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Studying the effect of source proximity in sperm whales and continous sonar in pilot whales using operational sonars

— the 3S-2019-OPS cruise report

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Summary

The 3S project is an international collaborative effort with the aim to investigate behavioral reactions of cetaceans to naval sonar signals. The objectives of the third phase of the project are to investigate if exposure to continuous active sonar (CAS) leads to different types or severity of behavioral responses than exposure to traditional pulsed active sonar (PAS) signals, and to investigate how the proximity of the source to a whale affects behavioral responses. This report summarizes the efforts, activities and data collection of the 3S-2019-OPS research trial conducted over 4 weeks in Norwegian waters in August-September 2019. The primary tasks of the trial were to tag sperm whales with mixed-DTAGs and expose them to PAS at different levels and ranges, and to tag long-finned pilot whales with Mixed-DTAG and expose them to PAS and CAS.

When a target species was localized, a tag boat was launched and mixed-DTAGs deployed. The mixed-DTAG contained a GPS, an Argos satellite transmitter, triaxial accelerometers and magnetometer sensors, stereo acoustic sensors and a pressure sensor. In addition to the tags, data on potential vocal responses or avoidance of the exposed area were collected by two moored acoustic buoys. Tagged whales were subject to controlled sonar exposure experiments (CEE). The experimental design involved dose escalation at different ranges and maximum source levels using operational sources towed by the FFI research vessel HU Sverdrup II (HUS) or the Norwegian Navy frigate KNM Otto Sverdrup (OSVE). The experiments were conducted under permit from the Norwegian Animal Research Authority, and all procedures were approved by the Animal Welfare Ethics Committee at the University of St Andrews. A separate risk assessment and management plan was developed for the trial to minimize risk to the environment and third parties.

During trial we deployed 24 tags onto 20 different animals (15 sperm whales and 5 pilot whales), and collected 355 hours of tag data. We conducted 11 experiments, including 10 controlled exposure experiments with 25 exposure runs to sperm whales. Using the CAPTAS source on OSVE we conducted 7 CEEs with 16 exposure runs, and using the SOCRATES source on HUS we conducted 3 CEEs with 9 exposure runs. During 1 session with pilot whales we only collected baseline data, because the tags detached prematurely before any exposures.

What we achieved during the trial was the collection of a unique dataset, and the trial is considered to be successful. We expect that the data collected on sperm whales will be sufficient to answer the questions related to the effect of source proximity on responses. Unfortunately, the question of the effect of CAS on pilot whales cannot be answered with the data collected. Additional field effort is required to achieve this. This primary task was given significant priority, with 7-10 out of 24 days of ship time dedicated to it, and 20 hours of baseline data collected on pilot whales. Despite this effort, the outcome was marginal. Weather conditions were rough early in the trial when this task had highest priority, and no pilot/killer whales were found in the protected fjords. When the weather was acceptable we found pilot whales only once. Unfortunately, the behavior of the tagged pilot whales led to early tag release in worsening weather, so no exposure experiment could be conducted.

A video showing the activities during the trial can be seen following this link.

Sammendrag

3S-prosjektet er et internasjonalt forskningssamarbeid som undersøker hvordan hvalers atferd påvirkes av militære sonarer. 3S-prosjektet er nå i sin tredje fase der målsettingen er å undersøke om moderne kontinuerlige sonarer (CAS) har større innvirkning enn konvensjonelle pulsede sonarer (PAS), og å undersøke om avstanden mellom sonarkilden og dyrene påvirker terskelen for respons. Denne rapporten oppsummerer aktivitetene og resultatene fra 3S-2019-OPS-toktet som foregikk i 4 uker utenfor Andenes i august-september 2019. Toktet er det fjerde og siste som gjennomføres i 3S3-prosjektet. Målet med toktet var å merke spermhval med såkalte mixed-DTAGs og eksponere dem for PAS ved ulike nivåer og avstander, samt å merke grindhval og/eller spekkhogger og eksponere dem for CAS og PAS.

Metoden går ut på å finne dyr og deretter merke dem med mixed-DTAG ved hjelp av en lang stang fra mob-båt. Mixed-DTAG inneholder GPS, Argos satellittsender, treakse akselerometer, treakse magnetometer, stereo hydrofoner og dybdesensor. I tillegg til disse merkene ble det også samlet inn data fra to akustiske bøyer som ble satt ut i operasjonsområdet. Merkede dyr ble eksponert for sonarpulser på en kontrollert måte. Det eksperimentelle designet innebærer en dose eskalering ved ulike avstander og til ulike maksimale lydnivåer ved hjelp av operative sonarkilder tauet av FFIs forskningsfartøy HU Sverdrup II (HUS) eller den norske fregatten KNM Otto Sverdrup (OSVE). Tillatelse til å gjennomføre eksperimentet er gitt av Mattilsynet og den etiske komiteen ved Universitetet i St.Andrews. En egen risikovurdering ble gjennomført i forkant av toktet for å redusere risikoen for miljøeffekter eller negative effekter for tredjepart (fiskeri og hvalsafari).

