method	Reaction
			DTAG	VHF	Argos	GPS			UTC time	Lat/Long			UTC time	Lat/Long		
sw17_186a	Sperm whale	1	303	218.8204	161596	65361	260	no	05.07.2017 17:0351	69.2148 14.3176	06.07.2017 11:46:32	18.7	06.07.2017 21:26:00	69.5021 15.6782	ARTS	
sw17_186b	Sperm whale	1	311	219.1650			264	yes	05.07.2017 23:0853	69.1963 13.9439	06.07.2017 13:32:42	14.4	06.07.2017 15:03:00	69.2694 13.6861	Cantilever	1
sw17_188a	Sperm whale	1	311	219.1650			297	yes	07.07.2017 13:5600	69.8268 16.4077	08.07.2017 07:08:30	17.2	08.07.2017 07:09:00	70.0925 16.9459	Cantilever	1
sw17_188b	Sperm whale	0	303	218.8204	161596	65361	299	no	07.07.2017 15:5100	69.863867 16.350483		Unknown			Cantilever	1
gm17_190a	Pilot whale	1	310	219.0845			370	yes	09.07.2017 04:0539	70.0811 17.0223	09.07.2017 15:14:00	11.1	09.07.2017 15:20:00	70.6264 17.7557	Hand-held pole	1
Attempt	Pilot whale	0						no	09.07.2017 09:4800			0.0			ARTS	1
sw17_191a	Sperm whale	1	310	219.0845			418	yes	10.07.2017 13:0457	69.8409 16.5285	11.07.2017 05:59:23	16.9	11.07.2017 06:45:00	69.8243 16.4391	Cantilever	1

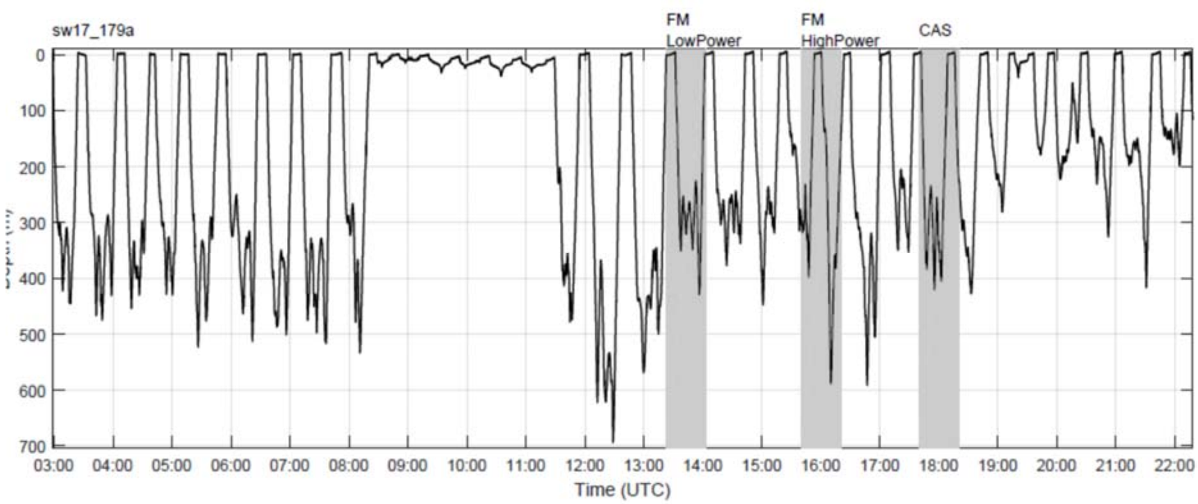
Figure 3.13 Examples of successful deployments of tags to sperm whales using the cantilever pole (photos: left-Rune Roland Hansen, right-Jacqueline Bort).

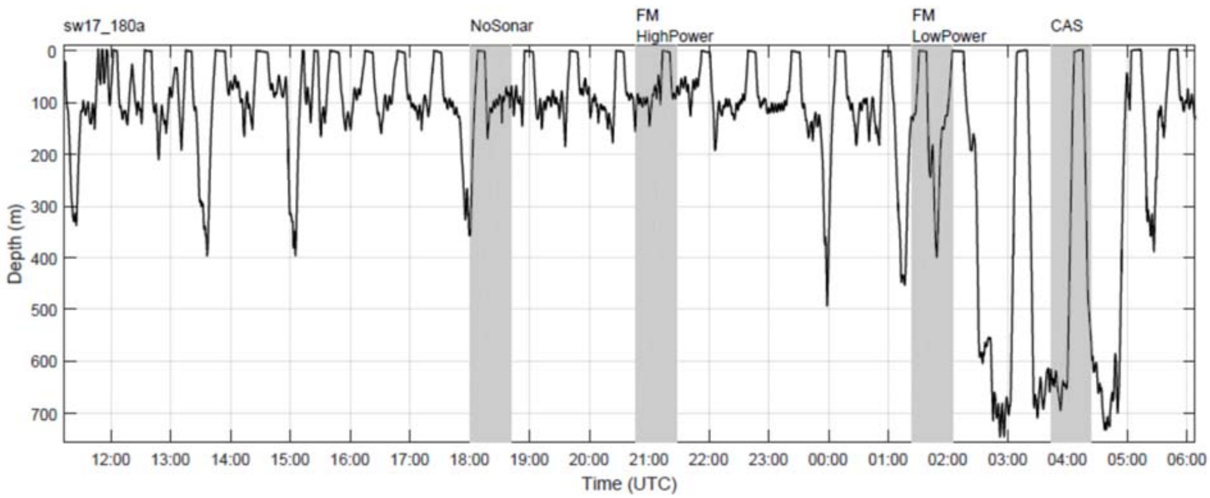
3.6 Sonar exposure experiments

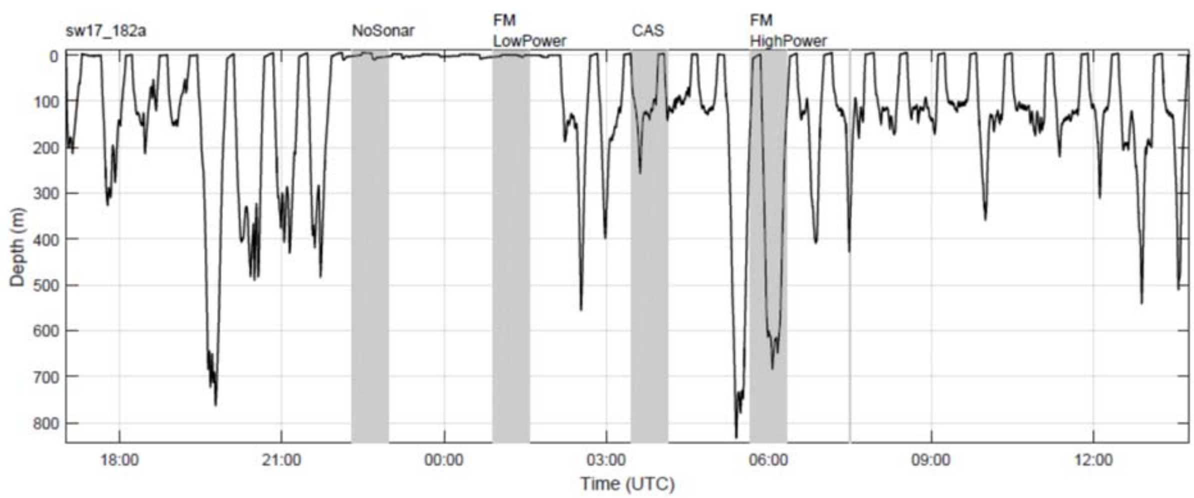
Baseline data were collected on 9 separate occasions on 11 individual whales, including 9 sperm whales and 2 pilot whales. Two dual tag deployments were successful (sw17_182ab and sw17_186ab). A second tag was attached but data could not be recovered from two deployments, sw17_179b (water intrusion) and sw17_188b (tag lost) (Table 3.7). Due to early tag detachment, both pilot whale baseline records were relatively short (3.2 and 3.6h). All sperm whale baseline records exceeded 4 hours in duration (range 4.3-9.2h) (Table 3.8). Sperm whale baseline data included both deep >1000m dives (e.g., sw17_186a, Figure 3.13) and relatively shallow 100-200m dives (e.g., sw17_180a, Figure 3.14). The tagged pilot whales conducted only 1-2 deep (>200m) dives (gm17_176b, gm17_190a, Figure 3.14).

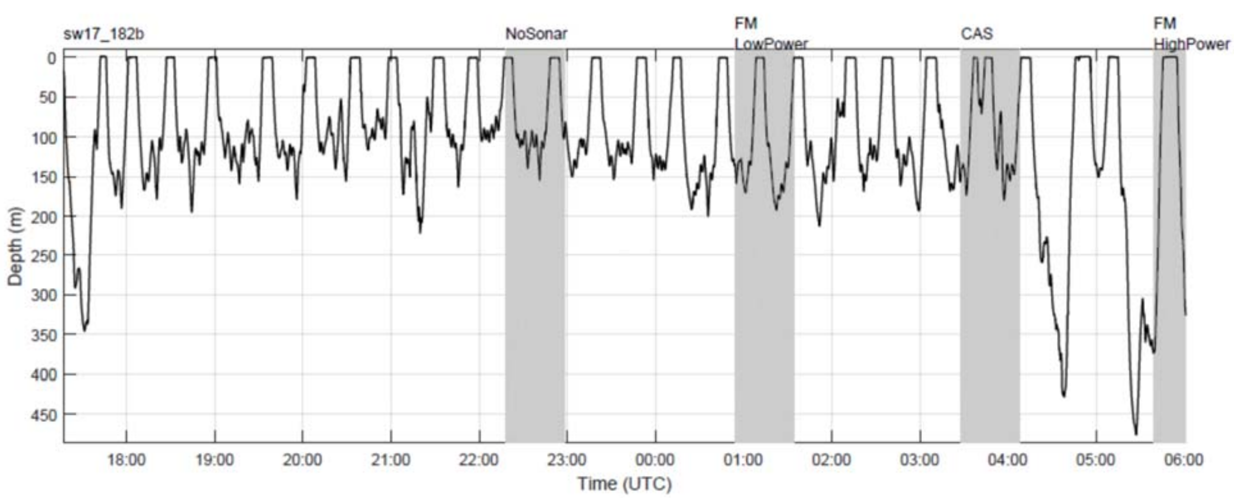
Seven Controlled Exposure Experiments (CEEs) were conducted on 9 individual whales, including 6 no-sonar exposures, 7 CAS exposures, 7 HPAS exposures, and 6 MPAS exposures (Table 3.2). All of the CEEs included at least 2 sonar exposures and using this criteria (as set out in the cruise plan), exposure blocks 2-4 were completed once and 5-6 were completed twice (Table 4.1). A full experimental cycle was conducted for blocks 2 and 4-6. Both premature detachment of tags and poor tracking conditions resulted in missed exposure sessions. In one instance, the tag detached from the whale during sonar exposure (sw17_182b). A second exposure of CAS was conducted at the end of the experimental cycle on the 8th of July. This exposure was conducted opportunistically in good tracking conditions in order to serve as a pilot study to test effect of repeat exposure to CAS. Combining both the 2016 and 2017 efforts, the first two sonar exposures of each block has now been completed twice (Table 4.1). Table 3.8 summarizes the deployments and experimental timeline.

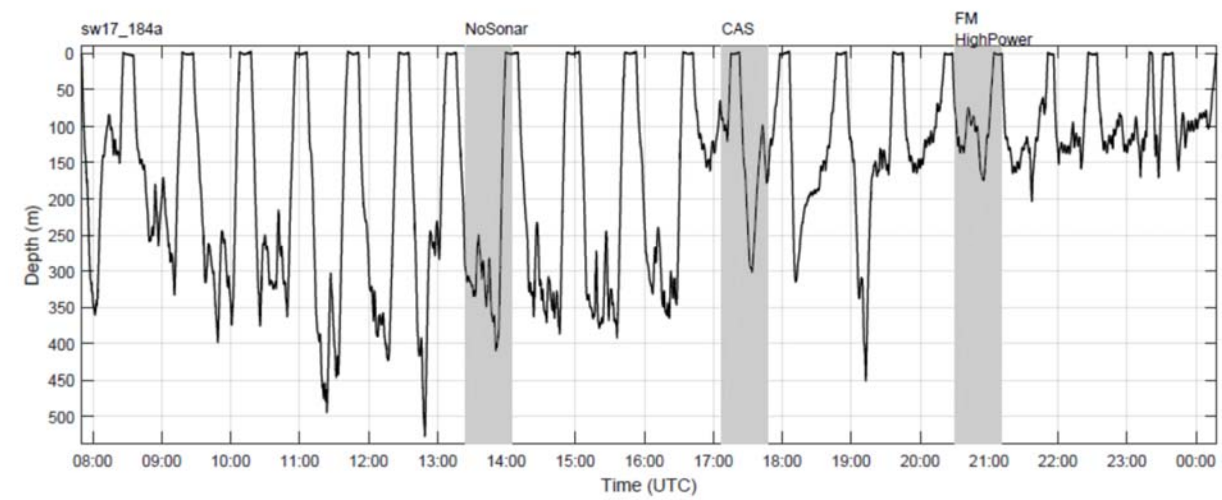
Figure 3.14 The following 9 figures show dive profiles from all sperm whales tagged.

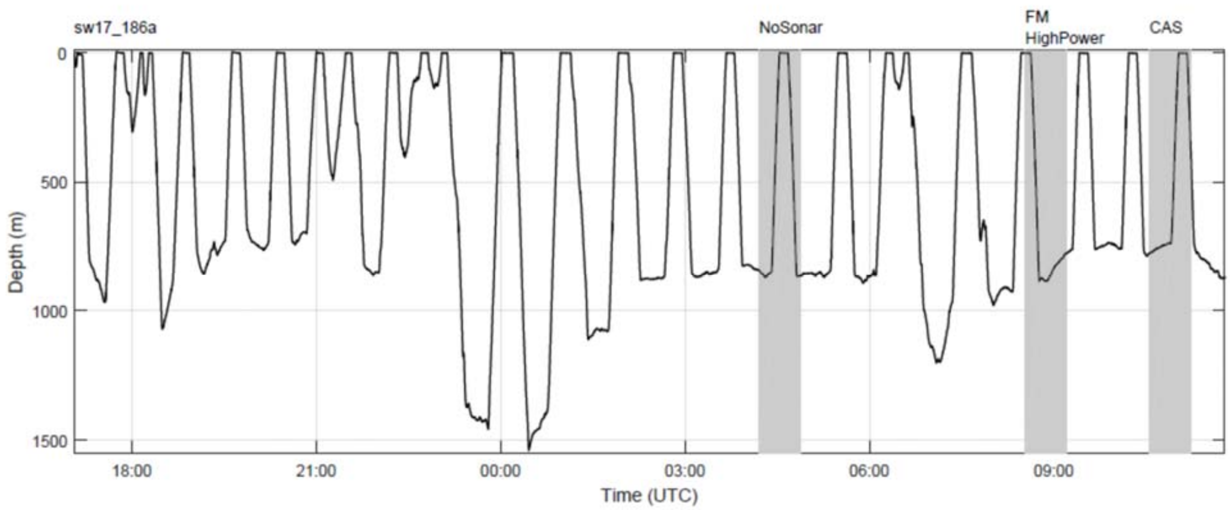


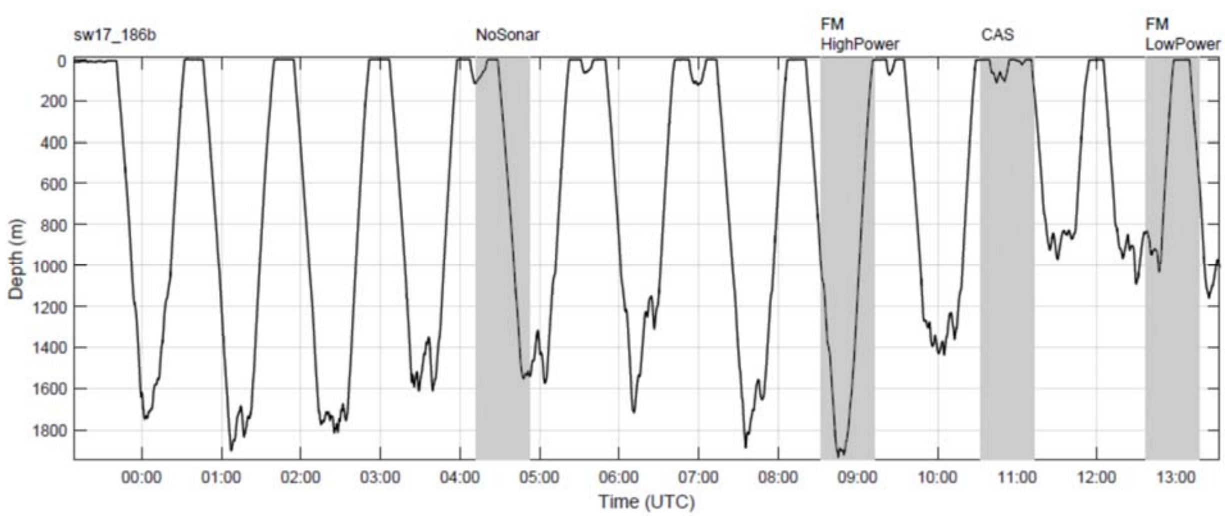

sw17_180a
NoSonar
FM
HighPower
FM
LowPower
CAS
Depth (m)
Time (UTC)

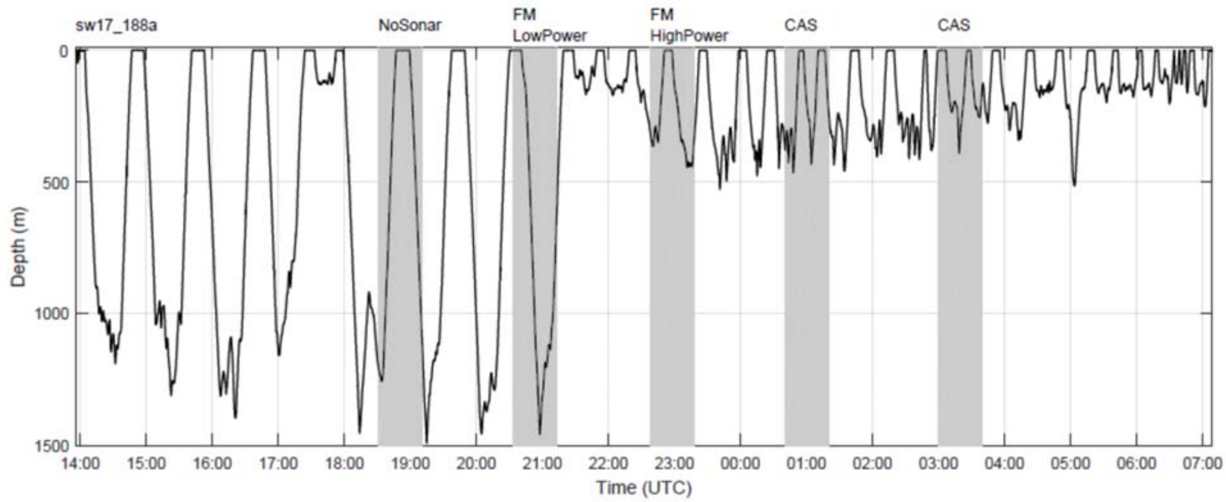

sw17_182a
NoSonar
FM
LowPower
CAS
FM
HighPower
Depth (m)
Time (UTC)

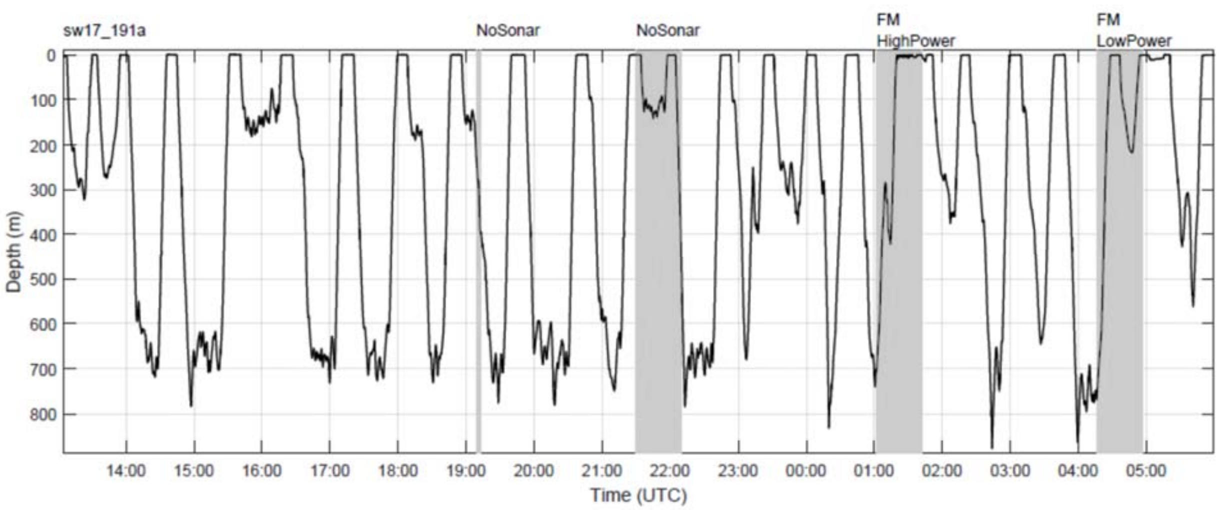

sw17_182b
NoSonar
FM
LowPower
CAS
FM
HighPower
Depth (m)
Time (UTC)

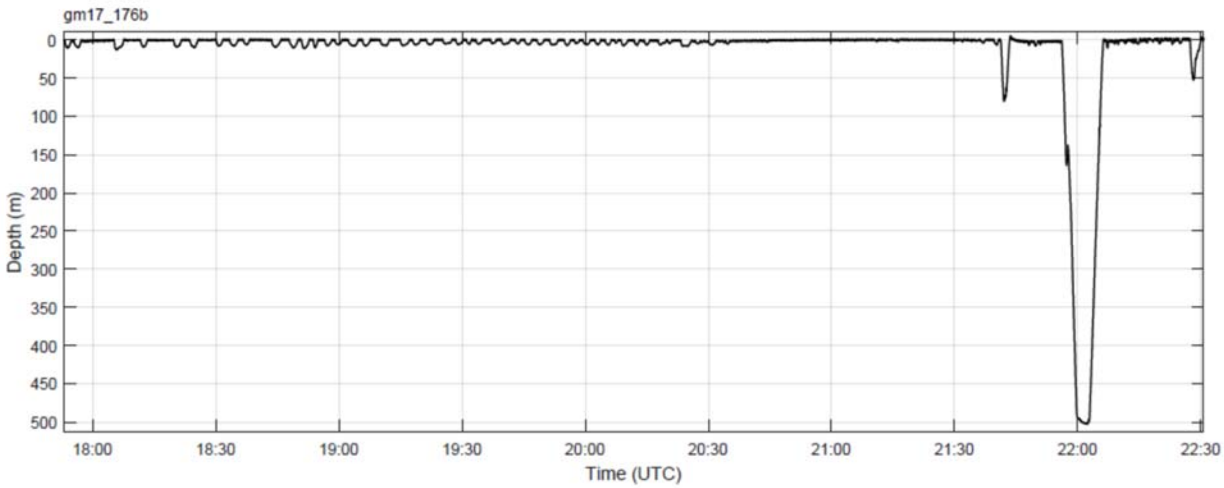

sw17_184a
NoSonar
CAS
FM
HighPower
Depth (m)
Time (UTC)


sw17_186a
NoSonar
FM
HighPower
CAS
Depth (m)
Time (UTC)


sw17_186b
NoSonar
FM
HighPower
CAS
FM
LowPower
Depth (m)
Time (UTC)


sw17_188a
NoSonar
FM LowPower
FM HighPower
CAS
CAS
Depth (m)
0
500
1000
1500
14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 00:00 01:00 02:00 03:00 04:00 05:00 06:00 07:00
Time (UTC)


sw17_191a
NoSonar
NoSonar
FM HighPower
FM LowPower
Depth (m)
0
100
200
300
400
500
600
700
800
14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 00:00 01:00 02:00 03:00 04:00 05:00
Time (UTC)



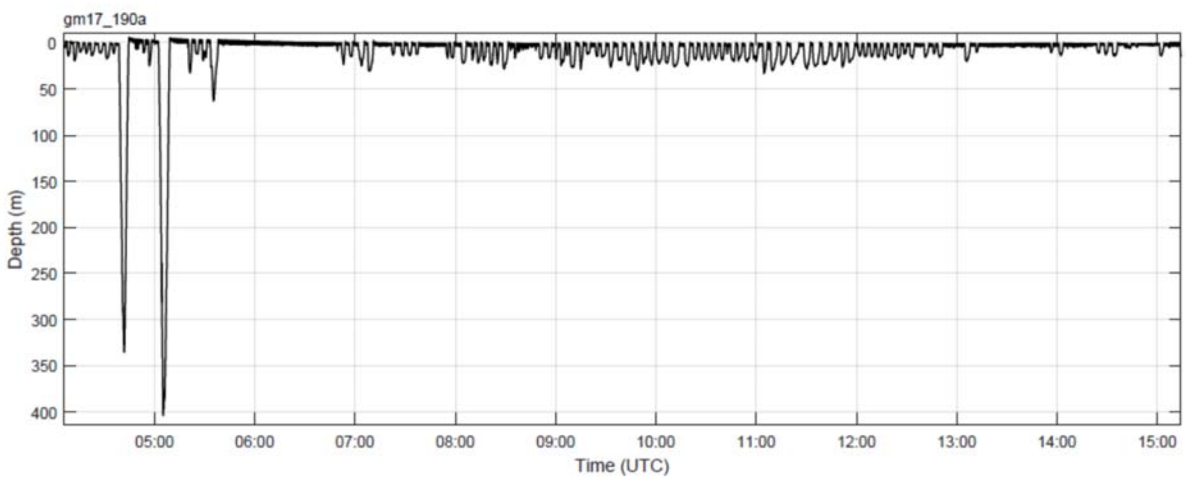


Figure 3.15. Dive profiles of the two pilot whales tagged.