Under toktet satte vi ut 24 merker (mixed-DTAG) på 20 ulike individer (15 spermhval og 5 grindhval). Vi samlet inn 355 timer med data på merkene. Vi gjennomførte 11 eksperimenter, inkludert 10 kontrollerte sonareksponeringer med 25 sesjoner på spermhval. CAPTAS-sonarkilden på OSVE ble brukt i 7 eksperimenter med 16 sesjoner, og SOCRATES-kilden på HUS ble brukt i 3 eksperimenter med 9 sesjoner. Under ett eksperiment på grindhval ble bare grunnlagsdata samlet inn fordi merkene falt av før eksponeringseksperimentet hadde begynt.

Under toktet har vi samlet inn et unikt datasett, og toktet betraktes som meget vellykket. Vi forventer at analyse av de innsamlede dataene vil kunne gi konkluderende svar på spørsmålet om avstanden til sonaren påvirker dyrets atferdsrespons. Spørsmålet om hvordan CAS påvirker grindhval kan derimot ikke besvares med data fra toktet. Her der det nødvendig med ytterligere feltarbeid. Datainnsamling på grindhval og CAS ble høyt prioritert, 7-10 av 24 seilingsdøgn med HUS ble dedikert til dette. Vi samlet inn 20 timer med grunnlagsdata på grindhval, men lyktes ikke med å få gjennomført noen CAS eksponeringer på grunn av dårlige værforhold i første del av toktet når grindhval hadde høyest prioritet. Vi fant heller ikke grindhval i samme antall som vi er vant med og ikke i det hele tatt i fjordene. Når været var akseptabelt, fant vi grindhval bare en gang. Disse dyrene hadde dessverre en atferd som gjorde at sugekoppmerkene ikke satt fast på huden lenge nok til at vi fikk gjennomført sonareksponering.

En video som viser aktivitetene under toktet kan ses om man følger denne linken.

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, SOCAL and Atlantic BRS projects) (Tyack et al. 2011, Southall et al. 2012, Southall et al. 2019) and in Norway (the three phases of the Sea Mammals and Sonar Safety 3S-projects) (Miller et al. 2011, Kvadsheim et al. 2015, Kvadsheim et al. 2019) over the past 10 years have shown large variation in responsiveness between different species, as well as 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 quantified. Results from BRS have helped navies to comply with international guidelines for stewardship of the environment, as well as rules and regulations within Europe and the USA.

The third phase of the Sea Mammals and Sonar Safety project (3S3) was started in 2016 and three successful sea trials have already been conducted to collect data on sperm whales and pilot whales (Lam et al. 2018ab) and on northern bottlenose whales (Miller et al. 2017). In the first two phases, 3S1 (2006-2010) (Miller et al. 2011) and 3S2 (2011-2015) (Kvadsheim et al. 2015), we investigated behavioral responses of six species of cetaceans to naval sonar signals, and addressed specific questions such as frequency specificity of behavioral responses (Miller et al. 2014) and the efficacy of ramp-up of source level (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 sonar operations on marine mammal populations. However, it is not obvious what the best measure of exposed 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 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 in 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 (proximity) the source affect behavioral responses?

Three CEE-trials have executed under the 3S3 project so far:

- The 3S16-ORBS trial off Jan Mayen to study the effect of range to the source in bottlenose whales (Miller et al. 2017).
- The 3S-2016-CAS trial off the coast of Northern Norway to study the effect of CAS and PAS in sperm whales and pilot whales (Lam et al. 2018a).
- The 3S-2017 trial off the coast of Northern Norway to study the effect of CAS vs PAS and effect of range on sperm whales (Lam et al. 2018b).

1.2 Tasks and priority of the 3S-2019-OPS trial

This report summarizes the outcome of the 3S-2019-OPS trial conducted off the coast of Northern Norway between August 24th and September 20th 2019 on the research vessel H.U. Sverdrup II (HUS) working alongside the Royal Norwegian Navy frigate KNM Otto Sverdrup (OSVE). The trial is the last planned trial under the 3S3 project and the specific tasks and priorities of the trial reflects the remaining issues to be addressed in order to meet the objectives of the project:

Primary tasks:

1. Tag sperm whales with Mixed-DTAG and expose them to PAS at different levels and ranges using the CAPTAS source on OSVE
2. Tag pilot whales or killer whales with Mixed-DTAG and expose them to PAS and CAS using the SOCRATES source on HUS.

Secondary tasks:

3. Tag sperm whales with Mixed-DTAG and expose them to PAS (HPAS) at distant ranges (close and distant) using the Socrates source on HUS, but mimicking the OSVE transmission scheme.

4. Collect data using moored passive acoustic sensors in the study area.
5. Collect baseline data of target species.
6. Collect information about the environment in the study area (CTD and XBT).
7. Collect acoustic data using towed arrays.
8. Collect sightings of marine mammals in the study area.