Table 3.8. Deployments and experimental timeline from the Logger master database.

Deployment (focal first)	Effort	Start UTC	End UTC
gm17_176a	Searching	24.06.2017 14:52:58	25.06.2017 13:23:00
gm17_176a	Tagging	25.06.2017 13:23:00	25.06.2017 15:25:00
gm17_176b	Searching	25.06.2017 15:25:29	25.06.2017 16:48:02
gm17_176b	Tagging	25.06.2017 16:48:02	25.06.2017 18:55:00
gm17_176b	Baseline	25.06.2017 18:55:00	25.06.2017 22:30:00
sw17_179a & sw17_179b	Searching	27.06.2017 21:54:50	28.06.2017 01:05:49
sw17_179a	Tagging1	28.06.2017 00:30:00	28.06.2017 02:58:34
sw17_179b	Tagging2	28.06.2017 02:58:34	28.06.2017 04:22:00
sw17_179a	Baseline	28.06.2017 04:22:00	28.06.2017 13:23:00
sw17_179b	Baseline	28.06.2017 04:22:00	28.06.2017 13:23:00

Deployment (focal first)	Effort	Start UTC	End UTC
sw17_179a & sw17_179b	MPAS	28.06.2017 13:23:00	28.06.2017 14:03:01
sw17_179a & sw17_179b	HPAS	28.06.2017 15:40:00	28.06.2017 16:20:01
sw17_179a & sw17_179b	CAS	28.06.2017 17:40:00	28.06.2017 18:20:19
sw17_179a & sw17_179b	Logger breakdown	28.06.2017 18:03:48	29.06.2017 02:00:56
sw17_180a	Searching	29.06.2017 02:50:51	29.06.2017 09:44:45
sw17_180a	Tagging	29.06.2017 09:44:45	29.06.2017 13:37:21
sw17_180a	Baseline	29.06.2017 13:37:21	29.06.2017 18:01:00
sw17_180a	NS	29.06.2017 18:01:00	29.06.2017 18:41:01
sw17_180a	HPAS	29.06.2017 20:47:00	29.06.2017 21:27:01
sw17_180a	MPAS	30.06.2017 01:24:00	30.06.2017 02:04:01
sw17_180a	CAS	30.06.2017 03:43:00	30.06.2017 04:23:19
sw17_180a	Biopsy	30.06.2017 04:57:40	30.06.2017 06:06:03
sw17_182b & sw17_182a	Searching	01.07.2017 13:59:51	01.07.2017 16:10:00
sw17_182a	Tagging1	01.07.2017 16:10:00	01.07.2017 17:00:35
sw17_182b	Tagging2	01.07.2017 17:00:35	01.07.2017 17:36:00
sw17_182a	Baseline	01.07.2017 17:36:00	01.07.2017 22:18:00
sw17_182b	Baseline	01.07.2017 17:36:00	01.07.2017 22:18:00
sw17_182b & sw17_182a	NS	01.07.2017 22:18:00	01.07.2017 22:58:01
sw17_182b & sw17_182a	MPAS	02.07.2017 00:54:00	02.07.2017 01:34:01
sw17_182b & sw17_182a	CAS	02.07.2017 03:28:00	02.07.2017 04:08:19
sw17_182b & sw17_182a	HPAS	02.07.2017 05:39:00	02.07.2017 06:19:01
sw17_183a	Searching	02.07.2017 14:26:04	02.07.2017 15:32:52
sw17_183a	Tagging	02.07.2017 15:32:52	02.07.2017 16:23:24
oo17_184a	Searching	02.07.2017 23:57:09	03.07.2017 00:23:52
oo17_184a	Tagging	03.07.2017 00:24:00	03.07.2017 03:41:00
sw17_184a	Searching	03.07.2017 03:40:22	03.07.2017 05:07:06
sw17_184a	Tagging	03.07.2017 05:07:06	
sw17_184a	Baseline	03.07.2017 08:43:44	03.07.2017 13:24:00
sw17_184a	NS	03.07.2017 13:24:00	03.07.2017 14:04:01
sw17_184a	CAS	03.07.2017 17:07:00	03.07.2017 17:47:19
sw17_184a	HPAS	03.07.2017 20:30:00	03.07.2017 21:10:01
sw17_186a	Searching	05.07.2017 13:05:23	05.07.2017 16:18:10
sw17_186a	Tagging	05.07.2017 16:18:10	05.07.2017 19:00:00
sw17_186b	Searching	05.07.2017 17:03:51	05.07.2017 20:00:00
sw17_186a	Baseline	05.07.2017 19:00:00	06.07.2017 04:12:00
sw17_186b	Baseline	05.07.2017 20:00:00	06.07.2017 04:12:00
sw17_186b	Tagging	05.07.2017 20:00:00	05.07.2017 23:40:00
sw17_186b & sw17_186a	NS	06.07.2017 04:12:00	06.07.2017 04:52:01
sw17_186b & sw17_186a	HPAS	06.07.2017 08:32:00	06.07.2017 09:12:01
sw17_186b & sw17_186a	CAS	06.07.2017 10:33:00	06.07.2017 11:13:19
sw17_186b & sw17_186a	MPAS	06.07.2017 12:37:00	06.07.2017 13:17:01
sw17_188a	Searching	07.07.2017 10:25:19	07.07.2017 12:44:02
sw17_188a	Tagging1	07.07.2017 12:45:00	07.07.2017 13:56:00

Deployment (focal first)	Effort	Start UTC	End UTC
sw17_188b	Tagging2	07.07.2017 13:56:00	07.07.2017 16:25:00
sw17_188a	Baseline	07.07.2017 14:15:00	07.07.2017 18:31:00
sw17_188b	Baseline	07.07.2017 16:25:00	07.07.2017 18:31:00
sw17_188a	NS	07.07.2017 18:31:00	07.07.2017 19:11:01
sw17_188a	MPAS	07.07.2017 20:33:00	07.07.2017 21:13:01
sw17_188a	HPAS	07.07.2017 22:38:00	07.07.2017 23:18:01
sw17_188a	CAS	08.07.2017 00:40:00	08.07.2017 01:20:19
sw17_188a	CAS2	08.07.2017 02:59:00	08.07.2017 03:39:19
sw17_188a	Biopsy	08.07.2017 06:02:46	08.07.2017 06:02:46
gm17_190a	Searching	09.07.2017 00:26:33	09.07.2017 03:49:42
gm17_190a	Tagging	09.07.2017 03:55:00	09.07.2017 15:30:00
gm17_190a	Baseline	09.07.2017 12:00:00	09.07.2017 15:09:21
sw17_191a	Searching	10.07.2017 09:11:04	10.07.2017 12:48:32
sw17_191a	Tagging	10.07.2017 12:46:00	10.07.2017 14:15:00
sw17_191a	Baseline	10.07.2017 14:05:00	10.07.2017 21:30:00
sw17_191a	NS	10.07.2017 21:30:00	10.07.2017 22:10:01
sw17_191a	HPAS	11.07.2017 01:02:00	11.07.2017 01:42:01
sw17_191a	MPAS	11.07.2017 04:16:00	11.07.2017 04:56:01

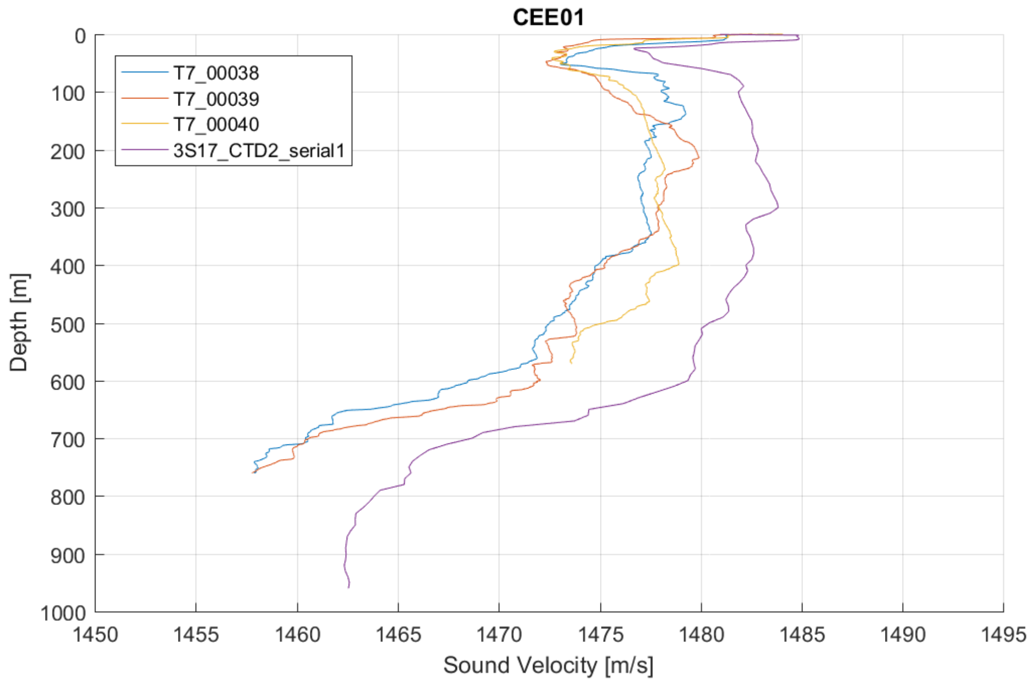
3.7 Environmental data (XBT & CTD)

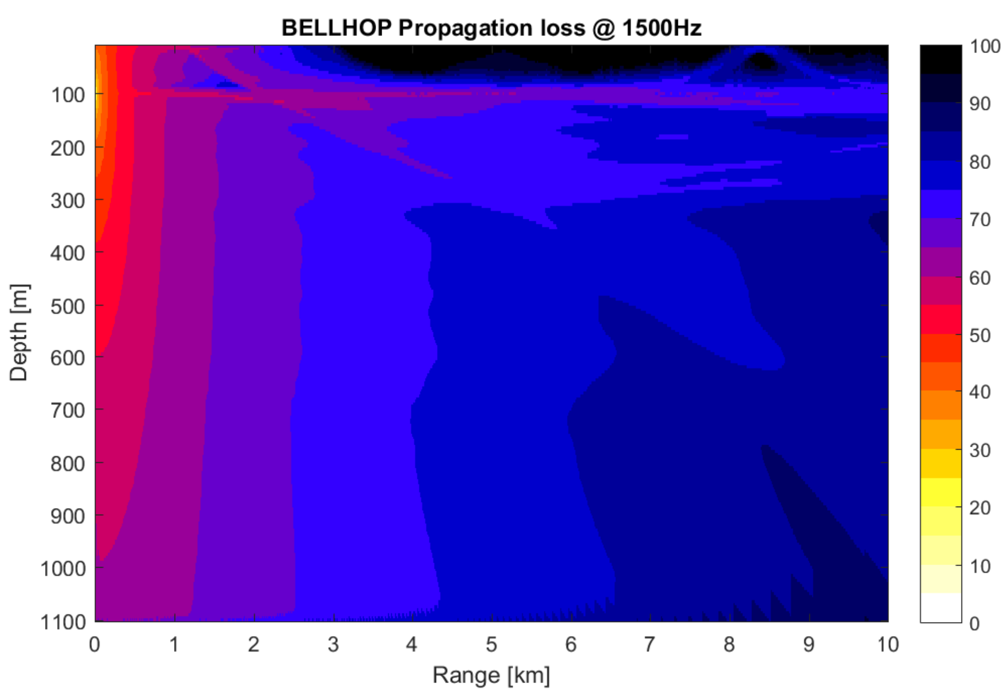
Measurements of sound propagation conditions were made in connection with the sonar exposure experiment. The DTAG had two hydrophones in it, which measure the sound levels on the animal during the sonar exposures. However, in order to understand the response of the animal, it is important in our analysis to have an idea of the overall sound picture in the environment. To achieve this, Sound Speed Profiles (SSP) are used as input to sound propagation models. Temperature profiles (XBT) were collected during each exposure run using Sippican 77 XBTs and after each exposure experiment also a more accurate Conductivity Temperature Depth (CTD) measurement was conducted using SAIV STD/CTD SD204 (Table 3.9). Figure 3.15 show the measured SSP for each exposure run and the modelled propagation loss based on the measured CTD SSP using the Bellhop software.

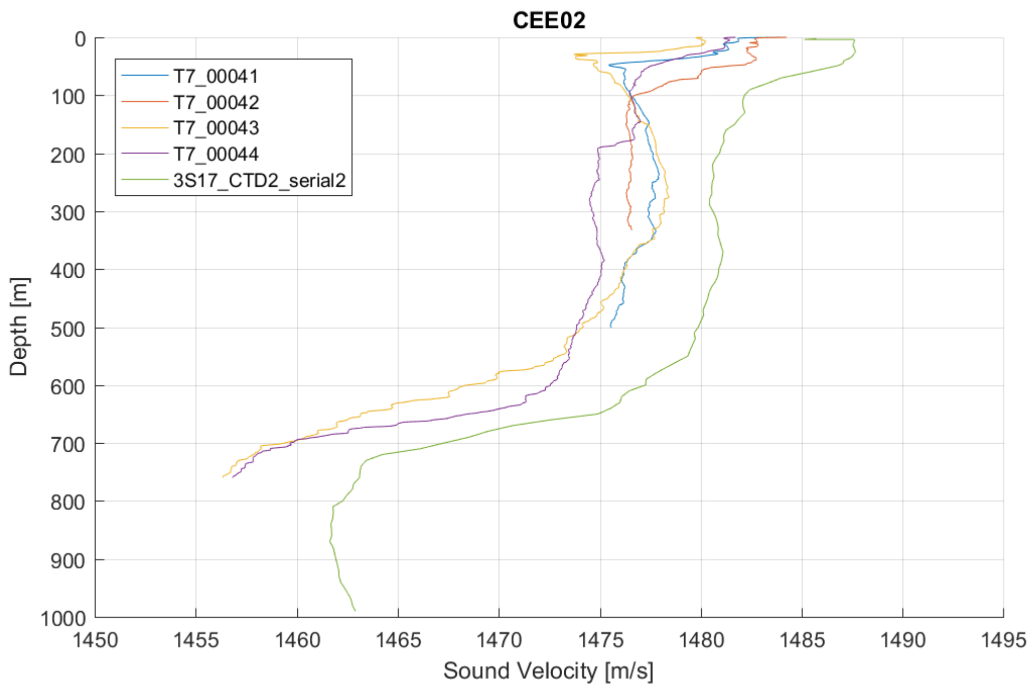
Table 3.9 Overview of XBT's & CTD's during 3S-CAS 2017.

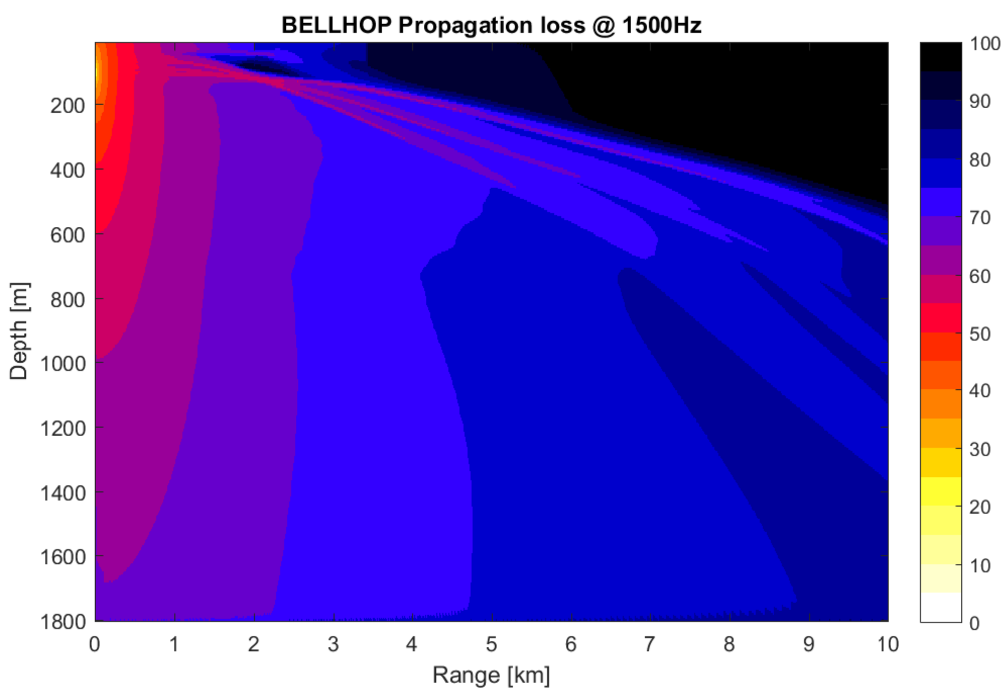
Exposure Experiment	XBT Name	Date & Time (UTC)	Max Depth [m]	Latitude	Longitude
CEE01	T7_00038.EDF	28-06-2017 13:49:34	760	69 49.15890N	16 19.47900E
	T7_00039.EDF	28-06-2017 16:01:26	760	69 48.71200N	16 20.41850E
	T7_00040.EDF	28-06-2017 18:01:04	570	69 50.84180N	16 31.14310E
	CTD2_serial1	28-06-2017 01:15:00	1000	69 52.17400N	16 30.30000E
CEE02	T7_00041.EDF	29-06-2017 18:21:14	500	70 14.20557N	16 46.65076E
	T7_00042.EDF	29-06-2017 21:06:51	330	70 10.86670N	16 43.01001E
	T7_00043.EDF	30-06-2017 01:45:58	760	70 03.33350N	16 35.64661E
	T7_00044.EDF	30-06-2017 03:55:04	760	69 59.30273N	16 30.60352E
	CTD2_serial2	30-06-2017 08:30:00	1000	70 01.69000N	16 30.72000E
CEE03	T7_00045.EDF	01-07-2017 22:42:06	480	69 29.96600N	15 40.55220E
	T7_00046.EDF	02-07-2017 01:14:08	600	69 50.43604N	16 31.34729E
	T7_00047.EDF	02-07-2017 04:10:38	366	69 23.57959N	15 20.95862E
	T7_00048.EDF	02-07-2017 06:02:02	622	69 25.86321N	15 04.12210E
	CTD2_serial3	02-07-2017 09:15:00	550	69 27.10000N	15 30.87000E
CEE04	T7_00050.EDF	03-07-2017 13:46:29	760	70 24.00830N	16 24.52612E
	T7_00051.EDF	03-07-2017 17:29:04	760	70 31.87402N	16 38.87854E
	T7_00052.EDF	03-07-2017 20:52:58	760	70 42.14160N	16 36.96606E
	CTD2_serial4	04-07-2017 02:45:00	1200	70 41.68000N	16 39.50000E
CEE05	T7_00053.EDF	06-07-2017 04:34:41	760	69 16.99219N	13 59.42444E
	T7_00054.EDF	06-07-2017 08:53:32	760	69 12.03076N	13 53.74292E
	T7_00055.EDF	06-07-2017 11:00:25	760	69 17.82422N	13 48.40100E
	T7_00056.EDF	06-07-2017 12:59:02	760	69 17.41406N	13 42.26440E
	CTD2_serial5	06-07-2017 16:30:00	1500	69 17.91000N	13 49.26000E
CEE06	T7_00057.EDF	07-07-2017 19:07:00	760	69 52.97170N	16 19.26580E
	T7_00058.EDF	07-07-2017 20:58:35	760	69 56.26570N	16 23.23430E
	T7_00059.EDF	07-07-2017 23:08:40	760	69 53.76410N	16 22.72290E
	T7_00060.EDF	08-07-2017 01:11:45	530	69 54.97030N	16 36.47080E
	T7_00061.EDF	08-07-2017 03:33:51	390	69 59.35400N	16 46.48035E
	CTD2_serial6	08-07-2017 11:50:00	1500	69 53.70000N	16 22.57000E
CEE07	T7_00062.EDF	11-07-2017 01:24:40	760	69 51.74414N	16 32.16455E
	T7_00063.EDF	11-07-2017 04:41:49	760	69 48.53809N	16 19.32068E
	CTD2_serial7	11-07-2017 08:00:00	800	69 52.72000N	16 32.47000E

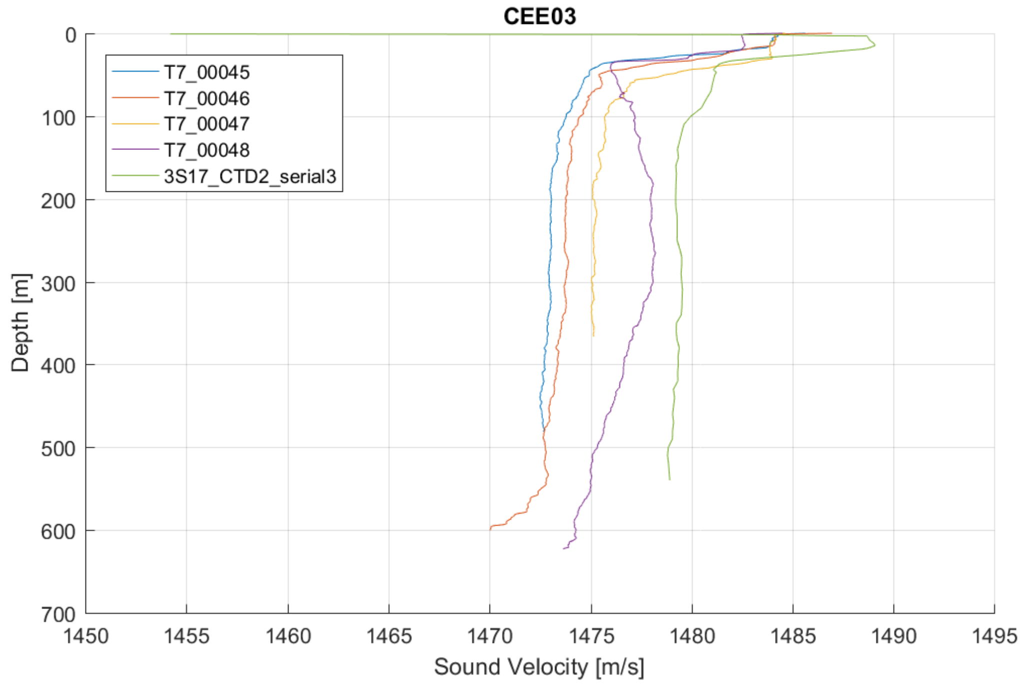
Figure 3.16. The following 7 figures show Sound Speed Profiles (SSP's) as measured by the XBT's and CTD for all exposure experiments (top panels), and propagation loss modelled by Bellhop using the measured CTD SSP (bottom panels).

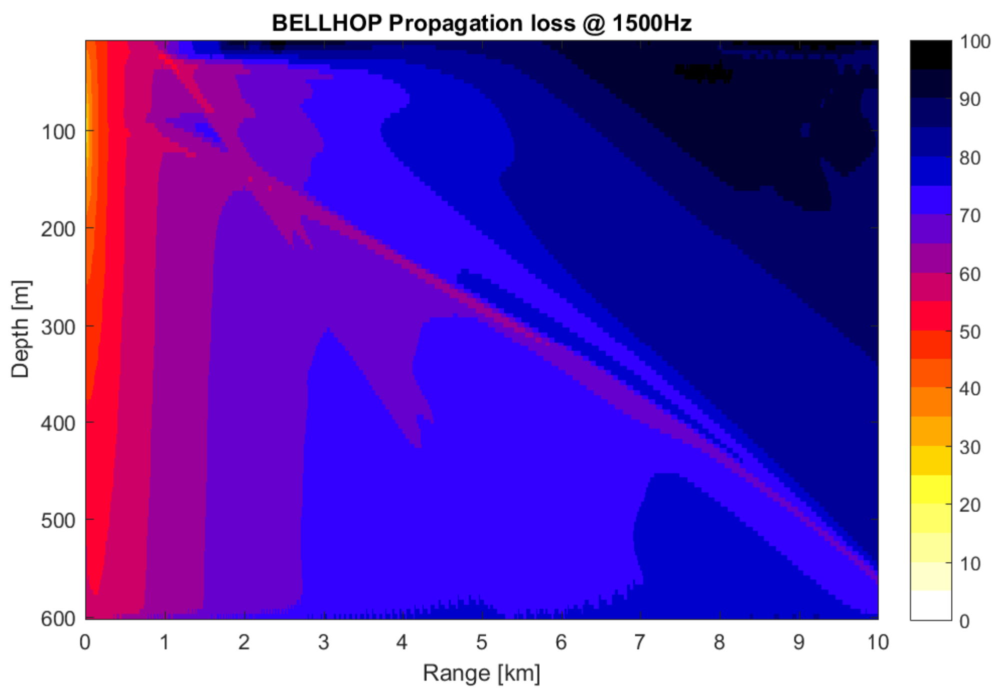


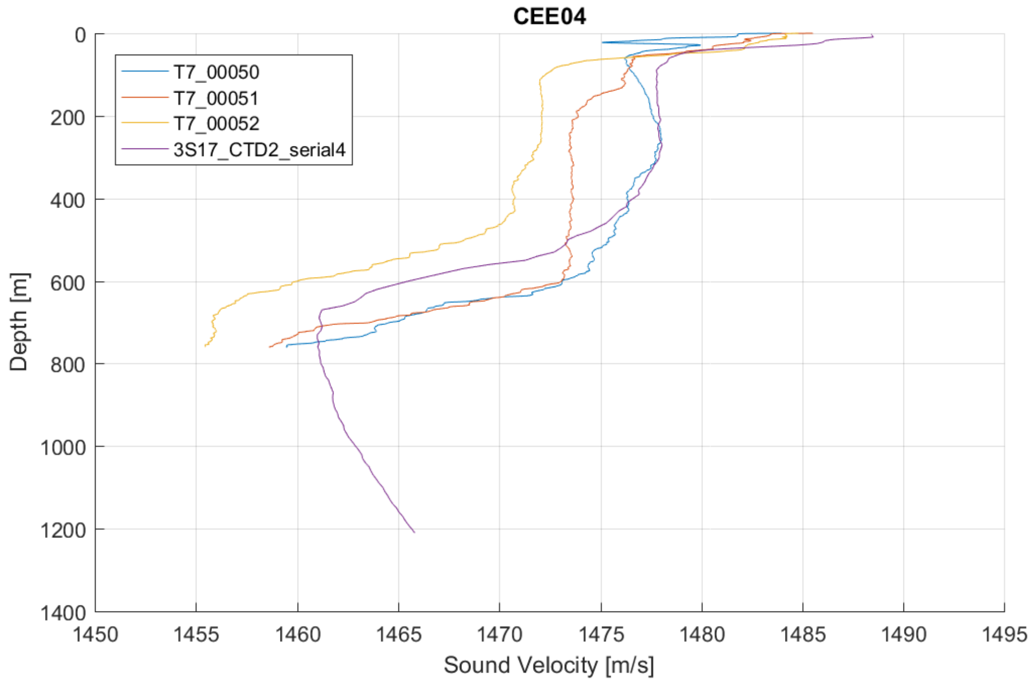


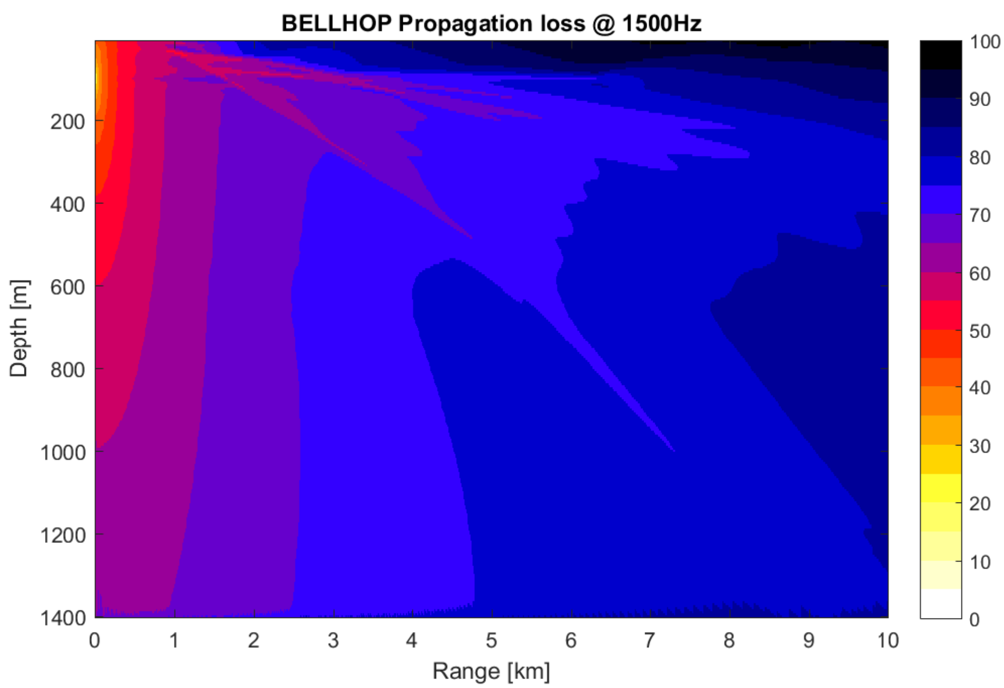

CEE02
T7_00041
T7_00042
T7_00043
T7_00044
3S17_CTD2_serial2
Depth [m]
Sound Velocity [m/s]

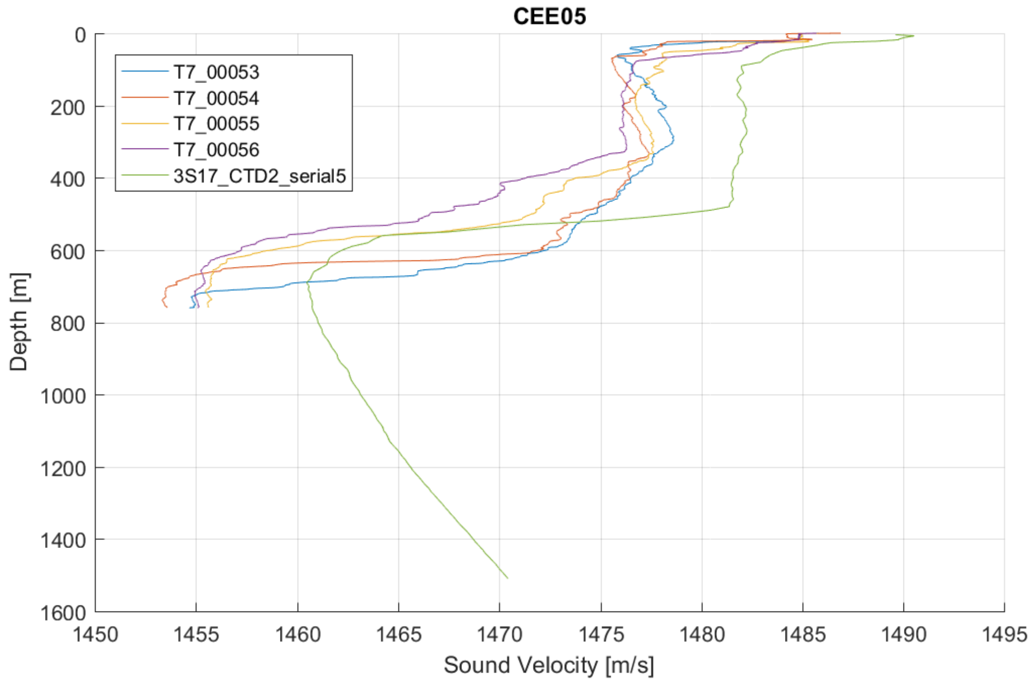

BELLHOP Propagation loss @ 1500Hz
Depth [m]
Range [km]

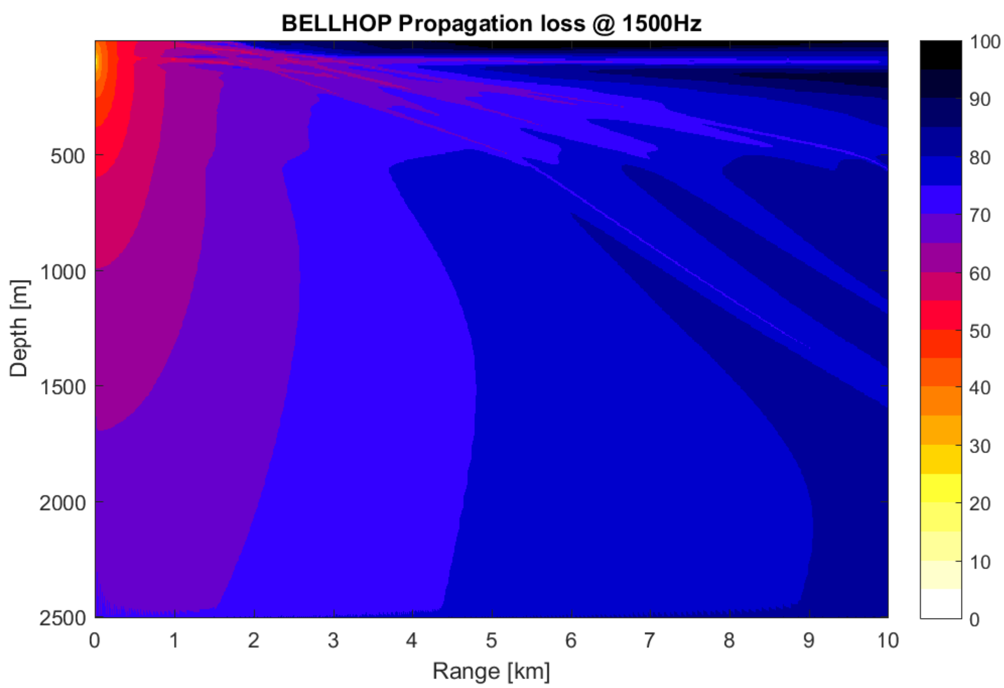

CEE03
T7_00045
T7_00046
T7_00047
T7_00048
3S17_CTD2_serial3
Depth [m]
Sound Velocity [m/s]
0
100
200
300
400
500
600
700
1450
1455
1460
1465
1470
1475
1480
1485
1490
1495

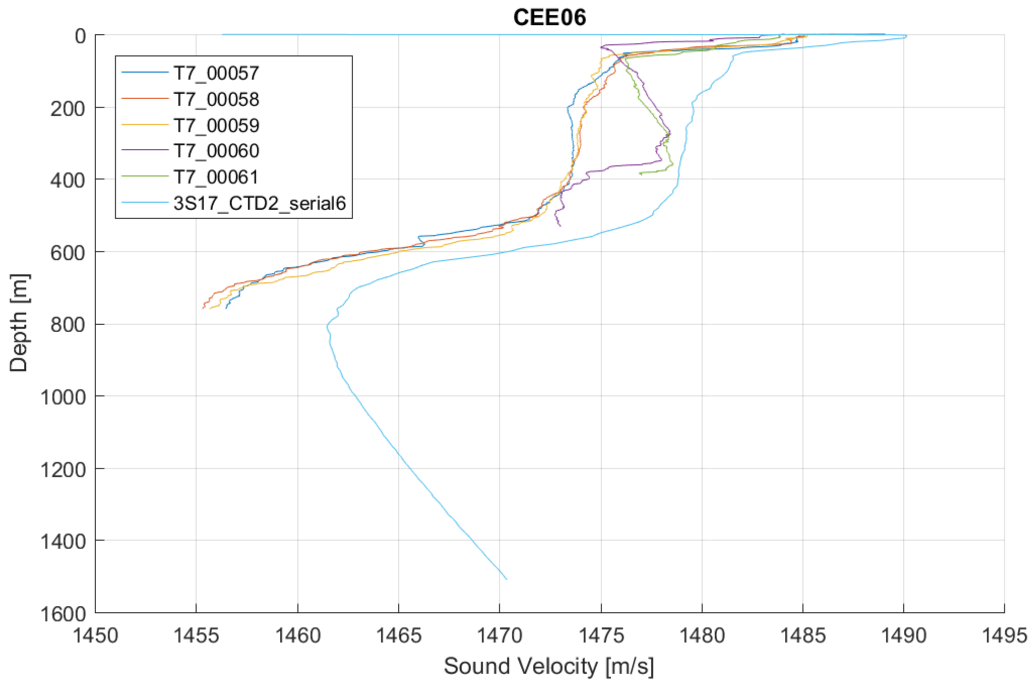

BELLHOP Propagation loss @ 1500Hz
Depth [m]
Range [km]
100
200
300
400
500
600
0
1
2
3
4
5
6
7
8
9
10
100
90
80
70
60
50
40
30
20
10
0

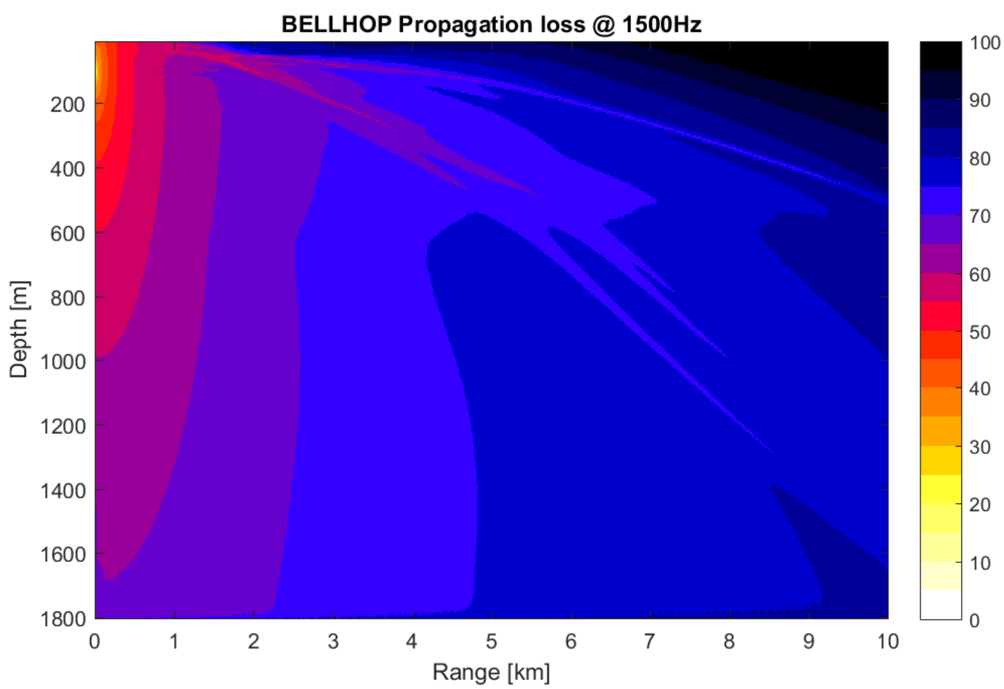

CEE04
T7_00050
T7_00051
T7_00052
3S17_CTD2_serial4
Depth [m]
Sound Velocity [m/s]
0
200
400
600
800
1000
1200
1400
1450
1455
1460
1465
1470
1475
1480
1485
1490
1495


BELLHOP Propagation loss @ 1500Hz
Depth [m]
Range [km]
200
400
600
800
1000
1200
1400
0
1
2
3
4
5
6
7
8
9
10
100
90
80
70
60
50
40
30
20
10
0


CEE05
T7_00053
T7_00054
T7_00055
T7_00056
3S17_CTD2_serial5
Depth [m]
0
200
400
600
800
1000
1200
1400
1600
1450
1455
1460
1465
1470
1475
1480
1485
1490
1495
Sound Velocity [m/s]


BELLHOP Propagation loss @ 1500Hz
Depth [m]
500
1000
1500
2000
2500
0
1
2
3
4
5
6
7
8
9
10
Range [km]
100
90
80
70
60
50
40
30
20
10
0


CEE06
T7_00057
T7_00058
T7_00059
T7_00060
T7_00061
3S17_CTD2_serial6
Depth [m]
Sound Velocity [m/s]
0
200
400
600
800
1000
1200
1400
1600
1450
1455
1460
1465
1470
1475
1480
1485
1490
1495


BELLHOP Propagation loss @ 1500Hz
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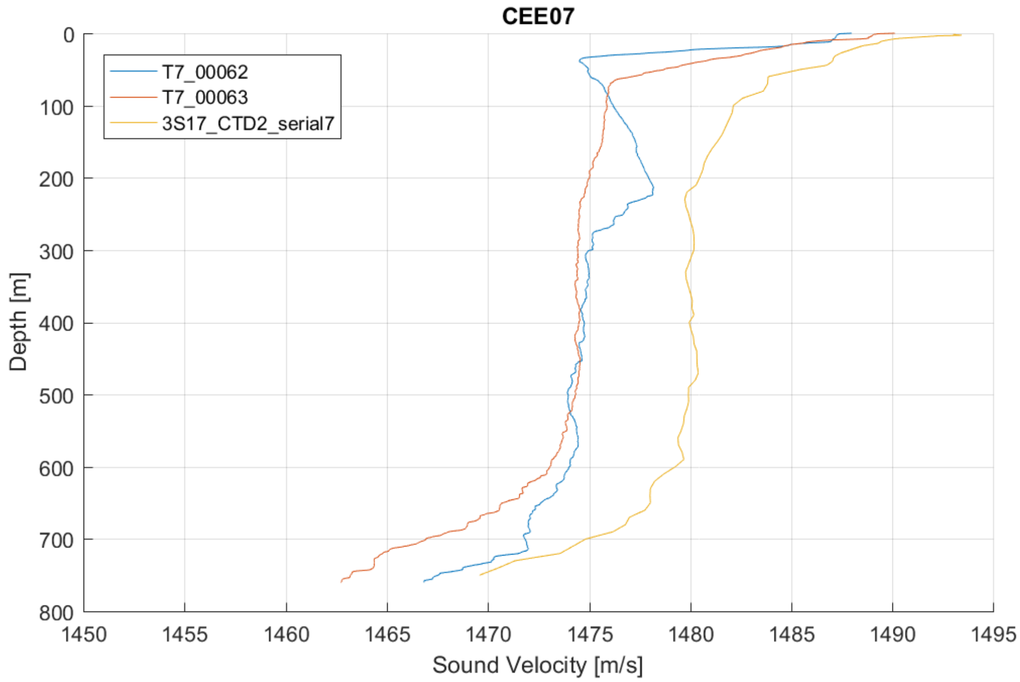
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T7_00063
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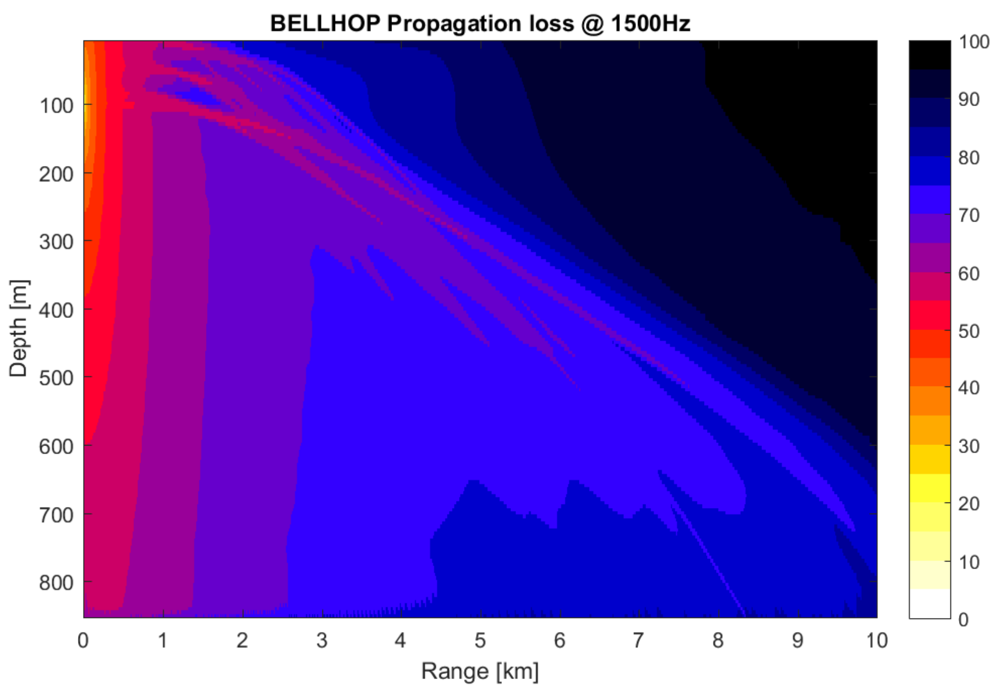
BELLHOP Propagation loss @ 1500Hz
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4 Discussion

4.1 Outcome of the trial

We consider this trial to be very successful. We tagged 13 animals, collected 56 hours of baseline data, and conducted 7 successful sonar exposure experiments. In 4 of these 7 experiments we deployed 2 tags of separate animals. In total we conducted 26 sonar or control runs. Combined with 2016 results (Lam et al. 2018), we have managed to complete two full cycles of experimental blocks on sperm whales (Table 4.1). Based on this dataset we expect to be able to address both exposure order effect, effect of CAS versus PAS and start addressing the effect of range on response threshold in sperm whales. The present dataset appears sufficient for upcoming analysis.

Table 4.1 Overview of the exposure sessions completed with primary target species sperm whales from 3S-2016 and 3S-2017 trials combined. We have deployed a total of 19 tags on different animals and collected baseline data for at least 4 h on all. We have completed a total of 12 exposure blocks, each with 2-3 sonar exposures runs with different signals in different orders. The dataset also includes 12 no-sonar control runs.