When the frigate (OSVE) was available the priority was to work on sperm whales (Task 1). When the frigate was not available the priority was to work with pilot or killer whales (Task 2).

The primary tasks had a higher priority than secondary tasks. We tried to accomplish as many of the secondary tasks as possible, and some of them are incorporated within our regular experimental protocol. However, secondary tasks were given a lower priority if they interfered with our ability to accomplish the primary tasks. Since we have already collected some data on pilot whales, it was a higher priority to replicate CAS-vs-PAS experiments on pilot whales than killer whales (task 2).

1.3 The 3S-2019-baseline trial

The 3S-2019 trial included two separate efforts. In addition to the full-scale controlled sonar exposure trial reported on here, a small team also conducted a baseline trial in the same area 2 months before the main trial using a sailboat. The primary task of the baseline effort was to test the redesign of the mixed-DTAG to assure optimal performance in the full scale sonar trial. We also wanted to test a new concept of using UAV drones to track the location of tagged whales and observe the social context of a focal tagged whale in its group. The cruise plan and cruise report of the baseline effort is included in Appendix D of this report.

2 Methods

2.1 Equipment and staffing

Conducting controlled sonar exposure experiments on free ranging cetaceans at sea requires a variety of sophisticated equipment and expertise. The main platforms of the trial were the FFI RV HU Sverdrup II (HUS) with a regular crew of 7 and the Royal Norwegian Navy frigate KNM Otto Sverdrup (OSVE) with a regular crew of more than 120. The research team consisted of 15 scientists on HUS with a multidisciplinary background, including experts in biology, underwater acoustics, oceanography, electronics, mechanical engineering, environmental science and operational sonar use. In addition, we had 1-2 dedicated liaisons on the frigate to accommodate coordination and communication between HUS and OSVE. HUS was a dedicated vessel to the 3S-operation. OSVE was primarily doing missile testing in the operation area, but supported our effort when available, mostly at night.

Figure 2.1 During the 3S-2019-OPS trial, scientists on board the FFI research vessel HU Sverdrup II (HUS) collaborated with the crew on the Royal Norwegian Navy frigate KNM Otto Sverdrup (OSVE).

Detailed descriptions of data collection procedures and equipment can be found in the 3S-2019-OPS cruise plan (Appendix C) as well as in the cruise report from previous trials under the 3S3-project (Lam et al. 2018ab) and in the data report (Kvadsheim et al. 2019).

Below follows a short description of the basic experimental design of the experiments conducted during the 3S-2019-OPS trial.

2.2 Data collection

Our target species were primarily sperm whale (*Physeter macrocepahlus*) and long-finned pilot whales (*Globicephala melas*), but killer whales (*Orcinus orca*) were secondary back-up species which we could work with opportunistically if we did not find the primary species in the areas with workable weather conditions. We operated along and off the shelf edge between Harstad and Tromsø (from Langnesegga to Fugløy deep), or 68.8-70.5° 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 and conditions allowed, a tag boat was launched and 1-2 mixed-DTAGs were deployed using a cantilever pole with sperm whales, and a hand-held pole with pilot whales (figure 2.2). The mixed-DTAG contained a GPS Fastloc sensor from Sirtrack and an Argos SPOT transmitter from Wildlife computers, in addition to the core unit containing the regular DTAG sensors (triaxial accelerometer sensors, triaxial magnetometer sensors, stereo acoustic sensors and pressure sensor). The core DTAG units were built and supplied by Alex Shorter at the University of Michigan. We aimed to deploy two tags on two separate animals, but if a second animal was not available the second tag could be deployed on the same animal to reduce risk of having to cancel part of the experimental program if the first tag falls off prematurely. On one occasion 4 tags were deployed at the same time, on three different animals. This was to optimize data collection when OSVE was scheduled to do a port call, and thus would not be available for a few days. Tag release time was set at 8-34 hrs, to release at least 4 hrs after the final scheduled exposure run.

Figure 2.2. Tagging of sperm whales with mixed-DTAG using cantilever pole (upper), and pilot whales using handheld pole (lower). Photos: Saana Isojunno (top), Elizabeth Henderson (bottom)

From tag-on until tag-off, focal animals were tracked using target localization based on an automatic direction finder (DF-Horten, LKARTS Norway) to track the VHF beacon on the tag in combination with acoustic tracking using the Delphinus system from HUS. During daylight hours the tracking was supported by visual observations.

In addition to the tags, data on potential vocal responses and avoidance of the exposed area was also collected by two moored acoustic buoys. Two Loggerhead Instruments DSG-ST Ocean Acoustic Datalogger (sampling at 144 kHz) with an aluminum housing were deployed using an IXSEA Oceano 2500S universal acoustic release. The two buoys were placed 27nmi apart at 1200-1500m depth in known hot spots for sperm whales within our operation area (figure 3.1 and 3.2). The idea was that they would monitor the vocal activity of sperm whales along a gradient from any exposure site.