Block #	**Baseline**	**1st Signal**	**2nd Signal**	**3rd Signal**	**4th Signal**	**Trial**		**Comment**
						3S-2016	**3S-2017**	
1	√	NS[b]	CAS	MPAS	HPAS	**X**		
2	√	NS	MPAS	CAS	HPAS[b]	**X**		
	√	NS				**X**		Unfinished block 3
	√	NS	CAS			**X**		Unfinished block 3
	√					**X**		Baseline only, no expo
3	√	NS	CAS	HPAS	MPAS	**X**		
4	√	NS	HPAS	CAS	MPAS	**X**		
5[a]	√	NS[b]	MPAS	HPAS	CAS		**X X**	Two animals tagged
6[a]	√	NS	HPAS	MPAS	CAS		**X**	
1	√	NS	CAS	MPAS	HPAS	**X**		
2	√	NS	MPAS	CAS	HPAS		**X X**	Two animals tagged
3	√	NS	CAS	HPAS	MPAS[b]		**X**	
4	√	NS	HPAS	CAS	MPAS		**X X**	Two animals tagged
5	√	NS	MPAS	HPAS	CAS		**X X**	Two animals tagged
6	√	NS	HPAS	MPAS	CAS[b]		**X**	

[a] *Missing block from 3S-16 trial to complete full cycle with all order options.*
[b] *Exposure run part of block, but not completed. If two or more exposure runs were missing from a block it would not be approved and therefore repeated.*

On the shortfall sides, we did not manage to do any exposure experiments on pilot whales. This was a secondary objective, but still something we wanted to do.
We encountered many pilot whales and deployed two tags. However, due to early tag release or bad tag placement we were not able to do any experiment. The Mixed-DTAG with GPS and a SPOT satellite transmitter in addition to the regular DTAG

sensors was used a lot. In fact 9 of the 13 tag deployments were Mixed-DTAGs. We think this tag has great potential in improving both the quality and quantity of the data if it works as intended. During this trial we had problems with the GPS sensor on it and were not able to get many fixes of the animal. We don't understand the reason for this, given that it has been working much better with other species. One of the DTAG core units also stopped working, apparently due to water leakage, and near the end of the trial we lost a tag due to VHF failure. Thus there are some things to work on and improve. Given these technical problems with the tag, for the first time during 3S trials, the number of tags available became a limiting factor for how much data we managed to collect.

We spent more time getting tags on animals this year compared to last year. We had less experienced taggers this year, which could have been a factor, but we think the main reason is that many animals had a behavior where they evaded the tag boat, and we did not see that type of behavior last year. We did see a lot of killer whales and pilot whales around, and this might explain why the sperm whales were more responsive when being approached. For future trials we should consider to use the ARTS system more to increase tagging efficiency. The new experimental design where we deploy multiple tags seem to have great potential, but only if the Mixed-DTAG works as intended. This seems to be within reach but we may need another stepping stone to test it, before a full scale trial with an operational source is conducted.

In conclusion we are very happy with the outcome, but there is room for some improvements. The team on the 3S-2017 trial has been a very dedicated group of people with different types of expertise from 7 different countries, all working very hard together to conduct these experiments.

4.2 Recommendations from the group

On the last day of the trial we gathered with the entire science team for a debrief of the trial and to brainstorm on ways to improve safety, the quality of data collected and efficiency. We also discussed possible changes to our design and procedures if we get an operational source (frigate) at the next trial.

We compiled the following list of issues to consider in preparations of future trials. This list is just a list of issues brought forward in a brainstorming session, they were not discussed in detail, nor did we do any cost benefit assessment. Thus, no decisions are made yet by the management group of the 3S-project on any of these recommendations.

TAGS AND TAGGING
- Consider adding more tags, the number of tags available ended up being a limiting factor this year.
- The Mixed-DTAG is preferred over the standard DTAG3 because it gives higher quality data.
- Consider developing and bringing a rescue tag (with VHF tracking capability but no actual data logger) in case of bad tag placements.
- Consider if ARTS would improve tagging efficiency
- Consider purchasing an Argos directional receiver to recover Mixed-DTAGs, as a replacement or back up for the VHF transmitter.

- Consider improving the VHF beacon on the Mixed-DTAG.
- Consider an intermediate low cost trial next year to test Mixed-DTAG performance
- Tags are very high maintenance during operation – we need several tag technicians (this year was ok).
- Solve the problem with the magnetic sensors on the tags.
- Consider improving the height of the cantilever swivel (lower it more).
- Consider having two certified tag boat drivers

DATA ANALYSIS
- Specify what kind of data analysis we should do on moored buoy data.

SAFETY ISSUES
- Consider a wind screen in the mast and improvements on the safety hatch (sliding hatch).
- Purchase a new VHF radio in MOBHUS, including helmet/headset for better communication
- Better catch hook on the MOBHUS.

EQUIPMENT
- Remember to bring enough duct tape, this year we almost run out.
- Work on possibility to automatically transfer visual fixes from Logger to Socrates and the bridge.
- Keep a camera on the observation deck.
- Consider developing an App to check on operational status from cabin.
- Improve HDF (Human Direction Finder) tracking by bringing more receivers to the observation deck (maybe with a switch between antennas/directions).
- Better headphones (noise reduction) in the mast (HDF).
- We need more R1000 VHF receivers.
- Improve angle board on big eyes.
- Consider replacing Logger with PAM-guard.

TRIAL MANAGEMENT
- Clearer communication on priority for tag systems and target species when tag teams go out.
- Better communication on overall status of operation
- Clearer criteria for when we stop re-approaching whales during tagging
- More consideration of the reasons and techniques of collecting biopsy

IDEAS TO CONSIDER FOR FUTURE TRIALS WITH AN OPERATIONAS SOURCE (FRIGATE)
- Design dependent on Frigate availability
- Consider using SPLASH LIMPET tags to improve data sampling (do power analysis on behavioral log to check if we can pick up responses first).
- Put out many Mixed-DTAGs for >24hrs.
- Use two tag boats and two drivers to be more efficient in tagging
- Consider using the ARTS to increase tagging efficiency
- Consider one focal animal or no-focal design (exposing a general area with a number of tagged whales).
- Consider the added value of no sonar runs.
- Consider if we need Sverdrup and Socrates at all.
- Consider adding other species (depends on frigate and time availability)

5 References

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A Data inventory

The following data files were uploaded to the central server in the end of the 3S-2017 trial

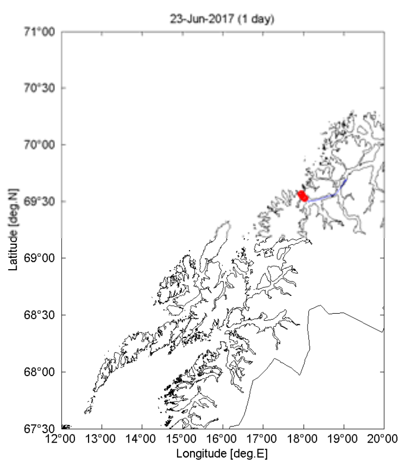
Folder	Subfolders/files	Summary of content
Documents	**Bridge Logs**	Daily text files created by CO/XO with the GPS event logger on the bridge, screenshots, overall activity record, weather and some specific event summaries
	Briefs	Power points of cruise briefing and debriefings
	Daily Orders	Daily work plans that we put up daily to inform the team about weather, work area, etc
	TNO logs	TNO events log book, TNO summary information about acoustic recordings and number of whales clicking
		Cruise plan and Andøyposten newspaper article
acousticDataAndResults	**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
	Screendumps	Daily screendumps of logger screen
	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
SocratesLogs		Log files of SOCRATES II source. Times of transmissions in the transmission.log file in each subfolder
CTD/XBT	**XBT**	XBT profiles including sound speed profiles and raw XBT data for use in MK21 program
	CTD	All CTD casts, CTD log and SD200W program to read data files.
SPOT VI	**ARGOS**	All ARGOS datafiles from Spot logger, download utility and use manual
Fastloc GPS	**Fastloc GPS**	Data files from Fastlock GPS deployments, user guide

B Daily sails tracks

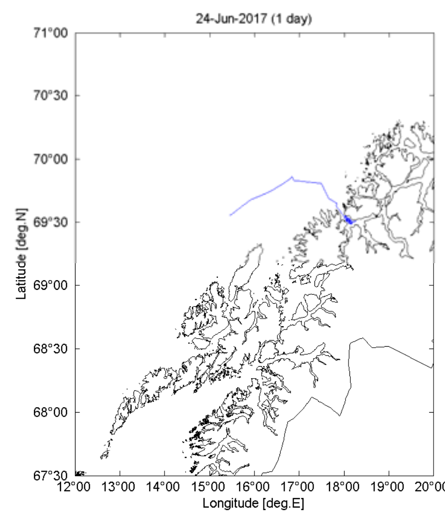
Daily sail tracks of H.U. Sverdrup II during the 3S-2017 trial (in blue). Red track means SOCRATES source was used.

June 21st: Rendezvous in Tromsø, joint brief at the hotel.

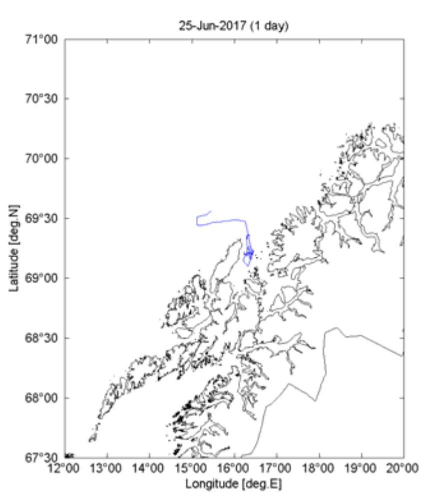
June 22nd: Embarkment and mobilization in Tromsø.



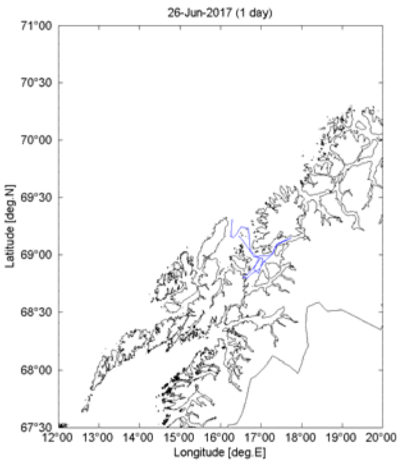
June 23rd: Technical tests in Malangen. The source passed the test, but some other problems were identified and needed to be solved before leaving protected water.



June 24th: Acoustic survey trough the operation area in bad weather. Detections of sperm whales and pilot whales, but condition did not allow any tagging attempts.

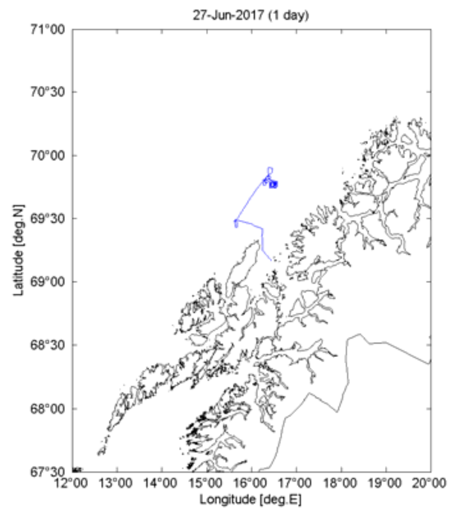


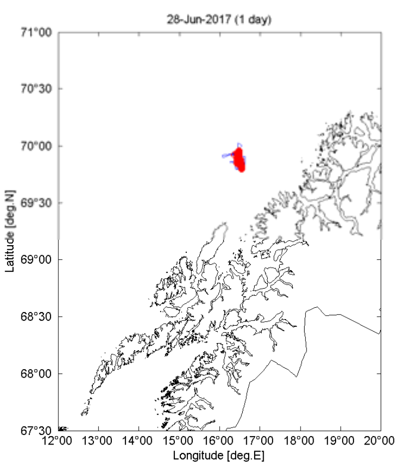
June 25th: Continued acoustic survey through operation area. Detected pilot whales in Andfjord. Conditions were rough, but we managed to tag a pilot whale. However, the tag detached prematurely and before any exposures were conducted.



June 26th: Too rough condition for tagging even in Andfjord. Searched for pilot whales in more protected waters but did not find any. Short port call to Harstad to fix the radio on MOBHUS.

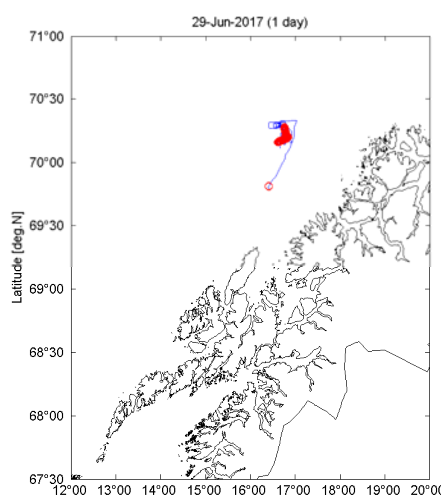
June 27th: Deployed the two moored buoys. Started tagging sperm whales as soon as the sea calmed down enough.
Two close attempts (one maybe two close), but no tags deployed.

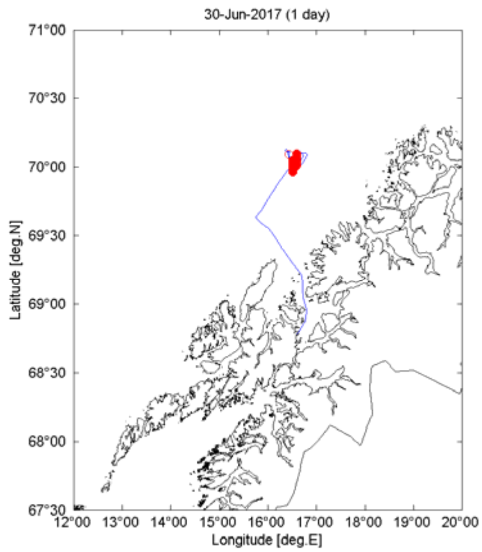




June 28th: Two tags deployed on two sperm whales. Conducted CEE I.

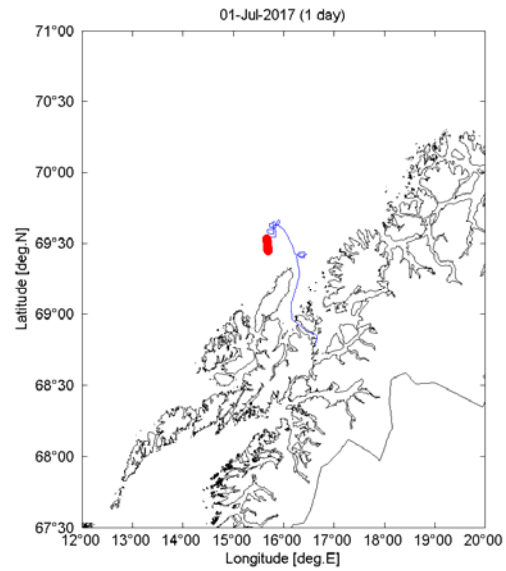
June 29th: Transited north out of the exposed area. One tagged deployed on a sperm whale. Conducted CEE II.

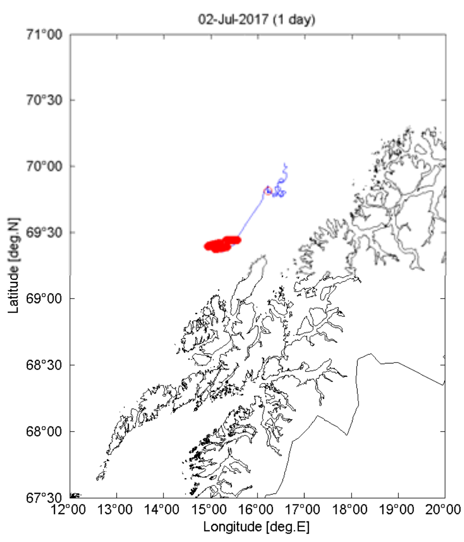




June 30th: Finished CEE II. Conditions aggravated. Transited to Harstad for a crew change.

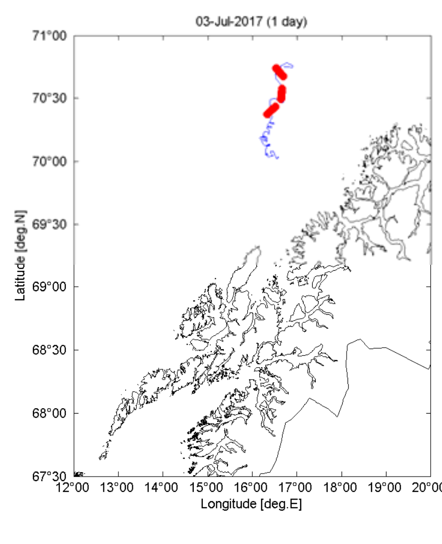
July 1st: Transited through Andfjord, detected sperm whales as soon as we approached the shelf edge. Tagged two sperm whales off Malangen. Started CEE III. Focal animal swam south *towards Bleik.*

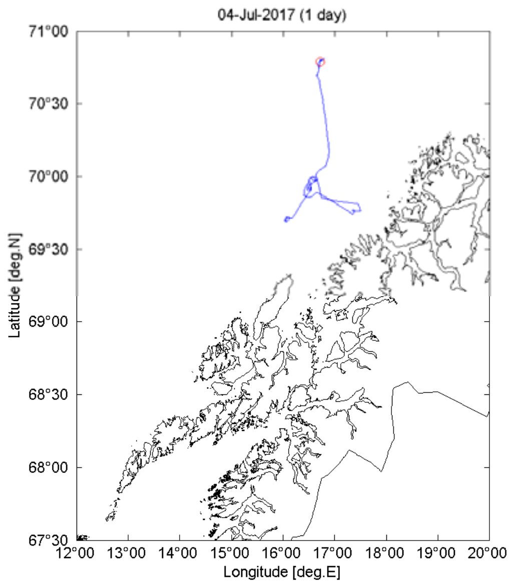




July 2nd: Completed CEE III and recovered tags. Transited northwards out of the exposed area. We were tracking a high number of sperm whales but decided to wait for the mixed tag to be read before we initiated any tagging effort.

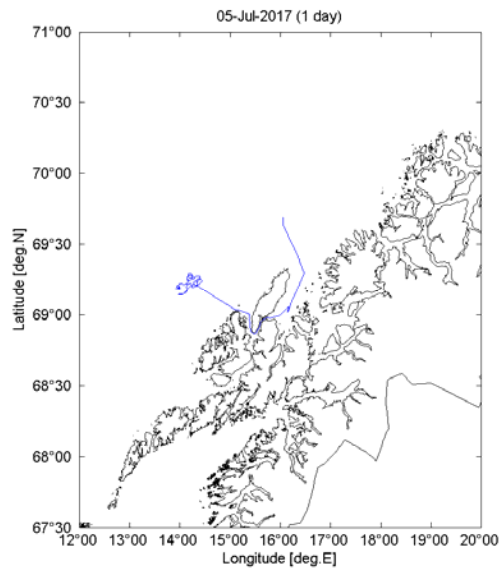
July 3rd: Many sperm whales and killer whales in the area. Tagged a killer whale, but tag came off after just a few minutes. Tagged a *sperm whales and conducted CEE IV.*



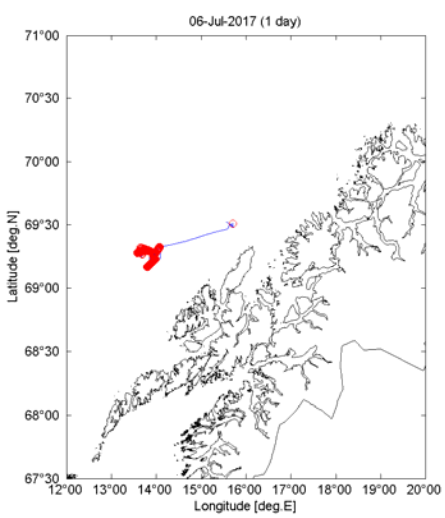


July 4th: Transited south out of the exposed area. Very marginal conditions for tagging, but we tried.

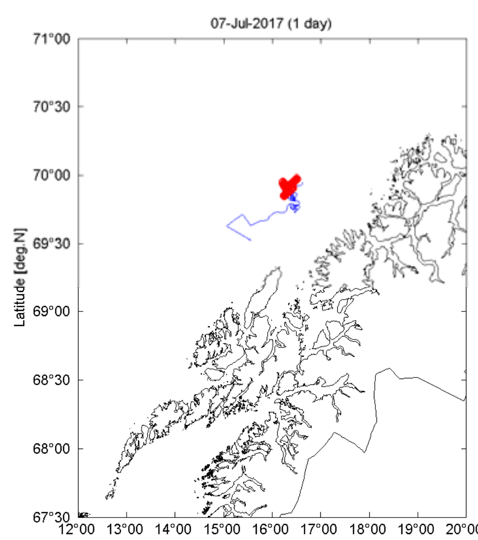
July 5th: Transited through Andfjord and Risøyrenna and continued to work with sperm whales as soon as we reached deep water again off the Langnesegga. Tagged two sperm whales.

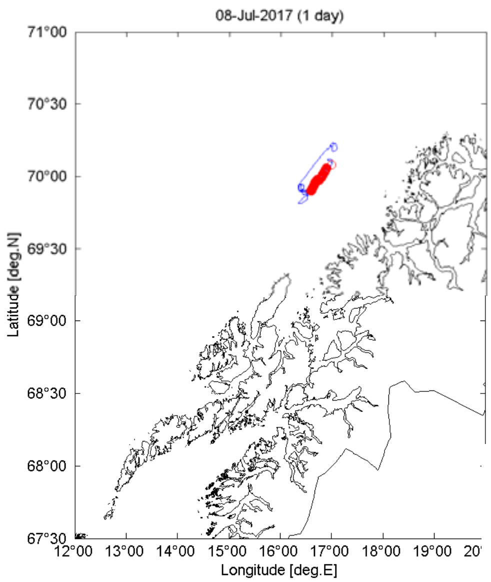


July 6th: Conducted CEE V. Transited north to Bleik to recover the second tag, and southern moored buoy.



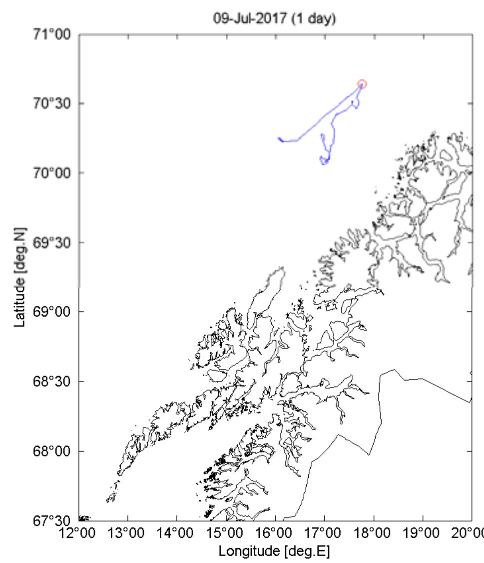
July 7th: Transited away from the core whale watching area in Bleik canyon before starting to tag new animals. Difficult weather condition and difficult animals, avoiding the tag boat. Deployed two tags further northeast. Conducted CEE VI.