2.3 Experimental design

Each tagged whale was subject to a controlled exposure experiment (CEE). To avoid habituation or sensitization from previous experiments, CEEs were never conducted within 20 nmi of the previous exposure within 24 hours when 214 dB max source levels was used, and 30 nmi when max source levels of >214 dB was used . This was based on expected response threshold and propagation loss.

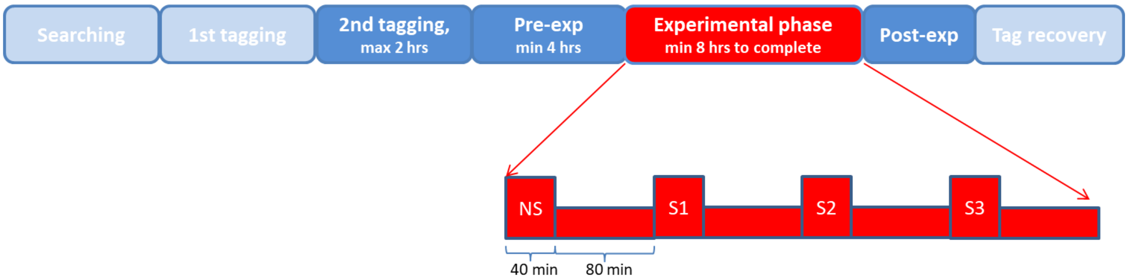


Figure 2.3 The experimental cycle of the CEEs goes through different phases. A search phase, a tagging phase, a pre-exposure phase for collecting baseline data, and an experimental phase with up to 4 different exposures were conducted lasting 40min, with min 1 hr 20 min of post exposure between each, a post exposure phase and tag recovery. Each cycle could include 1-3 tagged animals. The first exposure was always no-sonar control (NS), the following exposures used different signals (S1, S2, S3) depending on the species and source used. These signals are specified in table 2.1. The order of S1-S3 were rotated to maximize contrast.

The exposure protocol was developed to test differences in responses to continuous sonar signal compared to pulsed sonar signals in killer whales and pilot whales, and to address the importance of the distance to the source in predicting responses in sperm whales. During CEEs with killer whales and pilot whales, the SOCRATES source on HUS was the sonar source, and during CEEs with sperm whales the CAPTAS source on OSVE was the source. Thus, the priority was to tag sperm whales when the frigate was available and pilot/killer whales when the frigate was not available. The experimental protocols were designed to test these specific science questions, but also allow us to pool the data collected with data already collected during the 3S-2016 (Lam et al. 2018a) and 3S-2017 (Lam et al. 2018b) trials.

During the CEEs to sperm whales, four different sonar transmissions schemes with three different maximum source levels (figure 2.4, table 2.1) and two different approach distances (figure 2.5) were used. The sonar signal transmitted by the CAPTAS on the frigate and the signals transmitted by the SOCRATES source in previous trials (3S-206 and 3S-2017) are very similar, but do not match exactly, due to limitations in the CAPTAS system. Therefore, as a secondary objective, we planned to do a few control experiments to sperm whales where the SOCRATES source transmitted a signal matching the “frigate signal”, except for the lower maximum source level (table 2.1).

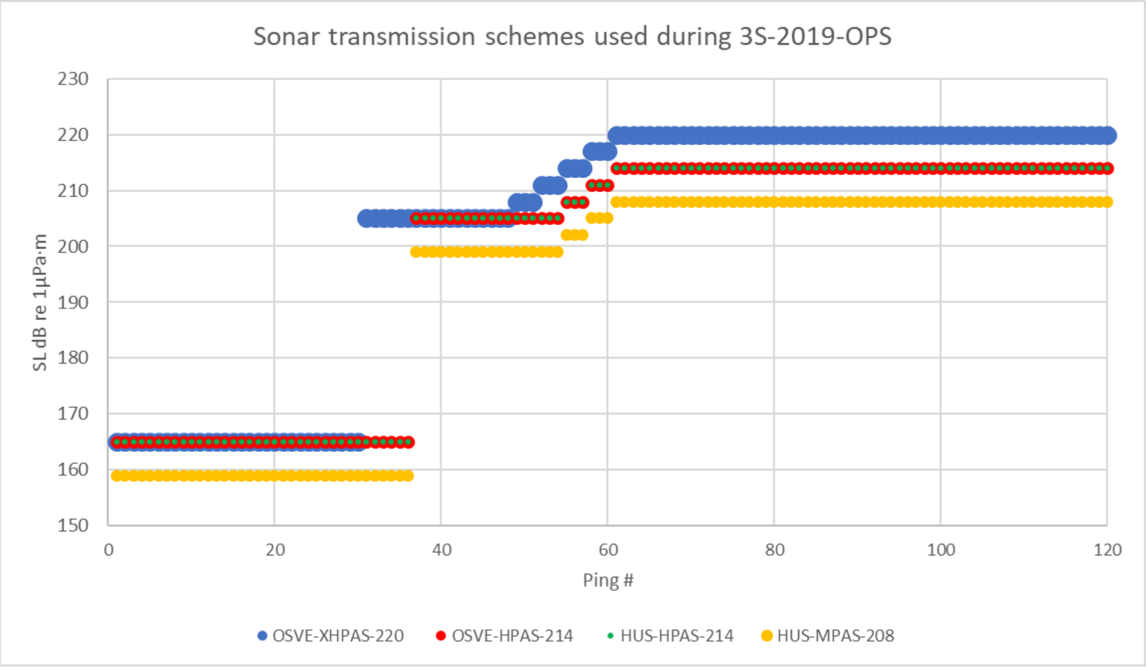


Figure 2.4 Transmitted source level and ping no (pulse repetition time was 20s) of the four different sonar transmissions schemes used during the sonar exposure experiment. OSVE-XHPAS-220 (blue) and OSVE-HPAS-214 (red) using the CAPTAS source on the frigate OSVE., HUS-HPAS-214 and HUS-MPAS-208 using the SOCRATES source on the research vessel HUS. Transmissions always started with a 20min ramp up followed by 20 min of full power transmissions. Further details of the transmitted pulses are given in table 2.1 and Appendix C.

A focal whale will be tracked by HUS throughout each experiment. With pilot/killer whales the tracking was supported with drones operated from a tag boat. Any additional tagged whale, beyond the focal whale, were considered non-focal whales. They would be exposed at the same time as the focal whale, but the position of the source vessel was determined by the movements of the focal whale, and therefore the distance and levels of the non-focal exposures were more variable. The track of both focal and non-focal whales could be reconstructed afterwards using the GPS logger on the mixed-DTAG.

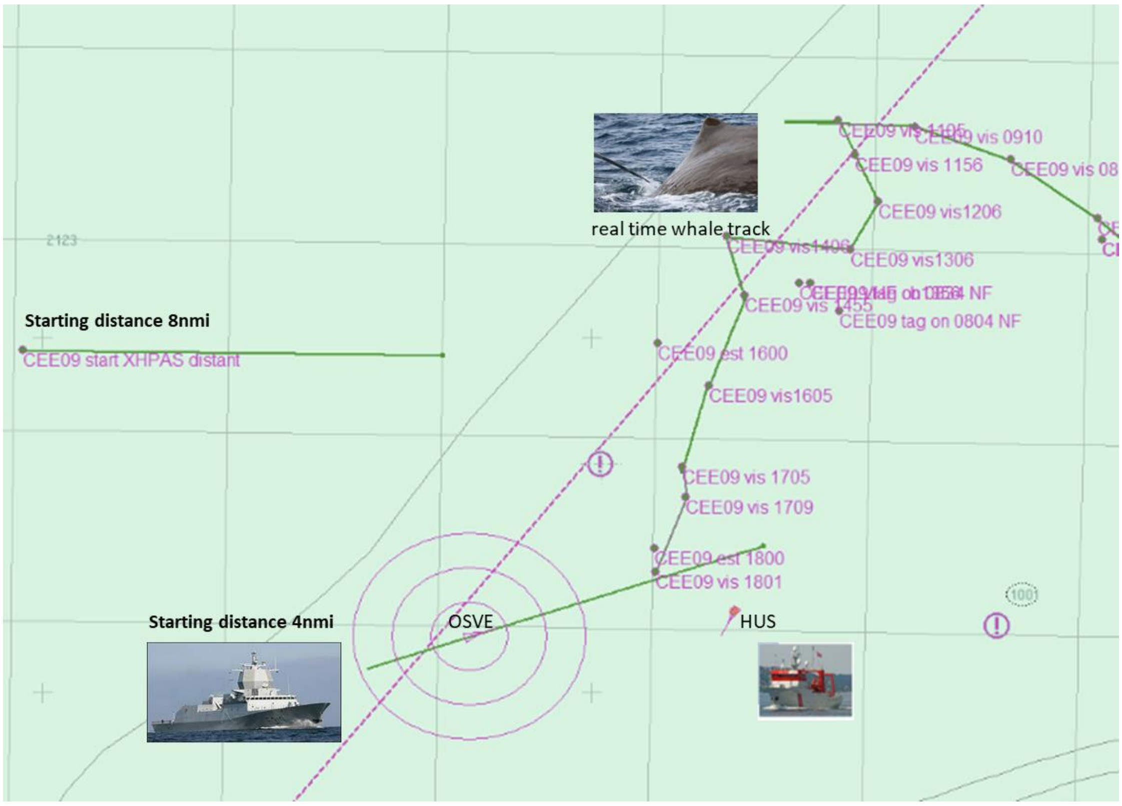


Figure 2.5 Geometry of the exposure experiments illustrated using the Helmsmann navigation display used to set up the experiments from HUS. This example is from CEE 09 of focal whale Sw19_255. In this case the real time track of the whale was based on visual observations from the marine mammal observer (MMO) station on HUS. OSVE first conducted a DISTANT exposure starting 8nmi from the whale, and later conducted a CLOSE exposure starting 4nmi from the whale. The runs were set up to approach the estimated position of the focal whale at the start of the exposures, intercepting the whale's path at a 45° angle to the front. The strict geometrical design of the experiments implied that OSVE approached on a course to intercept HUS tracking the whale, both ships with a long tow-tail behind them. This required very careful coordination to maintain safety and experimental design. The positions of HUS tracking the focal whale, and OSVE approaching the whale (half way through the planned 5.3nmi CLOSE exposure run) are shown.