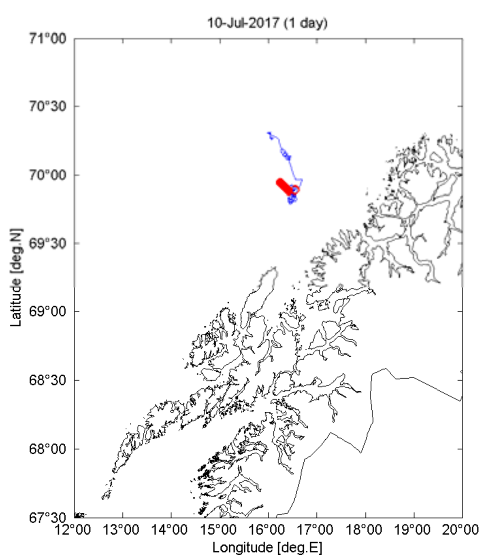




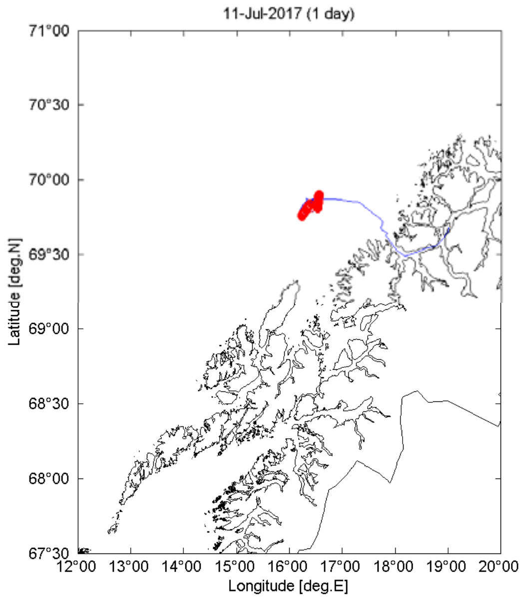
July 8th: Finished CEE VI. The DTAGv3 was recovered, but the mixed-dtag did not release. We left the tag after >10hrs of search, presumably still on the whale and transited northwards out of the exposed area.

July 9th: Trying to tag sperm whales and pilot whales. DTAGv3 deployed on a pilot whale, but low placement gave no VHF signal to track. We therefore had to focus on rescuing the tag, and could not do any CEE. Tag finally recovered after 10h. Transited to last Argos fix of lost mixed tag from CEE VI.





July 10th: Searching for lost mixed-dtag, which based on the Argos updates must now be off the whale. The VHF transmitter on the tag is clearly not working and after another 10 h, we had to give up and declare the tag lost. Searching for new animals to tag, and eventually deployed a DTAGv3 on a sperm whale. Started on CEE VII.



<u>July 11th</u>:Finished CEE CII. Recovered the tag and the northern moored buoy. Searched for new animals through the Malangen deep and channel - no detections. Transited to Tromsø, arrived just before midnight.

<u>July 12th:</u> In port in Tromsø for de-mobilization.

<u>July 13th:</u> Off-loaded all gear and disembarked. End of trial.

C Summary of technical issues with mixed dtag

1. Magnetometer issue

Magnetometer data collected by the DTAGv3 and mixed-dtag during the 3S-CAS-2016 cruise were not usable. As the 3S-2017 cruise was conducted using the same boat and types of tags, we decided to test the magnetometers more thoroughly beforehand. The different tests conducted indicated that the metal on the Sverdrup or specific equipment on board generated a magnetic field that interfered with the use of the magnetometers. The solution we found was to degauss the tags on the tag boat after it was launched. We checked that this procedure was not affecting the other components of the mixed-dtags and it was found to have no effect on either the VHF beacon or the Fastloc3 GPS logger, but it did act as a magnet swipe on the SPOT VI logger. To ensure that the degaussing of the DTAG was not changing the transmission mode of the SPOT VI, sufficient time was allowed between passing the tag through the degaussing coil for the SPOT VI to not change state. However, tests indicated that even degaussing onboard the tag boat did not always work. Possible explanations are that i) we underestimated the area of magnetic influence of the Sverdrup, and degaussed the tags before the tag boat was far enough away, and ii) the degaussing was not performed correctly.
The magnetometer issue did not happen prior to 2016. At that time, DTAGv2 were used on Sverdrup. It may be interesting to look at the components of each of these tags to see if the problem could be related to the type of magnetometer used in the DTAGv3. Alternatively, equipment onboard Sverdrup has changed the magnetic field so that we only see impact on the tags now.
We performed several tests to better understand the problem. The tags were armed, triggered and moved in a normalized way:

- First, the tag was held horizontal with suction cups facing down, and rotated around the z-axis clockwise by 90 degrees increments every 10-15 seconds;
- Then, it was rotated clockwise around the x-axis (from the hydrophones end);
- The last rotation was around the y-axis and started by pointing the antenna down.

The first test, for which the tags were armed in the tag lab inside the boat, then brought to the pier, triggered and tested outside, showed that the magnetometers were off (Figure 1).
Several other tests, testing different places to arm and trigger the tags at, seemed to indicate that the metal on the Sverdrup or equipment aboard generating a strong magnetic field could mess the magnetometers up.
The solution we found was to set up a coil on the tag boat, and use it to degauss the tags after the tag boat was launched and reached an area free from the Sverdrup magnetic influence. This procedure seemed promising, but did not work every time it was used (Figures 1, 2).

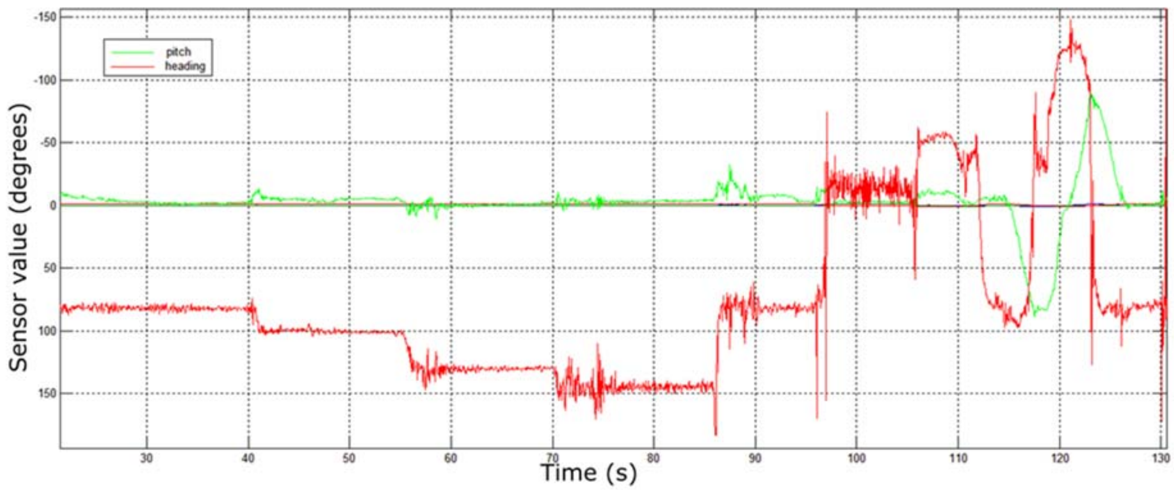


Figure 1: Pitch (green) and heading (red) data in degrees for the preliminary test of DTAGv3 with core unit 311. The heading varied between 75 and 150 degrees during the 360 degrees rotation of the test. Note that the pitch data cover the range from -90 to +90 degrees as expected.

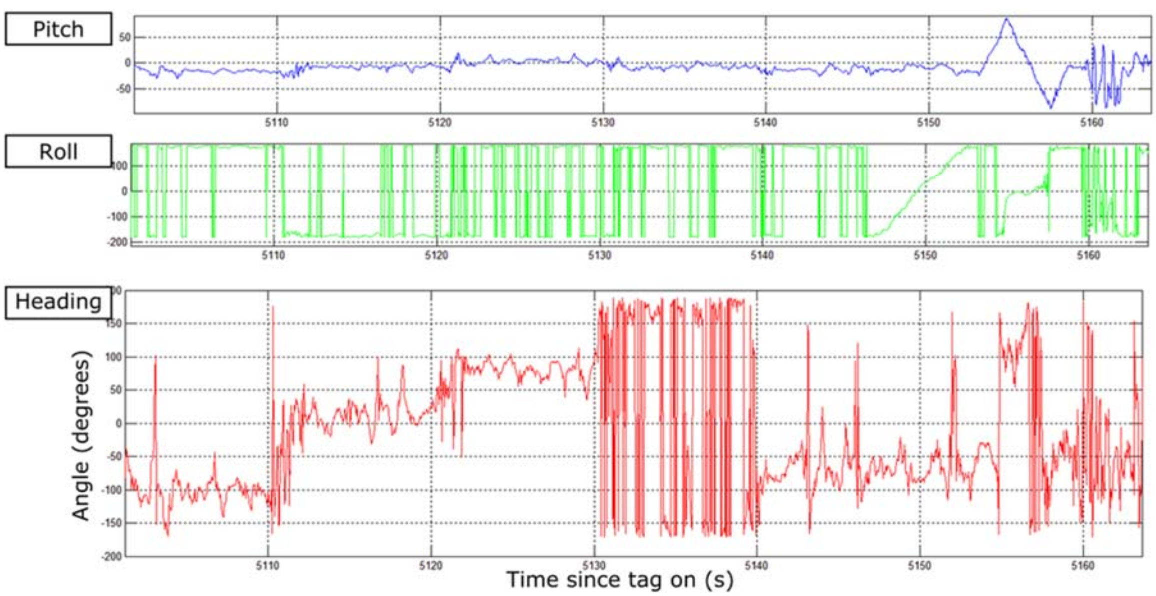
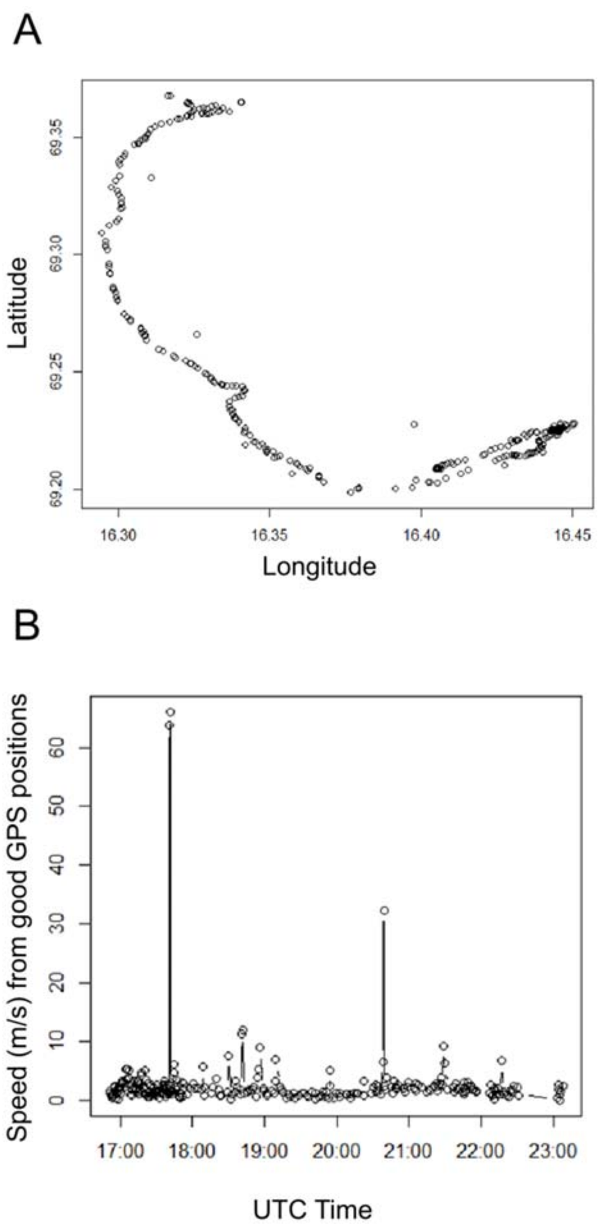


Figure 2: Pitch, roll and heading data for the mixed-dtag with core unit 302 after degaussing on the tag boat away from the Sverdrup. The heading data ranged from -180 to +180 degrees, now in steps of approximately 90 degrees, as expected.

2. Fastloc3 GPS logger issue

Overall, we received very few and often low quality (4 satellites) GPS fixes when the mixed-dtag was deployed on sperm whales. On the 5th of June, we deployed the first two mixed-dtags on pilot whales. The first tag (GPS logger 65370) only stayed on the whale for one dive and thus gave no relevant GPS data (gm17_176a). The second tag (GPS logger 65631) stayed on the whale for 4.5 hours, and recorded a good GPS track of the whole deployment (gm17_176b) (Figure 3).
Three days later, we deployed the first mixed-dtag on a sperm whale (GPS logger 65370). This tag only provided a good tracking of the animal for the last two hours of the deployment (sw1_179a) (Figure 4). There were very few GPS fixes during any of the subsequent deployments of both GPS logger 65370 and 65361, despite the loggers were tracking several GPS satellites.



<u>Figure 3:</u> A) GPS track for deployment gm17_176b. B) Timestamps of the fixes and apparent speed of the whale calculated from successive GPS fixes. The fixes shown are of good quality (5 satellites or more) and span the entire duration of the deployment.

In order to understand the overall lack of the GPS fixes, we performed several data checks and tests to check whether any of our hypotheses could explain the problem we were facing. Water was found to drain sufficiently quickly from the mixed-dtag's housing during typical sperm whale surfacings to allow the GPS logger to make fixes.
As both the GPS logger and SPOT VI operated using a salt-water switch it is likely that some of the transmissions of the SPOT VI interfered with the reception of GPS signals. However, the GPS logger was set to a higher rate so this does not fully explain the issue. A solution to this issue would be to add a small offset to the start of the transmission for one of the components. However, further testing is required to replicate the issue and confirm interference as the explanation for the GPS issue.

Shielding of GPS satellites by part of the body of the whale was flagged as another potential (although partial) explanation for the lack of GPS fixes, but tag placement did not explain the poor satellite reception consistently for all deployments. Here, again, further testing is needed.

A

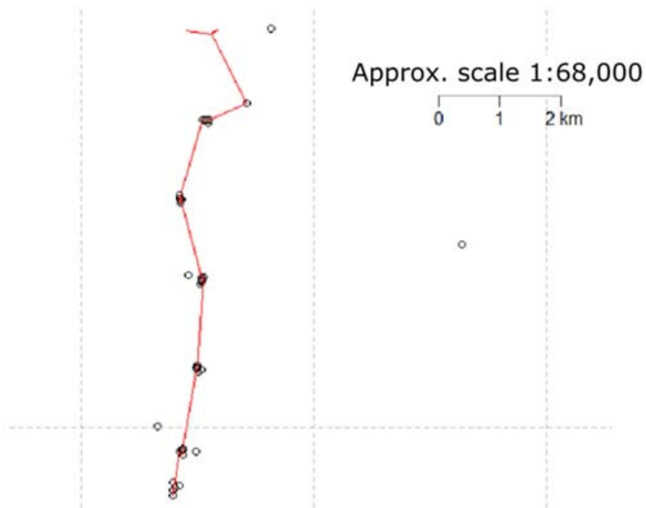
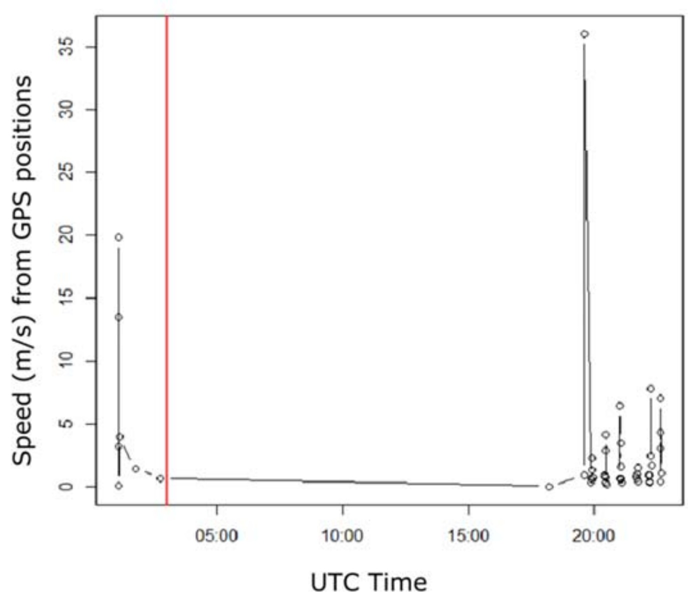


Figure 4: Incomplete track for deployment sw17_179a. A) GPS track B) Timestamps of the fixes and horizontal speed of the whale calculated from consecutive fixes. The vertical red line indicates tag-on time. The fixes are of good quality, but there is no fix before the last two hours of the deployment.

B



We had several hypotheses to explain the absence of GPS tracking on the field:

i) The GPS loggers may be damaged.
ii) This far north most GPS satellites will be south of our location and at a low inclination, and the body of the animal may block the satellite transmissions.
iii) The frequent flushing of water on top of a surfacing sperm whale may prevent the GPS logger from making fixes.
iv) There may be interferences between different components of the mixed-dtags, in particular between the GPS logger and the SPOTVI transmitter.

We did several data checks and tests to check whether any of these hypotheses on its own could explain the problem we were facing.

i) It was unlikely that the GPS loggers were broken. All the loggers had been tested in St. Andrews before the cruise. Moreover, both loggers got fixes during subsequent tests on board of the Sverdrup. And finally, both loggers managed to get fixes during deployments, even if only for a limited period of time. Some tags were found to be more sensitive (i.e. received signals from more satellites) than others in side-by-side tests, but the more sensitive loggers were used during deployments on whales.

ii) The hypothesis of the whale blocking the GPS signal also appeared unlikely. The loggers were sometimes receiving signals from as many as 12 satellites (Figure 5), yet wouldn't calculate a position. Furthermore, the whales didn't have a consistent heading that could have lead the body to block the GPS signal all along the deployments. Also, the problem persisted even if the tag was right on top of the animal. However, shielding may have contributed to the low number of GPS fixes received.

iii) We tested the GPS loggers' ability to calculate positions when water flushed regularly over them. We tested the tags in a bucket, and simulated flushing at different rates by holding the tags underwater and bringing them to the surface for different amounts of time (Figure 6 and 7). As the draining ability of the tags depends on the orientation we also tested several orientations (Figure 8).
The loggers didn't seem to be greatly sensitive to the range of flushing rates we tested, and were able to calculate positions in every single test.

iv) Interference between the GPS and the SPOT VI resulted in the absence of fixes. Both components being set to different minimum rates (15 s for the GPS logger and 30 s for the SPOT VI) should have resulted in at least some reception of GPS signals. However, as both components make use of a salt-water switch to sense if the tag is at the surface, many of the attempts by the GPS logger to receive GPS signals may have been interfered by SPOT transmissions. Indeed, a bucket test with a mixed-dtag onboard. Sverdrup confirmed that GPS signals were not received when the tag came first out of the water but were received at the second attempt at 15-29 sec after the first one if the tag was still dry.

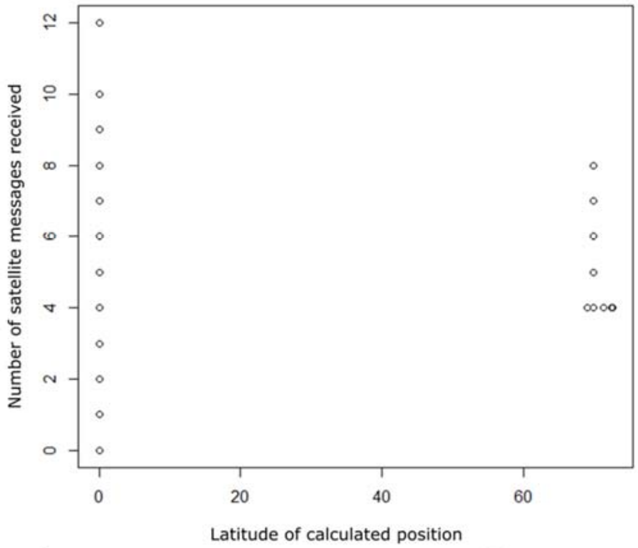


Figure 5: Number of satellite messages received by the GPS logger as a function of the latitude of the calculated position (deployment sw17_179a). A latitude of 0 indicated that the GPS couldn't calculate a position. Note that any number of satellite messages could result in no position.

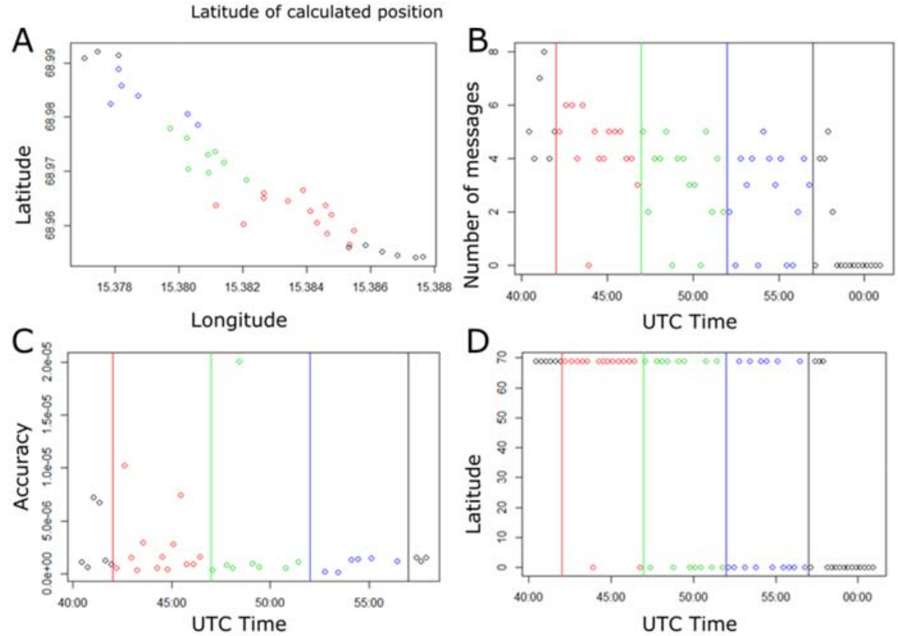


Figure 6: Dry duration test. The mixed-dtag was held underwater, then brought to the surface every 10s for 3 s (red), 2 s (green) and 1 s (blue). Each phase lasted 5 minutes. The tag was held horizontal during the whole duration of the test. The SPOT VI transmitter was disabled by the application of silicone grease on the saltwater switch. A) Latitude and longitude of the good quality positions calculated by the GPS logger. There is consistent tracking all along the test. B) Number of satellites messages received by the logger. There was a slight decrease in the number of messages with the reduction of dry time. C) Accuracy index of the fixes. There was no visual difference between the accuracy of the fixes made during different test phases. D) Latitude of the positions calculated. Latitude of 0 indicates the logger was unable to calculate a position. There were good fixes during every phase of the test, but the number of such fixes decreases with the duration the logger spent dry, as expected.

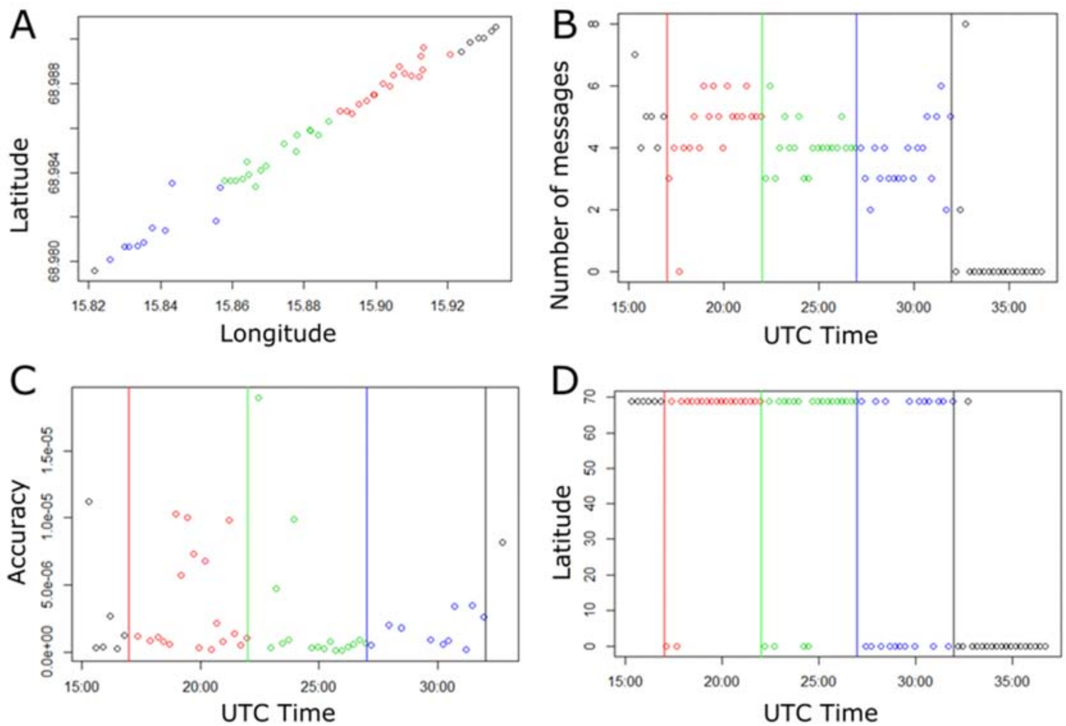
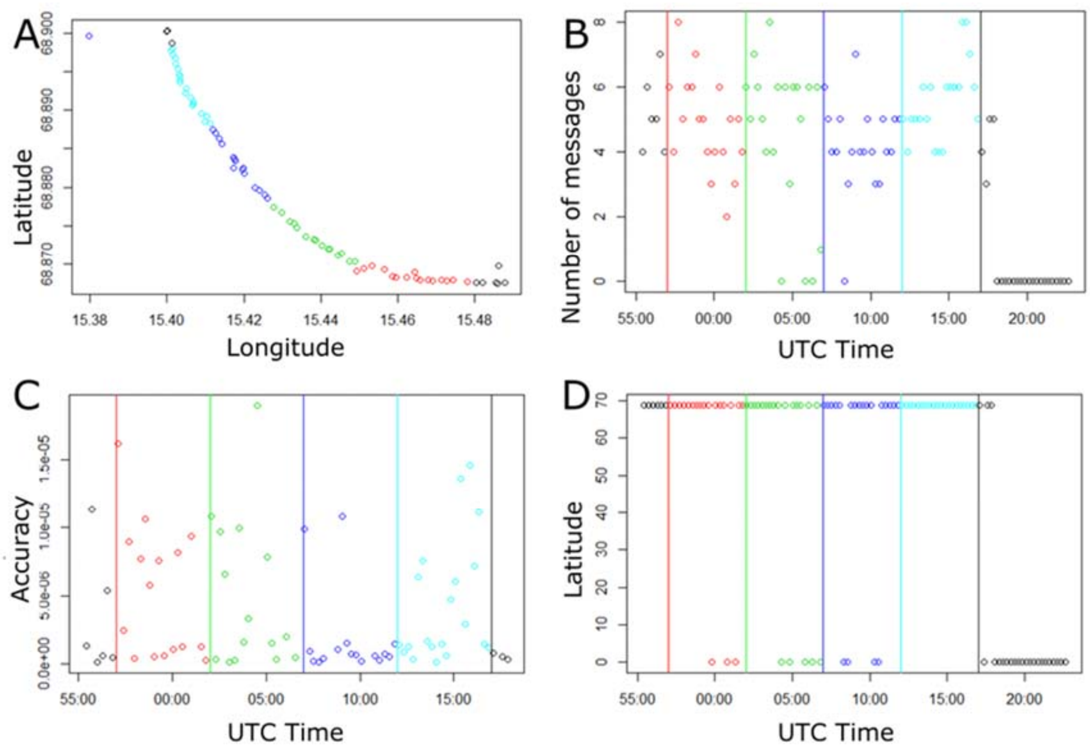


Figure 7: *Flushing rate test. The tag was held underwater for 1-2s every 20 s (red), 10 s (green) and 5 s (blue). Each phase of the test (colour-coded) lasted 5 minutes. The saltwater switch of the SPOT VI transmitter was disabled with silicone grease for the data presented here. A) Latitude and Longitude of the good quality fixes calculated during the test. There is good tracking for the whole test duration. B) Number of satellite messages received by the GPS logger. There is a slight decrease in the number of messages as the flushing rate increases, but the logger was able to calculate positions in every phase of the test. C) Accuracy index of the GPS fixes. There is no apparent change in position accuracy from one test phase to another. D) Latitude of the calculated positioned. There is a decrease in the number of good fixes as flushing rate increases, but there are good positions for every part of the test.*



<u>Figure 8:</u> Orientation test. For the same dry time and flushing rate (immersion of 1-2 s every 10 s), the mixed-dtag was tested antenna up (red), antenna down (green), antenna horizontal and GPS logger facing up (dark blue), antenna horizontal and GPS logger facing down (light blue). Each phase of the test lasted 5 minutes. A) Latitude and longitude of the good quality fixes calculated during the test. There is good tracking for the whole test duration. B) Number of satellite messages received by the GPS logger. There is no apparent difference in the number of messages received between tested tag orientations. C) Accuracy index of the GPS fixes. There is no great change in position accuracy from one test phase to another. D) Latitude of the calculated positioned. There are good positions for every part of the test.

3. VHF beacon issues

When embedded in the mixed-dtag housing, the VHF signals from the mixed-tags beacons were slightly weaker than the VHF signal from the DTAGv3. However, it didn't prevent VHF tracking of the mixed-dtags. Whether the poor signal is due to interference between the VHF antenna and the close SPOT VI antenna is currently under investigation.
On the 5th of July, the VHF antennas were reinforced with heat-shrink tubes and glue to avoid bending of the antenna. Based on photographs taken during tagging, VHF antenna bending under the tag was a suspected cause for lack of VHF signal from sw17_180a.
One VHF beacon stopped transmitting during a deployment, which led to the loss of one mixed-dtag (sw17_188b). The beacon had been running for 7 days. Before the cruise, we ran a battery life test on a VHF beacon: the battery voltage had barely decreased after 8 days of continuous transmission. The low ambient temperatures during sperm whale and pilot whale diving may have reduced its lifetime, but based on experiences on other field trials we still think unlikely that it ran out of battery. While the VHF signal was confirmed soon after the deployment, it is possible that the beacon of sw17_188b accrued damage when it was deployed or from previous deployments and attempts - the beacon had been deployed previously both using the cantilever pole (N=8 animal touch-downs) and ARTS (N=4 touch-downs).
The reinforcement of the VHF antenna may also have increased the strain on the base of the antenna, which might have played a role in the VHF breakdown.
The search for the lost tag was continued next day on the 9th, when the frequency of ARGOS locations received via satellites increased indicating the tag was off the whale, around 40 hours after deployment. We received ARGOS signals on a handheld radio receiver during the search for the lost tag; however, the range of this radio receiver was unknown and signals were only transmitted every hour between minute 0 and ~15 due to a pre-set hourly limit on the number of ARGOS messages. In future trials, a directional receiver for ARGOS signals would be a useful backup system for locating tags without a working VHF beacon.

4. Damaged Mixed-DTAG core unit

On the 28th of June, the mixed-dtag core unit 302 was recovered swollen after a deployment on a sperm whale. We were unable to offload the data from that deployment. It seemed the core unit was water-logged and the tag had swollen, but when we cut through the protective layer of the tag, there was no water beneath. All the liquid was inside the tag, which led us to think it was a leakage from a tag component. The battery seemed intact. We left it to dry, but did not use it for the rest of the trial.
After that, we replaced core unit 302 by core unit 303 and used this mixed-dtag thereafter. This change of component was motivated by the fact that GPS logger 65361 (previously with core unit 302) was the only one that provided a complete track on the field. Please see the Deployments table in the master Logger database for the list of components used for each mixed-dtag deployment.

D 3S-2017 – Cruise plan

Cruise Plan

3S-2017

Saana Isojunno

Final version
02/06/2017

The 3S-2017 research trial is conducted by the 3S-consortium as part of the 3S^3-project.

CONTENT

PROJECT OBJECTIVE

- Test if exposure to continuous-active-sonar (CAS) lead to different types or severity of behavioural responses than exposure to traditional pulsed active sonar (PAS) signals, or if the CAS feature of high duty cycle lead to acoustic responses that indicate masking
- Test how the distance to the source affect behavioural responses

CRUISE TASKS AND PRIORITY

Primary tasks:

1. Tag sperm whales with DTAGv3 or mixed-DTAG and record vocal-, movement- and dive behavior, and thereafter carry out no-sonar control-, pulsed sonar- and continuous active sonar exposures.
2. Prepare the ground for future studies using operational sonar sources, including testing mixed-DTAG on sperm whales and protocols and procedures for parallel exposures of multiple tagged animals.

Secondary tasks:

3. Tag pilot whales and killer whales with DTAG3s and do CAS and PAS experiment on them following the same protocol as with sperm whales.
4. Collect baseline data of target species.
5. Collect information about the environment in the study area (CTD and XBT).
6. Re-approach of tagged animal after experimental cycle to collect biopsy sample.
7. Collection of bio-acoustic data using towed arrays.
8. Test the use of moored passive acoustic sensors in the study area, to address the range of effects of sonar on whales.
9. Collect sightings of marine mammals in the study area.

Priority:

The primary tasks have a higher priority than the secondary tasks. We will try to accomplish as much of the secondary tasks as possible, 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. Since we already have collected some data on pilot whales last year, it is a higher priority to replicate the CAS-v-PAS experiment on pilot whales than to tag killer whales.

The trial is split in two separate efforts. In the period just before the main trial a smaller team will work shore based to tag sperm whales to collect baseline data, test the mixed-DTAG on sperm whales and train the taggers. Immediately after, the larger team will embark the RV HU Sverdrup II for the main trial, which will also include controlled exposure experiments.

3S-CONSORTIUM

The main partners of the 3S^3-project conducting the 3S-2017 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
- Living Marine Resources (LMR) Program at NAVFAC, USA
- DGA, French Ministry of Defense
- DSTL (Defense Science and Technology Lab), UK Ministry of Defence

The 3S-2017-trial is sponsored by;

- Living Marine Resources (LMR) Program at NAVFAC, USA
- The Royal Netherlands Navy and the Netherlands Ministry of Defence
- DGA, French Ministry of Defense
- DSTL (Defense Science and Technology Lab), UK Ministry of Defence

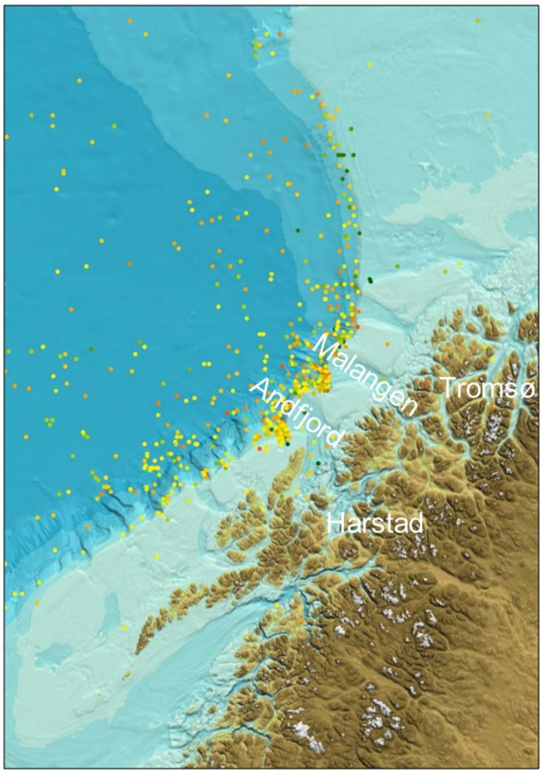
SAILING SCHEDULE

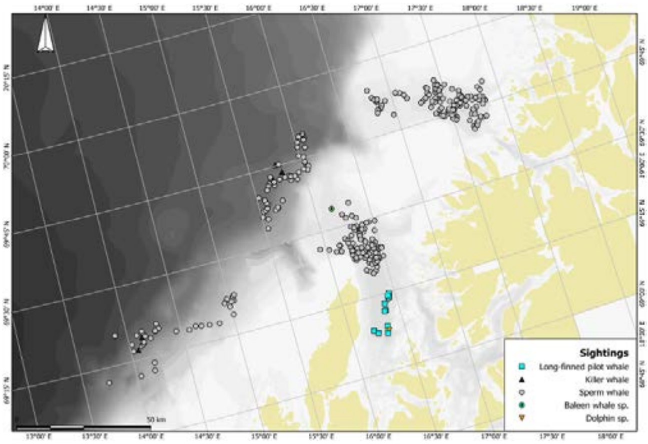
Date	**Time**	**Event**
Wed June 21st	18:00	General brief at Sydspissen military hotel in Tromsø. Joint no-host dinner.
Thurs June 22nd	09:00	Embarkment HU Sverdrup II in Brevika port, Tromsø Loading and technical installation Bunkering of fuel and food supplies for 3 weeks at sea without port calls. Celebration of the midnight sun
Fri June 23rd	08:00 14:00	Finalize technical installation Training of MMOs Safety training of tag boat crew Brief of ship's crew Safety briefing Transit to Malangen for engineer test of SOC-source and drill of operation. Transit back to port if needed.
Sat June 24th	08:00	Sail off – transit to operation area Regular watches **Fully operational**
July 1-3		Crews change (Mark/Martijn) in Harstad /Tromsø/Andenes
Wed July 12th	 16:00	Transit to Tromsø, de-brief Arrival Tromsø port De-installation and packing Celebration.
Thurs July 13th	09:00 12:00	Off-loading. Disembarkment Return travel

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 between Harstad and Tromsø. The initial engineering test will be carried out close to Tromsø in waters were sonar transmission do not propagate into the main operation area off shore.

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 search for whales in 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 of 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, killer whales and pilot whales. They can often be found in the more protected waters in Vestfjorden.





Left: The operation area for 3S-2017 with positions of sperm whale sightings recorded in the IMR database. (colours represent different months)

Right: Sightings of sperm whales (grey dots) and pilot whales (green dots) during the 3S-2016 trial.

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, and 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 centre 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 (MOB) 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. TB2 is the preferred tagging platform, and TB1 is only used if we decide to work with two tagging teams in parallel. TB2 can only be operated by certified MOB boat drivers. The tag boats will be launched when whales are sighted and weather permits tagging attempts. In the tagging phase the tag boat 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 2 (TB2) will be the main platform. It will be equipped with a swivel in the bow for the cantilever pole.

The primary tagging tool for sperm whales is the long cantilever pole, and therefore TB2 will primarily be used. The ARTS-tagging system will be used from both platforms as a secondary back up system for sperm whales, and the primary tagging system for killer whales. The preferred method to tag long-finned pilot whales is the hand-held pole.

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 and versatile source that was developed by TNO to perform 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 and sensors to monitor and record depth, pitch, roll and temperature. Because of risk of cavitation and damage to the source, it must stay below cavitation depth during operation. A minimum of 200m 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 both LF and UHF hydrophones. 18 LF hydrophones are used for the detection and classification of marine mammal vocalization up to 20 kHz. Three UHF hydrophones with a 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, both 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. We will use two versions of this tag, the regular one and a mixed DTAG (M-DTAG). The M-DTAG consists of the electronic package of the regular DTAG3, but is built into the version 2 DTAG housing. This housing is bigger than the current v3 housing therefore allowing us to add a GPS-logger and 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. The M-DTAG is therefore the preferred tool over the regular DTAG3s. The tags are deployed using a cantilever operated carbon fibre pole, or a pneumatic remote deployment system (ARTS).

DTAG3 with suction cups (upper left) and model of the new mixed DTAG (lower left) with GPS logger and SPOT transmitter in addition to the DTAG3 electronic. Deployment of the M-DTAG with the ARTS system was tested during the 3S-16-ORBS trial (right). During this year's trial the M-DTAG is the preferred tool deployed with the cantilever pole.

The M-DTAG is approved for use with the ARTS system, but the regular DTAG3 can only be deployed using the cantilever pole. If we decide to tag pilot whales or killer whales with a regular DTAG3, a shorter hand held pole will be used instead of the long cantilever pole. However, ARTS is the preferred method to tag killer whales when M-DTAGs are available. The tags are 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 DTAG 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.

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, CTD's, 2 VHF DDF, 2 sets of high quality ADF-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: 2 DTAG3, 2 M-DTAG, DTAG accessories, cantilever pole, 2 ARTS carriers for M-DTAG, 5 LKDarts, 1 VHF DDF, 3 VHF receivers (219 MHz), 1 set of VHF yagi antennas, 1 set of high quality ADF-cables, 4 handheld VHF-tracking antennas, Logger laptop, directional hydrophone, visual tracking

equipment for 2 platforms (laser range finders, compass, protractor etc), 2 digital cameras for photo id, biopsy kit, 2 mini big eyes, 3 binoculars.
Permits: SMRU ethics approval

LK-ARTS

Personnel: Certified tag boat driver/tagger/marine mammal observer
Equipment: 2 ARTS with connector and pressure bottles (including spear kit and extra manometer), 1 set of VHF yagi-antenna (219Mhz), 2 handheld VHF-tracking antennas (219Mhz), 2 VHF Receiver (219 MHz), 2 hand binoculars, 1 ID canon Camera (MK4-70-200mm), 2 GoPro (3+ and 4) with uw housing and brackets, 1 Speaker for the DFHorten box, 1 audio 3,5mm splitter, Biopsy removal tools, 2 headsets, 5 stoppers for LKDarts, short antenna cables

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, wireless network and data server, binoculars

DGA

Personnel: Marine mammal observer/acoustic operator

IMR

Personnel: Marine mammal observer

CEREMA

Personnel: Marine mammal observer/tag technician

NAVFAC

Personnel: Marine mammal observer/photo id.

BASELINE TRIAL

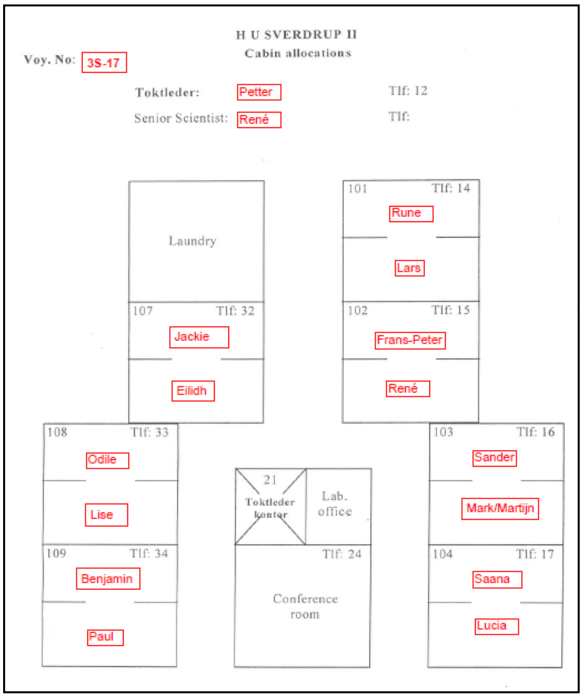
A one-week baseline trial (June 13th -20th) will be conducted prior to the main BRS trial. The field work will be carried out as day trips from Sommarøya, covering a smaller portion of the inshore and offshore operational area of the main sonar trial. The objectives of the baseline trial are to test the M-DTAG deployment on sperm whales using the cantilever tag pole system, train taggers on the cantilever system, collect baseline tag data in the study area, and collect drone footage of the tagged whale. All the work is to be carried out aboard the small boat, with a potential for second boat and a team to operate the drone (lead by Martin Biuw). Sperm whales are searched at sea both visually and using a directional hydrophone that is deployed over the side of the boat. When whales are found, they will be tagged and photographed for individual identification. Tags will be programmed to release from whales after 6 hours to allow recovery on the same day. The relatively short deployment duration will allow more opportunities for tag deployment testing and training of taggers but also minimizes risk of tag loss and time cost of tag recovery using the small boat. The GPS sensor on the M-DTAG allows us the option to return to Sommarøya during the tag deployment and re-launch for tag recovery. Returning to Sommarøya and not tracking the tagged whale removes any potential effects of the tag boat on tagged whale behaviour, and enables a crew change prior to tag recovery.

CREW PLAN

The total number of scientific crew is 15, including engineers, biologist, oceanographers and naval staff. *There is one planned port call to replace Mark with Martijn sometimes between July 1-3. The exact time and place of this port call will be kept flexible.

Crew list

Name	**Main role**	**Secondary roles**	**Affiliation**	**Nationality**
Petter Kvadsheim	CO	MMO	FFI	NOR
René Dekeling	XO	SOC/MMO	RNLN	NL
Saana Isojunno	PI/Tagger	Tag technician/(MMO)	SMRU	FIN
Frans-Peter Lam	SOC	MMO	TNO	NL
*Mark van Spellen/ Martijn van Riet	SOC	MMO	TNO	NL
Sander van Ijsselmuide	SOC	Data management/MMO	TNO	NL
Lars Kleivane	Tag boat driver/tagger	MMO	FFI	NOR
Rune Roland Hansen	MMO/photo id	Tag boat driver	FFI	NOR
Paul Wensveen	Tagger	MMO	SMRU	NL
Lise Sivle	MMO	Data management	IMR	NO
Lucia Martin Lopez	Tag technician	MMO	SMRU	SPA
Odile Gerard	MMO	SOC	DGA	FR
Jacqueline Bort	MMO	Photo id	NAVFAC	USA
Benjamin Benti	MMO	Tag Tech/Data management	CEREMA	FR
Eilidh Siegal	MMO	Data management	SMRU	UK



Cabin plan

DAILY WORK PLAN

The 3S-2017 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 continuous 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.

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

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 labour demanding experimental phases. It also requires a well-defined chain of command and communication plan.

Planning meeting

Every morning before breakfast (0700), the chief scientists from the main 3S partners (Kvadsheim, Lam, Isojunno) 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 Kleivane who is on a 24 hrs stand by watch as the tag boat driver, 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. 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). 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 (Sivle and Siegal) will organize the watch and make a watch plan for the MMO's which also includes the secondary MMO's. The lead MMOs is also responsible for data collection at the MMO station and to check logger data and back it up.

During tagging, three of the MMOs are in the tag boat and thus not available on the MMO-station. This means the MMO team is a bit understaffed! This is particularly critical after the first tag is deployed, because the tag team will continue to try to tag another whale, but the MMOs have to start tracking the tagged whale. During this phase we need to shift as many people as possible to support the work on the MMO-station. This is the responsibility of the CO/XO in coordination with the lead MMO. The priority of the MMOs on Sverdrup is to track the tagged whale, and therefore the tag team has to work independent and can not expect much support from the Sverdrup during the second tagging attempt.

Name	08 - 14	14 – 20	20 – 02	02 - 08
Petter Kvadsheim	X		X	
René Dekeling		X		X
Saana Isojunno	X		X	
Frans-Peter Lam	X		X	
Mark/Martijn		X		X
Sander van Ijsselmuide	X		X	
Lars Kleivane	24-hr stand by			
Rune Roland Hansen		X		X
Paul Wensveen		X		X
Lise Sivle	X		X	
Lucia Martin Lopez		X		X
Odile Gerard		X		X
Jacqueline Bort	X		X	
Benjamin Benti	X		X	
Eilidh Siegal		X		X
	7+	**7+**	**7+**	**7+**

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.

Tag teams consist of three people, a driver, a tagger and someone in charge of photo documentation. Depending on which team is on watch the tag teams will be (driver-tagger-photo id): Kleivane – Wensveen – Hansen during the 14-20 and 02-08 watches and Kleivane – Isojunno – Bort during the 08-14 and 20-02 watches. TB2 is a Man Over Board boat and Kleivane is the only member of the science crew certified to drive it. He will therefore be flexible in his watch schedule to be available whenever needed. Hansen is certified to drive the work boat (TB1), but we don't expect that we will operate two tag boats at the same time.