Table 2.1 The sonar transmission schemes used during the sonar exposures of sperm whales. Two sonar systems were used, the SOCRATRES source on HUS and the CAPTAS source on OSVE. For both systems exposures using full power and a -6 dB signal were used. In addition to the sonar exposures no-sonar control approaches were also used. Sonar exposures always started with a 20min ramp-up and then 20 min of full power. Source levels are given as dB re µPa·m. During all exposures source depth was 100-120m, approach speed was 8 knots. Approach distance started either 4 nmi from the animal during CLOSE exposures or 8 nmi during DISTANT exposures.

SONAR SOURCE	**SOCRATES on HUS**		**CAPTAS on OSVE**	
SONAR SIGNAL	**HUS-HPAS-2014 (max)**	**HUS-MPAS-208 (-6 dB)**	**OSVE-XHPAS-220 (max)**	**OSVE-HPAS-214 (-6 dB)**
Min-Max Source level	165 - 214 dB	159 - 208 dB	[1] 165 - 220 dB	[1] 165 - 214 dB
Pulse duration/Pulse repetition time	1s/20s	1s/20s	[2] 1s/21-24 s	[2] 1s/21-24 s
Sonar pulse form	[3] 1280-1920 Hz HFM UpSweep	[3] 1280-1920 Hz HFM UpSweep	1280-1920 Hz HFM UpSweep	1280-1920 Hz HFM UpSweep
Approach distance	CLOSE=4nmi, DISTANT=8nmi	CLOSE=4nmi	CLOSE=4nmi, DISTANT=8nmi	CLOSE=4nmi
Ramp up (20min)	[4] 12min at 165dB, 6min at 205dB, 1min at 208dB, 1min at 211dB	[4] 12min at 159dB, 6min at 199dB, 1min at 202dB, 1min at 205dB	[1]10min at 165dB, 6min at 205dB, 1min at 208dB, 1min at 211dB, 1min at 214dB, 1 min at 217dB	[1] 12min at 165dB, 6min at 205dB, 1min at 208dB, 1min at 211dB

[1] These numbers are rough values because the max source level of the frigate is restricted information. The max level of the CAPTAS system on OSVE was used and given to be >220 dB. Here we assume that it was 220 dB. During reduced power transmissions the sonar system uses an attenuation factor (e.g. max attenuation -55 dB is then assumed to be 165 dB source level).

[2] The pulse repetition time of the CAPTAS system on OSVE is chosen automatically by the system to optimize search within a set range. It might therefore change from ping to ping if the sound speed profile changes.

[3] The pulse used in previous experiments with SOCRATES was 1000-2000 Hz HFM UpSweep. This bandwith was slightly altered because of limitation in the CAPTAS system of OSVE. These pulses were introduced to mimic the frigate pulses.

[4] Ramp-up used in previous experiments with SOCRATES started at -60 dB, then +1 dB/pulse to full power in 20 min. This ramp-up scheme was slightly altered due to limitation in the CAPTAS system of OSVE. This Ramp-Up scheme was introduced to match the frigate Ramp Up.

2.4 Risk management and permits

Experimental exposure of marine mammals to high levels of sound implies some risk that animals could be negatively affected (that is why it is important to study it). The experiments reported here were conducted under permit from the Norwegian Animal Research Authority (permit no 18/126201), and experimental procedures were approved by the Animal Welfare Ethics Committee at the University of St Andrews. A separate risk assessment and management plan was developed for the trial to minimize risk to the environment and third parties (Appendix C). This document also specifies suitable mitigation measures, endpoints and responsibilities.

Permits and ethics approvals implies monitoring of a mitigation zone 100-200 m from the source during active sonar transmissions depending on the source level. If animals are in danger of entering this mitigation zone the source must be shut down. After permits and ethics approval were in place we realized that nighttime operations were inevitable. In order to comply with permit and ethics approval, the following amendment to the mitigation procedures was implemented for nighttime operations:

> *"We will try to avoid doing experiments in the dark. However, if it happens and we are able to track the focal whale, we will do the experiments, as long as we can visually observe the mitigation zone. The mitigation zone will be extended to 100-200m from the ship and source together, and monitoring should be focused on the sector in front of the source and ship. On HUS visibility will be aided by search light in the front and aft, and OSVE will be instructed to use infrared night time vision equipment".*

This procedure was confirmed by the naval crew on OSVE.