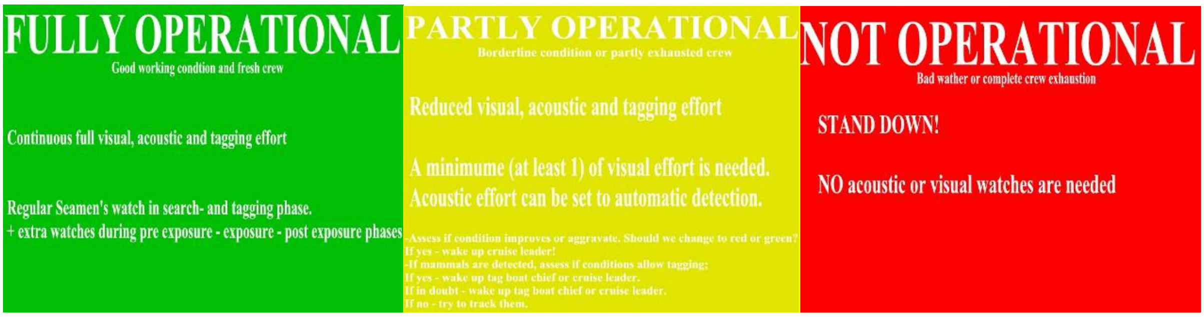
Watch plan in experimental phases

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 4 MMOs during the exposures. XO/CO will make ad-hoc adjustments to the watch plan prior to the exposures if needed to fill these requirements. At this time the tag team will have returned to Sverdrup and will be available to support the MMOs.

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 at all times rather 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!

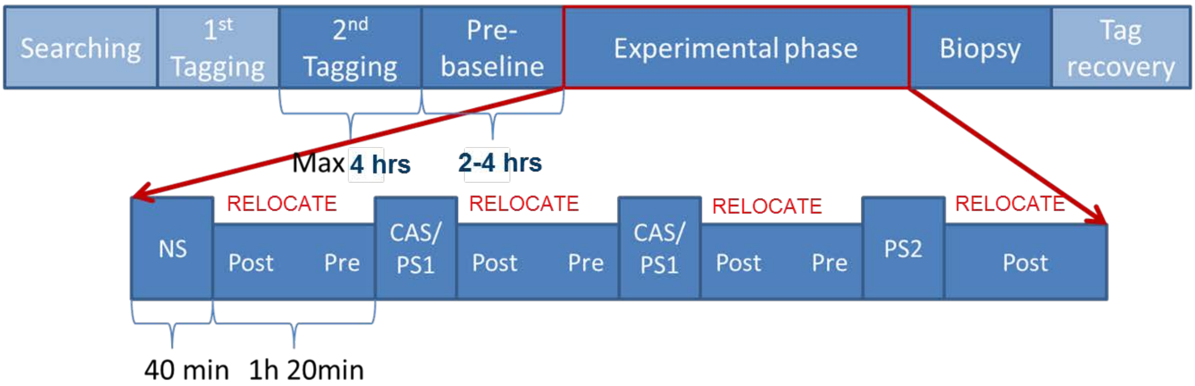
On the other hand, increased risk to personnel in some phases of the operation, and increased risk of reduction in the quality of the data collected in other phases are factors which also have to be considered carefully in these periods of intense work load. Thus, the cruise leader may decide to reduce 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 exposure protocol is developed to test differences in responses to continuous sonar signal compared to pulsed sonar signals, and to address the importance of the distance to the source. The same protocol will be used with sperm whales, killer whales and pilot whales. This protocol was established and used also in 2016, and preliminary analysis of the data collected indicates that the experimental design works as intended.



Experimental phases. The second tagging period should be 4 hr max. The pre-exposure baseline on the focal whale 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 of the focal whale starts 16 hrs after tag on. The tag is expected to come off after 17-18hrs.

A change in the procedure compared to last year is that we will try to tag more than just one animal at the same time. This enables us to increase sample size without doing more exposures, with respect to different source-to-whale distances in particular. We aim to tag two separate animals before starting the experimental cycle. The focal whale which will be tracked by the Sverdrup throughout the experiment will be the first whale tagged, unless the second whale is tagged with a regular DTAG and the first with a M-DTAG, in which case we should switch to track the second whale with the regular DTAG instead. A minimum of 4 hours of baseline data will be recorded on the focal whale before the experimental phase starts. For the non-focal whale tagged the pre-exposure baseline should be at least 2 hours. 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 for the first tag deployed and 14 hours for the second tag, thus we expect 15-17 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). If the weather is good, there is a preference to work with sperm whales off-shore rather than in the confined channels. This is to get a better balance between shallow and deep water behaviour and not become biased towards animals involved in shallow water behaviour.

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 not as re-sightings. 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, TB2 will be launched from the Sverdrup with tagging and photo-id capability. The tag teams should consist of three people, a driver, a tagger and someone doing photographic documentation. During tagging, the MMO team should provide support to the tag boat and start searching for new animals. Dtag3 technicians will ensure that a minimum of two tags are armed and ready for deployment prior to tagging. The M-DTAG is the preferred tag and should be used if available. However, we have less experience with the endurance of this tag compared to the regular DTAGs. If the M-DTAGs tend to release early we might have to reconsider priorities of tags. Release time will be set to 16 hours for the tag intended to be deployed first, and 14 hours on the tag intended to be deployed second.

The tag team will always bring the ARTS-system as backup, but the default method to deploy tags should be the cantilever pole, because this system has been proven to be very robust and efficient to tag sperm whales. Cantilever pole will be used for at least 3 tagging attempts with sperm whales before moving to use of ARTS with sperm whales. With killer whales the ARTS system is the preferred method, while hand-pole is the preferred technique with long-finned pilot whales. We are only allowed to use the M-DTAGs with the ARTS. Regular DTAGs need to be deployed with a handheld pole.

Once a tag is attached the MMO-team on Sverdrup will start tracking it. The tag boat will start searching for new animals based on the report from the MMO-team on Sverdrup. The second subject whale should be the one closest to the first tagged whale, except that the tag boat should never approach the first tagged whale closer than 1000m. The MMOs should help the tag boat to avoid approaching the already tagged whale again. Staying away from the focal whale is important to ensure clean baseline data, and it is the MMOs responsibility to both report any close approaches to the CO/XO and record such events in Logger. The tag boat should always stay within 3nmi of Sverdrup, and second tagging attempts are limited to animals within this range. This is partly due to safety considerations and partly it is a limit set to avoid tagged animals ending up too far apart. If we are working off shore (as opposed to working in the confined channels) this limit will be reduced to 1nmi, otherwise the already tagged animal might end up very far apart from the second deployment position. The duration of the second tagging effort depends on weather and animal availability, but is ultimately limited to 2 hours after the first tag was attached. After that the tag boat is recovered and we move on to the experimental phase after the pre-exposure baseline period.

One of the main tasks of this trial is to test and develop protocols and procedures for parallel exposures of multiple tagged animals. This is important to have in place before the planned trial using an operational source next year. We will therefore assess the above procedure during the trial and might decide to adjust it as we get more experience with this modus operandi.

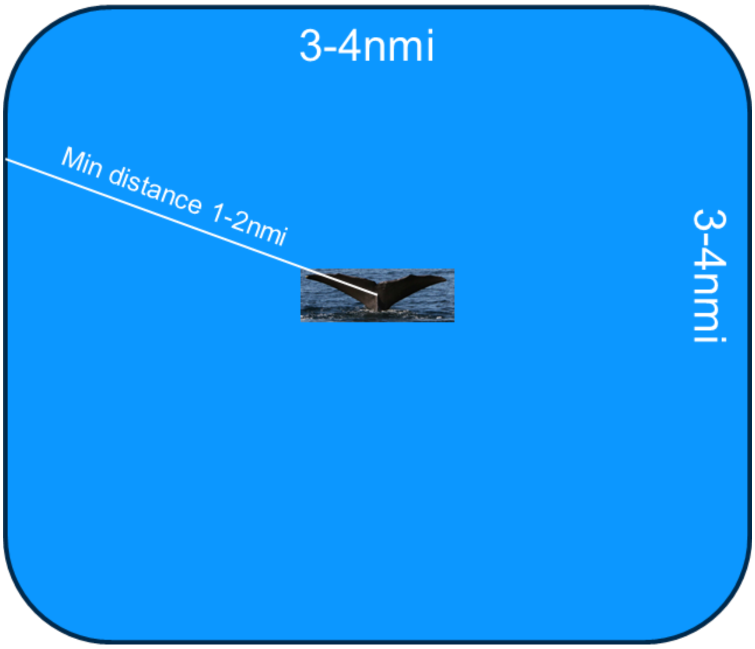
If we work on secondary species, we should also try to deploy 2 tags, but only on animals which appear to be associated. Data from killer whales and pilot whales will not be used to address the received level versus range issue, but having two tags deployed gives us some redundance in the experimental phase in case one tag detaches early during the experimental phase.

One thing to be aware of for the tag team is that the robot used to deploy M-DTAGs is not the same as the robot used to deploy regular DTAGs. The robot therefore has to be changed if we switch tags. Tag teams have to bring both robots and tools to exchange them.

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. As soon as the tag team is back after the second tagging attempt they will support the MMOs. 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.



Idealized navigation pattern of HUS during tracking

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 centre. 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.

If a M-DTAG is deployed it contains a spot satellite unit, which transfers position of the whale via ARGOS, although there is a delay in this transfer. The acoustic team will monitor via internet for updates. Position updates will then be plotted on the tablet so that the MMOs can see it.

Pre-exposure baseline period

Pre-exposure baseline phase starts when the tag boat leaves the tagged animal and the MMO team has taken over tracking. The tag team might stay on the water for a second tagging attempt on another animal, but unless they stay closer than 1000 m we still consider it baseline data for the first tagged whale. The MMOs should help the tag boat to retain a sufficient distance to the already tagged whale, and report any close approaches (<1000m) in Logger. The duration of the pre-exposure baseline period should be 4 hrs minimum for the focal whale, and minimum 2 hrs for the second tagged whale. If the second tag deployed is a regular DTAG, but the first tag deployed is a M-DTAG, we should switch focal whale from the first tagged animal to the second tagged. In this case the 4 hrs baseline period starts counting from the time when the tag boat leaves it to be recovered. The end of tag boat effort should be recorded in Logger by the MMO responsible for data entry. 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 the focal whale of 40 min each, with a minimum of 1h 20min of post/pre-exposure time in between them. The non-focal tagged whale is not tracked by Sverdrup, but has a M-DTAG which records the track using the on-board GPS-sensor. The approaches of the source ship will be aimed at the focal whale, and thus the position of the second tagged animal relative to the source will not be controlled. After an exposure there is a post-exposure period, during which the highest priority is to relocate the focal whale, because its track is probably lost during the approach. The post/pre-exposure time may be extended if the whale does not appear to recover to post-exposure baseline level after exposure or if we have not managed to relocate the focal whale.

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.

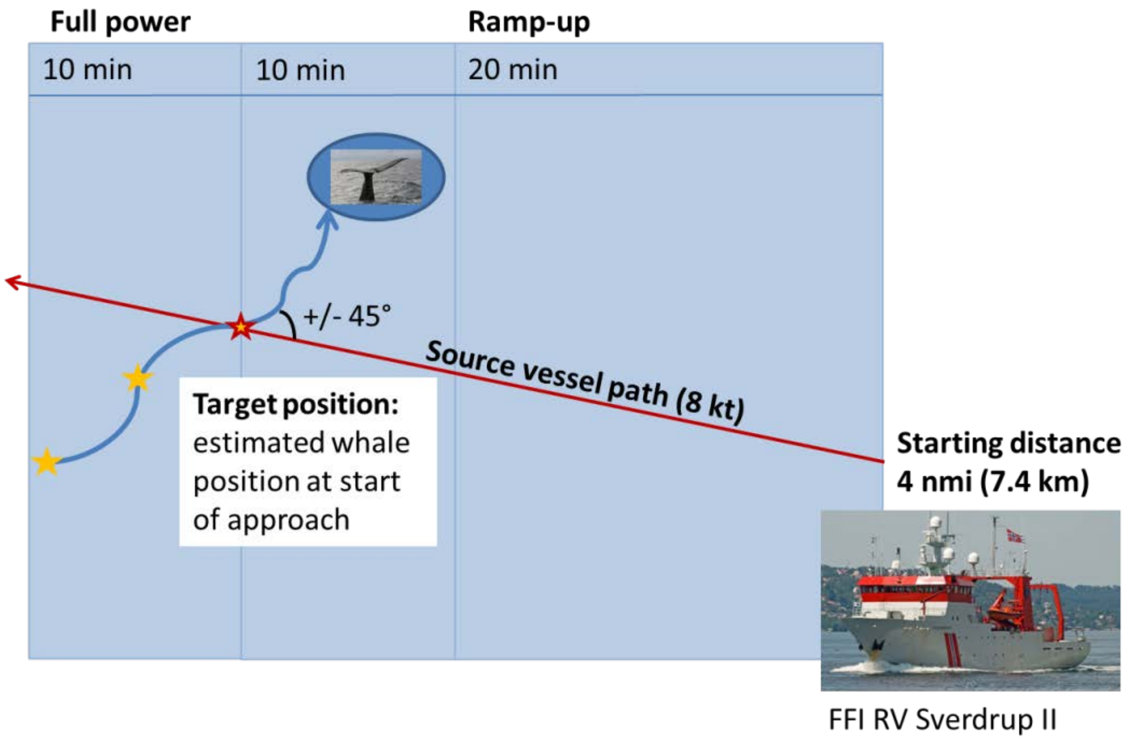
The order of the four exposure sessions is determined to maximize the contrast between the different signals with minimum amount of data. No-sonar control approach (NS) is always conducted first to test the effect of ship on whale behaviour, before any sensitization by sonar can take place. Last year the order of subsequent exposures were optimized to contrast CAS and PAS, thus it was prioritized to have the CAS exposure early in the sequence. We established a cycle of 4 blocks, which was completed once plus we covered the first block of the 2nd cycle. This year we have to establish a new cycle of 6 blocks, to consider all possible option of the sequence of the three exposure conditions. By repeating the cycle at least three times, we should be able to statistically account for any order effects on the observed responses to the different stimuli. This year we will start by filling in missing blocks in the first cycle (block 5 and 6 in the table above), before we complete block 2-6 in the second cycle, and then start on the first block of the third cycle.

New experimental cycle of 6 blocks with equal priority to all exposure conditions. Block 5 and 6 were not covered last year. This year we will therefore start with block 5 and 6 to complete the first cycle, then continue with block 2-6 to complete the second cycle before we start on the third cycle from block 1. Thus with sperm whales we will use the exposure order:
Block no 5,6,2,3,4,5,6,1,2,3,4,5,6.

Experiment	**1st Signal**	**2nd Signal**	**3rd Signal**	**4th Signal**	**Completed blocks (trial)**		
					Once	Twice	Three times
1	NS	CAS	MPAS	HPAS	3S-16	3S-16	
2	NS	MPAS	CAS	HPAS	3S-16		
3	NS	CAS	HPAS	MPAS	3S-16		
4	NS	HPAS	CAS	MPAS	3S-16		
5*	NS	MPAS	HPAS	CAS			
6*	NS	HPAS	MPAS	CAS			
Repeat cycle three times							

** Missing block from 3S-16 trial to complete full cycle with all options*

With secondary species we are only focusing on the CAS-PAS contrast, and we will therefore only use block 3 and 4, alternately.



Geometry of all CEE approaches

If the tag falls off before all exposures are completed, the rest of the exposures need to be cancelled. However, if 3 treatments or more (i.e. 2 sonar exposures or more) are completed, we will move on to the next step of the cycle in the next experiment. If there is more than one animal tagged and the tag comes off the focal whale midway, we switch the focal whale and continue the exposure cycle at the point where it was broken off. If 3 treatments or more (i.e. 2 sonar exposures or more) were completed with the first focal animal, we will move on to the next step of the cycle in the next experiment. Otherwise, the step will be repeated with the next experimental subject.

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 active sonar (MPAS), and high source level pulsed active 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.		

Post exposure phase

After each 40min exposure session there is a post-exposure phase of minimum 1 h 20 min. Usually we will lose the track of the whale when Sverdrup sail away to position for an approach. It's very important to try to relocate the animal as soon as possible during or after the approach using the DDF system and visual search. Unless we relocate the animal, the rest of the experiment has to be cancelled. Once we have relocated Sverdrup will again manoeuvre 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 h 20 min, but preferably longer. Around the time of tag release, 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.

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 100 m. 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.

Sound speed profiles (CTD and XBT)

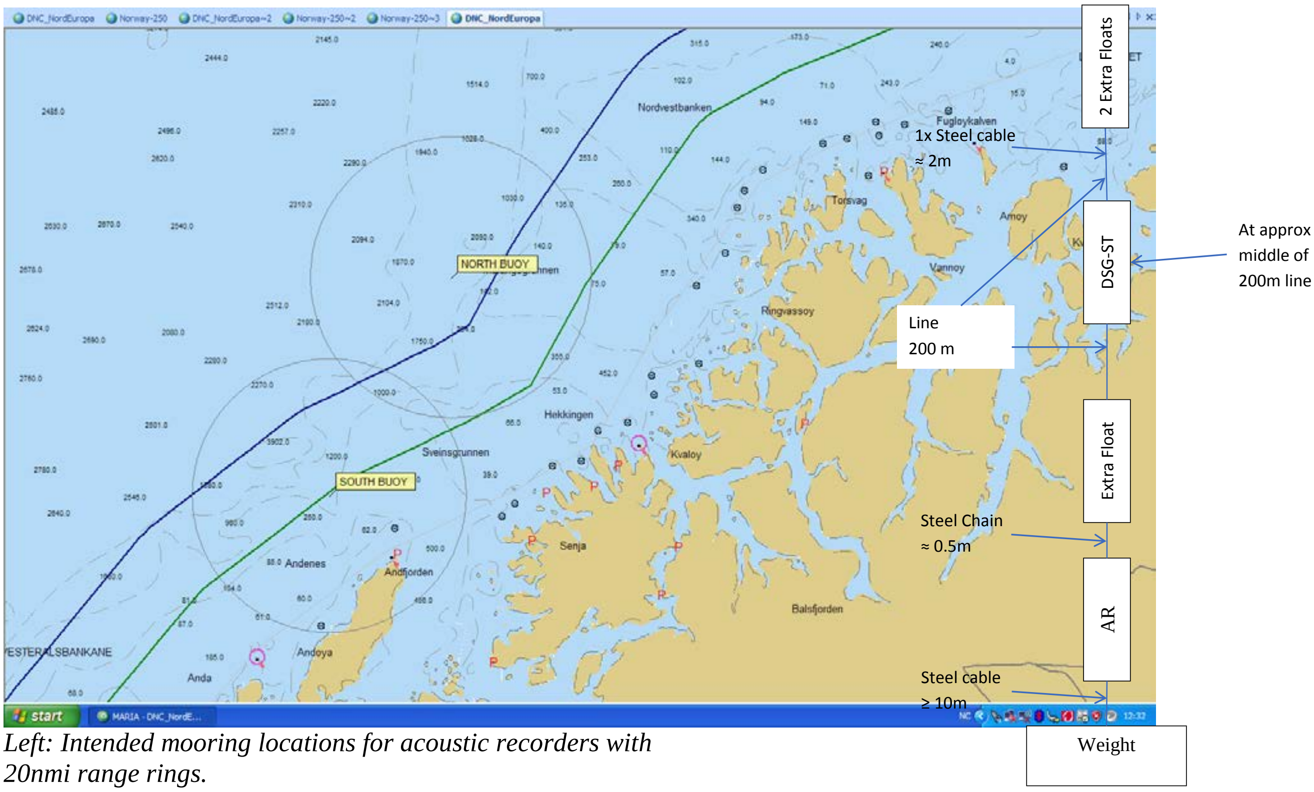
A temperature profile (XBT) should be taken during or as soon as possible after the end of transmissions during all animal approaches of the source ship, including no-sonar approaches. CTD profiles will be taken form the Sverdrup after the end of the full experimental cycle. However, Sverdrup cannot 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).

Passive acoustic monitoring using moored buoys

Two moorings with acoustic recorders will be deployed in the beginning of the trial, and recovered before the end. The positions of deployment are chosen based on knowledge that there is high density of whales around, that we cover the main operation area, and such that we get different ranges from expected exposure sites:

70º00.000N / 016º30.000E
69º28.500N / 015º39.300E

Due to the large detection ranges of sperm whale clicks and the relatively high abundance of sperm whales in the study area, it is expected that we will have a high probability to detect many echolocating sperm whales. The aim of the buoy data is to assess the range at which sonar might affect whales. Specifically we are looking for changes in clicking rates, which we also see from our DTAG data, but the buoys allow us to obtain more data over a wider range of distances from the sonar at the same time. Having an idea about the feasibility of this approach may help us plan for any future operational sonar trial, and to optimize data collection for these exposures. The acoustic recorders will provide us with a continuous acoustic recording of the area and allows us to monitor possible large scale effects of sonar exposures. This set-up can therefore be used to test the possible use of moorings in BRS studies in general. Deployment and recovery of a mooring will take approximately 3 hours per mooring.



Left: Intended mooring locations for acoustic recorders with 20nmi range rings.
Right: Schematic overview of the mooring setup (not to scale).
AR=Acoustic Release, DSG-ST= the actual acoustic recorder (code for type of recorder).

MANAGEMENT AND CHAIN OF COMMAND

Operational issues

Operational decisions such as decisions on sailing plan, decisions to deploy tag boats/Socrates/ Delphinus, and crew dispositions are ultimately made by the cruise leader. Any deviations from the protocols specified in the cruise plan will only be made with consensus of all 3 chief scientists. 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. Isojunno replaces Miller as the PI and chief scientist representing SMRU, however, Miller might be consulted by phone on important issues if necessary.

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.

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).

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 – TagData – Calibration - Logger - 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. Close to the coast 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 (Appendix B) 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 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, 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/Isojunno 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 might be 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 June-July the air temperature will still be relatively cold at sea in these Arctic oceans (5-10 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 midsummer, thus we will have 24 hours of daylight and working conditions. 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. No alcohol is allowed on board.