3 Results

3.1 Overview of achievements

During the 3S-2019-OPS trial we managed to deploy 24 tags to 20 different animals (15 sperm whales and 5 pilot whales), and collect 355 hours of tag data. We conducted 11 experiments, including 10 controlled exposure experiments with 25 runs to sperm whales (figure 3.1, table 3.1). Using the frigate (OSVE) with the operational CAPTAS source we conducted 7 CEEs with 16 exposure runs, and using the SOCRATES source on HUS we conducted 3 CEEs with 9 exposure runs. During one experiment, we only collected baseline data, because the tags detached before the exposures started (table 3.1). This was the only session conducted on pilot whales, and thus no exposures to pilot whales were conducted.

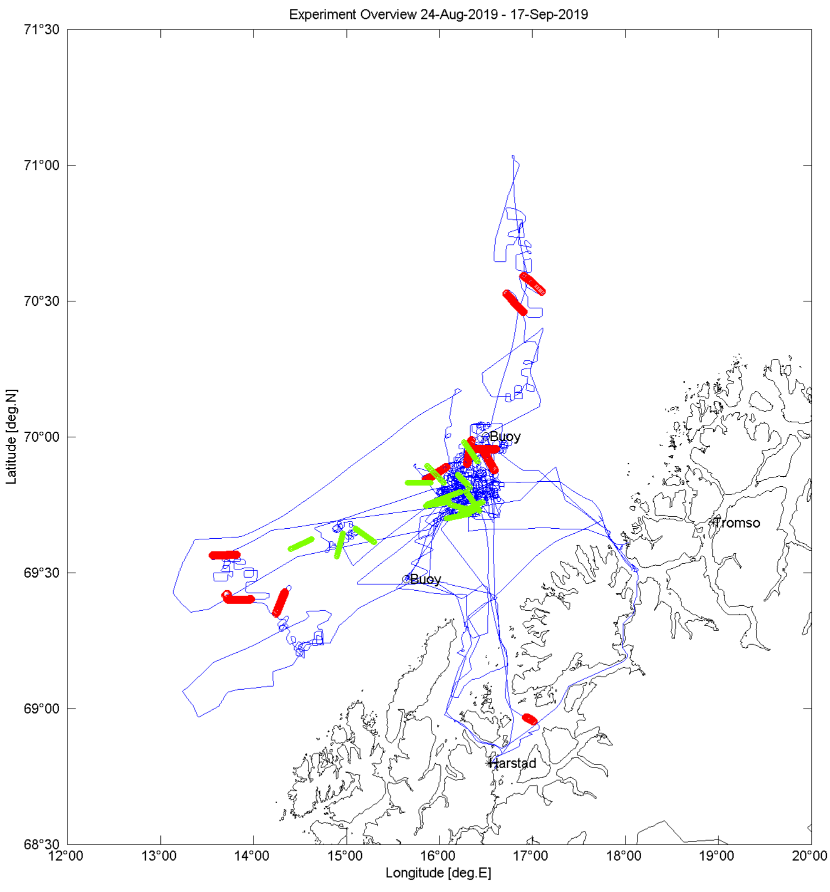


Figure 3.1 Overview of the sailed tracks of HUS between August 24th and September 17th 2019 (blue thin lines) and the exposure runs executed with SOCRATES (red thick tracks) and OSVE (green thick tracks). The positions of the two moored acoustic buoys are also indicated.

As usual, sperm whales were abundant in this area, and easily found along and off the shelf edge using the Delphinus acoustic array towed by HUS (figure 3.2) or marine mammal visual observers on HUS (figure 3.3). Compared to previous trials in the same area in 2016 and 2017 (Lam et al. 2018ab), we found surprisingly few pilot whales or killer whales. This forced us to spend significant effort searching for these target species, particularly in the first week of the trial, when OSVE was not available and working with pilot whales or killer whales in order to conduct CAS and PAS exposures with SOCRATES had the highest priority (table 3.2).