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:

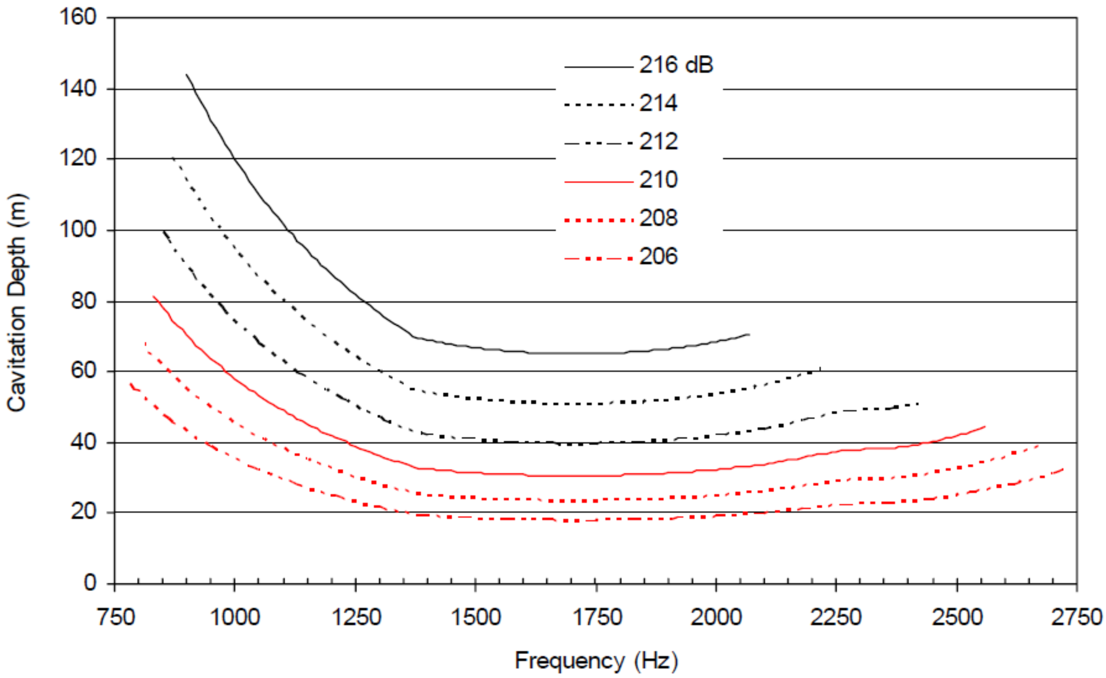
- Starboard turn for 3-12 kts with 20 deg/min.
- Port turn for 3-12 kts with 25 deg/min.
- While turning (and shortly before and after that (2min)) **speed should remain constant**

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

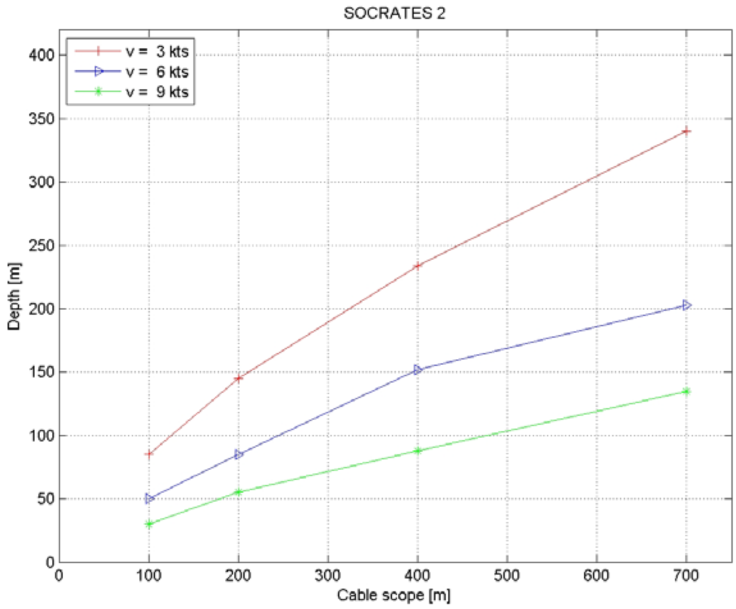
H.U. Sverdrup II can tow both the SOCRATES source and the Delphinus array simultaneously. The deploying sequence will be first the towed array and then the SOCRATES towed source. Consequently the retrieval sequence will be first SOCRATES and then the array.

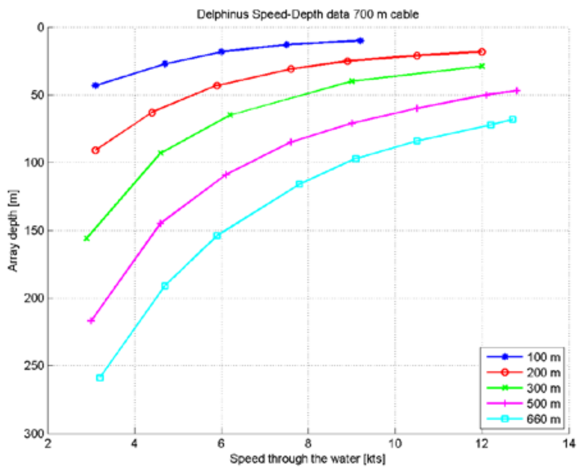
Data Sheet

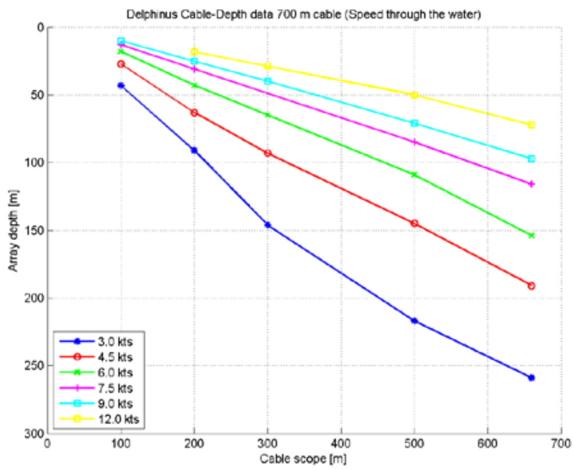
The operational limitations and additional information for H.U. Sverdrup II while towing are presented below:

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

Risk assessment and management plan for the 3S-2017 research trial with HU Sverdrup II

Introduction

This document describes the risk identified for the 3S-2017 research trial. The trial will primarily take place along the shelf break between Andenes and Tromsø in Norwegian territorial waters and EEZ between June 22nd and July 13th 2017.
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 active sonar (PAS) signals, and to test how the distance to the source affect behavioral responses

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-2017 cruise plan.

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 seem 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 bottlenose whales, sperm whales, pilot whale, killer whales and humpback 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-17 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.

4 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

5 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.

6 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

7 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 20nmi 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 A) 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 (Appendix A).
- 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) (Appendix A).
- 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) (Appendix A).

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 (Appendix A).

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 summarizes the safety regime, and responsibilities. For the 3S-2017 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 than 3nmi 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. All scientific staff should read and understand the "Instructions to survey personnel on board "HU Sverdrup II".

Relevant documents

3S-2017 cruise plan
NARA permit 2015/223222
Instructions to survey personnel on board "HU Sverdrup II

APPENDIX C – Project outline

3S3 - Behavioral responses of sperm whales to naval sonar – Comparing responses to continuous active sonar (CAS) and pulsed active sonar (PAS), and disentangling received level from range as the response driver

Petter Kvadsheim[1], Frans-Peter Lam[2], Patrick Miller[3], Saana Isojunno[3]
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SUMMARY

The 3S international research consortium has been conducting behavioral response studies on six different species of cetaceans in North Atlantic waters with great success since 2006. We have published more than 20 peer-review papers on effects of sonar on marine mammals and fish (Kvadsheim et al. 2015). The third phase of the 3S project started in 2016, focusing on studies of behavioral responses to continuous active sonar (CAS) compared to conventional pulsed active sonar (PAS), and on how range and received levels affect responses. We are focusing our effort on two deep diving species, sperm whales (*Physeter macrocepahlus)* and northern bottlenose whales (*Hyperoodon ampullatus*). This document describes the technical approach for our proposed study on sperm whales. The objective of this study is to address two separate questions in parallel using the same experimental design: 1) How does the distance to the source affect behavioral responses? 2) Does exposure to continuous-active-sonar (CAS) lead to different types or severity of behavioral responses than exposure to traditional pulsed active sonar (PAS) signals, or does the CAS feature of high duty cycle lead to acoustic responses that indicate masking?

We are using an experimental design where multiple target animals are tagged with acoustic and motion sensor tags (mixed-DTAG) and exposed to different sonar signals (CAS and PAS) at different levels and ranges. This multiple exposure design increases sample size but also allows us to better deal with individual differences, since each animal is it's own control. The challenge is that we have to balance the dataset and collect enough data to account for any order effects (i.e., habituation or sensitization to repeated exposures). To achieve maximum output from the exposure experiments we also plan to deploy multiple tags before starting the exposure sessions. This not only increases the sample size, but also allows a larger received level to range interval without conducting more exposures. We started this study in 2016, focusing on CAS versus PAS, and have already conducted a successful sea trial, during which we collected valuable data and proved the feasibility of our experimental design. In addition, we already have a substantial dataset on sperm whales from previous years, with 10 tag deployments, 10 sonar exposures (PAS only) and substantial amount of baseline data (Miller et al. 2011). However, we need more data to fully address both the CAS versus PAS and received level versus range issues. We are proposing a two year project (2017-2018), which includes a 3 week sea trial in 2017. During this trial we will use a scaled sonar source (SOCRATES) at 214 dB re $1\mu Pa^2 \cdot m^2$ source level. The mixed-DTAG with GPS and satellite transmitter, which allows us to tag several animals in parallel but still maintain full data quality, will be prepared and used. Already established procedures for processing and analyzing data statistically will be used to address the PAS versus CAS and RL versus range issue. As an optional 1 year extension of the project we will prepare for having a Norwegian ASW-frigate available for an additional 2 week trial in 2018. This will require additional funding for the trial but also additional analysis. There is considerable (>50%)

matched funding already in place for this project from NL-MOD (DMO), FR-MOD (DGA), UK-MOD (DSTL) and in kind contributions from FFI (NO). Additional matched funding will be requested from other partners for the one year extension of the project in 2018-2019.

INTRODUCTION

Behavioral response studies (BRS) 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 have shown large variation in responsiveness between different species, but also variation within a species depending on the behavioral context of the animals and probably also other unknown factors. Behavioral responses such as avoidance of the sonar source, cessation of feeding, changes in dive behavior and changes in vocal and social behavior have been observed, and response thresholds defined. Results from BRS have helped navies to comply with international guidelines for stewardship of the environment, as well as rules and resolutions within Europe and the USA.

The third phase of the Sea Mammals and Sonar Safety project was initiated in 2016 (3S^3). 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 signals, and we addressed specific questions such as frequency specificity of behavioral responses and the efficacy of ramp-up. A key output from these studies was 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 (Miller et al. 2014), pilot whales (Antunes et al. 2015), sperm whales (Harris et al. 2015) and humpback whales (Sivle et al. 2015), have been established and compared (Harris et al. 2015, Sivle et al. 2015). Such functions can be used to define an affected area around a source and estimate cumulative effects of operations on marine mammal populations. However, it is not obvious what the best measure of exposure or sonar dose is. The received RMS sound pressure level (SPL) is the most commonly used metric, but accumulated Sound Exposure Level (SEL) has also been used. However, 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 therefore implies that there is no effect of distance, i.e. that whales respond only to sound levels rather than to how far away the whale judges the source to be. Recent studies indicate that response to sonar may be influenced by the distance from the source (DeRuiter et al. 2013; Moretti et al. 2014). However, more empirical data 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, while avoiding unnecessary restrictions on naval training activity. Furthermore, all BRS research so far has been conducted using pulsed active sonars (PAS), typically transmitting only 5-10% of the time (a short pulse followed by a much longer period of listening). 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 (van Vossen 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 to implement this technology in operational use. This raises imminent questions about the environmental impact of such future sonar systems.

THIRD PHASE OF THE 3S-PROJECT (3S3)
In the third phase of the 3S-project, which started in 2016, we address the following specific research questions:

1) Does exposure to continuous-active-sonar (CAS) lead to different types or severity of behavioral responses than exposure to traditional pulsed active sonar (PAS) signals, or does the CAS feature of high duty cycle lead to acoustic responses that indicate masking?
2) How does the distance to the source affect behavioral responses?

The running 3S3 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) study on sperm whales. Both address the received level versus range issue. These two components use similar technology, experimental design and analysis techniques and thus there is significant synergy between them, even though they are focused on different species and collect data during separate sea trials. The project is being supported by US, UK, French and Dutch naval authorities, and we have already conducted two very successful research trials in 2016.

TECHNICAL APPROACH

CONTROLLED EXPOSURE EXPERIMENTS (CEE)
Conducting controlled sonar exposure experiments on free ranging cetaceans at sea requires a variety of sophisticated equipment and expertise. The main platform will be the FFI RV HU Sverdrup II (HUS). During field trials the research team consists of 15 scientists with a multidisciplinary background, including experts in biology, underwater acoustics, oceanography, electronics, mechanical engineering, environmental science and operational sonar use. We have already conducted a sea trial in 2016. The outcome of this 2 week trial was 7 tags deployed and 6 exposure experiments conducted. Here follows a short description of the basic experimental design of the experiments.

Target species
We will primarily target sperm whales (*Physeter macrocepahlus*), but as a back-up, we can also work with pilot whales (*Globicephala melas*) and killer whales (*Orcinus orca*) opportunistically if we do not find sperm whales in areas with workable weather conditions. All target species have been studied by the 3S group before (Miller et al. 2011), and the basic design of the experiments is to replicate the previous dose escalation experiments to be able to use existing data in combination with new data.

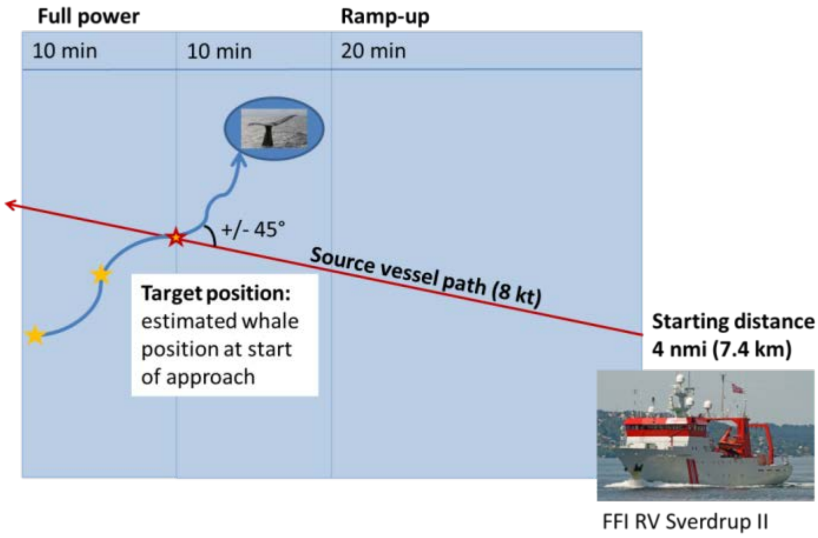

Figure 1. Planned geometry of CEE approaches (top) and example of actually sailed tracks during the four approaches during an experiment on a sperm whale on May 14th 2016 (bottom).

Data collection
Sea trials take place in Norwegian waters along the coast of northern Norway between Bodø and Tromsø. We search for whales using both visual observers and the TNO developed acoustic array Delphinus. When a target animal is localized, a tag boat will be launched and a standard DTAGv3 or a mixed-DTAG will be deployed using primarily a cantilever pole system. The mixed DTAG, which in addition to the DTAGv3 sensor package also contains a GPS logger and satellite transmitter to increase quality of the track of the whale and aid us in recovering the tag (see below). The long arctic days allow us to work 24/7 and to set the tag release time to 15-17 hours.
The tagged whale will be tracked using visual observers, aided by radio tracking of the VHF-beacon on the tag and acoustic tracking of vocalizing whales under water. During tracking the ship will sail in boxes of 2-3nmi by 2-3nmi around the expected location of the tagged whale. This sailing pattern has proven to be the optimal compromise between the visual effort, the acoustic tracking, the VHF tracking range and the desire to not affect the behavioral of the focal animal by the close presence of the ship. Good communication between the operators tracking the whale acoustically under water and the marine mammals observers (MMOs) using visual and radio tracking of the whale at the surface is important to achieve good tracking from a moving platform at such distances. This communication will be aided by a real-time geographical display of the acoustic tracks at the MMO platform. MMOs record the bearing and distance to the tagged whale and other animals in the area at each surfacing in Logger software, which is also used to display the tracks of the tagged whale at the surface.

CEE using the scaled SOCRATES sonar source
The experimental phase starts after 4 hours of baseline data collection. The SOCRATES source was developed at TNO, and is used as an experimental system within the Netherlands Navy. The maximum source level is 214 dB re 1μPa^2·m^2, and thus slightly lower than most operational LFAS systems. The source will be deployed and the source ship will position to approach the whale from a distance of 4nmi (7.4 km) (Figure 1). The course and speed of the tagged whale will be estimated using the NaviPac tool and a future position of the whale at the start of the approach will be estimated. The approach speed (8 knots, about 4 m/s) and course are kept constant throughout the 40 min approach. The approach course of the ship is 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. No course change will be made during the approach.

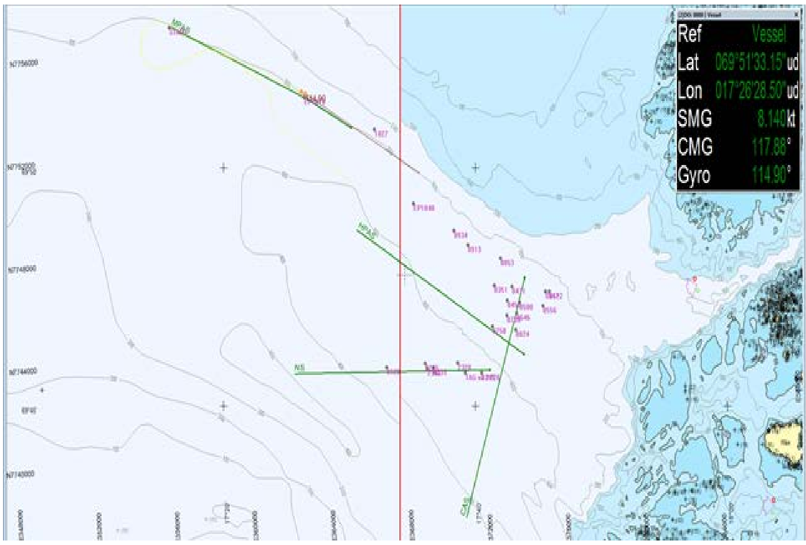

Table 1. During the CEE approaches with the scaled SOCRATES source, one of four different sonar signals were transmitted. No-sonar (NS), Continues active sonar (CAS), Moderate source level pulsed sonar (MPAS), and high source level pulsed sonar (HPAS)

SIGNAL	NS	CAS	MPAS	HPAS
Start and end source level (dB re 1μ$Pa^2 \cdot m^2$)	No-signal	141-201	141-201	154-214
Ramp-up duration (min)	20	20	20	20
SL increase	No-signal	1dB/pulse	1dB/pulse	1dB/pulse
Full power period (min)	20	20	20	20
SEL_{19s} (dB re 1μ$Pa^2 \cdot m^2$)	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 (kHz)	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.		

Transmission starts with a 20 min linear ramp-up (1 dB/pulse) at a level of 60 dB below maximum level, and continues with 20 min of full power transmission. The transmission and approach scheme aims to achieve a gradual increase of the received levels (dose escalation). Four different approaches will be conducted as part of each experiment (Table 1); each using one of four different transmission schemes of 1-2kHz frequency modulated up-sweeps (table 1); no-sonar (no signal transmitted), continuous active sonar (SPL=141-201 dB re 1μ$Pa^2 \cdot m^2$ / SEL_{19s}= 154-214 dB re 1μ$Pa^2 \cdot m^2 \cdot s$) and pulsed active sonar at two different source level ranges (SPL=141-201 dB re 1μ$Pa^2 \cdot m^2$ / SEL_{19s}=141-201 dB re 1μ$Pa^2 \cdot m^2 \cdot s$ and SPL=154-214 dB re 1μ$Pa^2 \cdot m^2$ / SEL_{19s}=154-214 dB re 1μ$Pa^2 \cdot m^2 \cdot s$). Between each approach the animal has to be relocated to estimate the start position and course of the next approach. The approaches will always be separated in time by at least 1 hour and 20 min from end of one approach to the start of the next.

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 distinguish between responses to the approaching ship alone from responses caused by the sonar signals. We will contrast the effect of continuous versus pulsed sonar by quantifying differences in the response thresholds and types of responses during the CAS and PAS exposures. Similarly, by contrasting the response to MPAS and HPAS exposures we can look at effect of range, because these two experiments give us the same received levels but 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.

Multiple exposures to multiple animals design

To achieve maximum output from the exposure experiments we plan to deploy multiple tags before starting the exposure sessions. This not only increases the sample size, but also allows a larger received level to range interval without conducting more exposures. We plan to use a mixed-DTAG and GPS logger which records the surface position of the whale as well as audio to quantify received level. The mixed tags also contain a satellite unit which helps us to retrieve it more efficiently than with VHF-tracking alone. This will allow us to deploy 2-3 DTAGs per exposure experiment. One of the tagged whales will be the focal whale for visual observation and tracking during each experiment, while data is simultaneously recorded from other tagged whales in the area during sonar transmissions.

We also plan to use a multiple exposure design, which means that tagged whales are exposed several times to different exposure conditions (Table 1). There are pros and cons to this approach. The main advantages are that the sample size of exposures can be increased without having to tag a new animal, and when comparing different exposure conditions (e.g. CAS versus PAS, or exposures at different ranges) individual and/or contextual variations can be dealt with more effectively because every animal acts as its own control. Within the 3S project we have been quite successful using this approach (e.g. Miller et al. 2012, Sivle et al. 2015). The key challenge is to balance the dataset, so that we can account for any order effect, which in itself is an important research question to address any habituation or sensitization to repeated exposures. So far we have not seen very strong order effects (e.g. Antunes et al. 2014, Miller et al. 2014, Isojunno et al. 2016). If there was a clear order effect, we would have to use subsequent exposures with care. Thus the first exposure is always the most valuable one. The time spent conducting multiple exposures to a single animal could be replaced by more single exposures to different animals. However, we don’t think that we are losing many opportunities to tag new animals by this multiple exposure design, and high levels of between-individual variation could swamp differential effects of the different signal types. The only potentially serious caveat with this design is that the post-exposure period is shortened to the time period allowed between subsequent exposures (here, ~1.5h). However, with sperm whales we have shown that the responses cease very soon after end of exposure (Miller et al. 2012, Isojunno et al 2016).

<u>CEE using a Norwegian ASW-frigate - optional 1 year expansion of the project</u>

In addition to the experiments with the SOCRATES source we will, as part of the current plan explore the possibility of using Norwegian ASW-frigates in controlled exposure experiments in the future. We will work to assure funding from 3S-partners for a sea trial in 2018 or 2019 and a 1 year expansion of the project to achieve this. The Nansen class Frigate of the Norwegian Navy operate the CAPTAS system which can transmit the same signal as the SOCRATES source but at higher levels (>220 dB re µPa·m). The Norwegian Navy operates their ASW frigates in the area of the experiments very regularly and FFI has received the strongest possible assurances that a frigate could be made available for this purpose. FFI has also previously worked with the Norwegian navy in a similar project where herring were exposed to sonar using a Nansen class frigate (Doksæter et al. 2012). The main benefit of using the frigate’s sonar systems is that we can achieve the same exposure levels but at much longer distances compared to the SOCRATES source. This is expected to give more statistical power to quantify the effect of distance versus received level. These experiments therefore supplement the dataset on the effect of range, and also allow us to investigate whether the effect of range is more important at relatively long distances. The exact geometry of the exposure with the frigate as the source ship will be decided based upon what we have learned from the initial experiments with the scaled SOCRATES source. The primary goal will probably be to start the exposure further away to achieve the same exposure level at greater distance. Alternatively, we could use the same approach and achieve higher received levels compared to the SOCRATES exposure, or even as a control to match one of the SOCRATES exposures at reduced level. As with the SOCRATES source, we plan to conduct 2-3 exposures on the same animal. During the trial with the frigate we will also have the SOCRATES source available on the Sverdrup.

DATA ANALYSIS APPROACHES AND EXPECTED SAMPLE SIZES

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. 2016), we have conducted similar experiments with pulsed sonar and therefore have reasonable estimates of both factors. Using state of the art statistical methods, in these cases hidden state-switching models 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 to 6 animals. Conclusive statistical analyses of the outcome of experiments have been possible because of the powerful experimental design in which animals are their own control (i.e., multiple exposures are conducted on a single tagged whale), with observations of rich multivariate observational data, and large effect sizes. However, the proposed research implies comparison between pulsed sonar at different levels and continuous active sonar, and even though individual variation can be expected to be similar, we have no means to estimate the effect size as we have yet no indication of whether responses will be greater or smaller when animals are exposed to CAS compared to pulsed sonar. However, analysis of the data collected during the trial in 2016 is expected to give us some first indications soon. We are therefore planning to conduct 12-18 experiments with the primary target species (sperm whales). During the 2 week trial in 2016 we already successfully conducted 6 experiments.

We will use established analytical approaches to contrast the effects of range and CAS versus PAS (DeRuiter et al 2013, Isojunno et al. 2016). 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 behavior, 2.) statistical analysis of the audits will address whether the use of CAS led to any acoustic responses that indicate biologically relevant signals were masked.

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