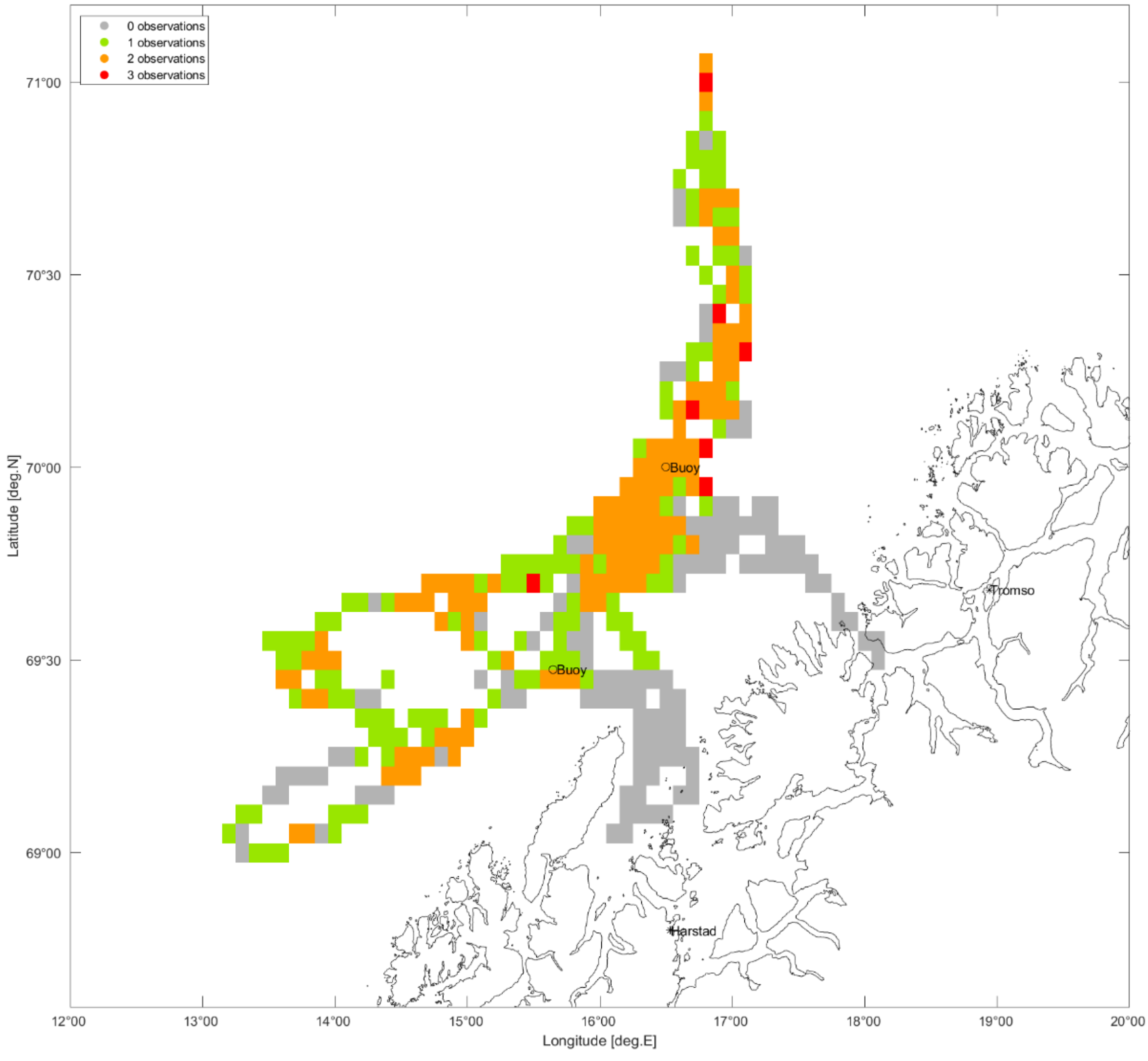


Figure 3.2 Average density of acoustically detected sperm whales on the Delphinus array towed by HUS between August 24th and September 18th 2019. The positions of the two moored acoustic buoys are also indicated.

Table 3.1 Overview of tag deployments and controlled exposure experiments (CEE) during the 3S-2019-OPS trial. NS=no sonar runs, PAS is Pulsed Active Sonar runs at max source level of 208 dB (MPAS-208), 214 dB (HPAS-214) or 220 dB (XHPAS-220). For CLOSE exposure runs the starting distance was 4 nmi, for DISTANT exposure runs the starting distance was 8 nmi. HUS means exposures conducted using the SOCRATES source on RV HU Sverdrup II, OSVE means exposures conducted using the CAPTAS source on the RNoN frigate KNM Otto Sverdrup.

CEE # / Source Vessel	DTAG ID	Species	Date/Area	Block/Runs
CEE 01 HUS	Sw19_241a Sw19_241b	Sperm whales	August 29th Off Stø	Baseline HUS-HPAS-214-CLOSE HUS-HPAS-214-DISTANT HUS-MPAS-208-CLOSE
CEE 02 HUS	Sw19_243a	Sperm whale	August 31st Off Fugløy banks	Baseline HUS-HPAS-214-DISTANT HUS-HPAS-214-CLOSE
CEE 03 OSVE	Sw19_244a Sw19_245a	Sperm whale	September 3rd Malangen	Baseline OSVE-XHPAS-220-DISTANT OSVE-XHPAS-220-CLOSE
CEE 04 HUS	Sw19_248ab[1]	Sperm whale	September 5th Malangen	Baseline HUS-NoSONAR-CLOSE HUS-HPAS-214-DISTANT HUS-MPAS-208-CLOSE HUS-HPAS-214-CLOSE
CEE 05 OSVE	Sw19_250ab[1]	Sperm whale	September 8th	Baseline OSVE-XHPAS-220-CLOSE OSVE-XHPAS-220-DISTANT
CEE 06 OSVE	Sw19_253ab[1,2]	Sperm whale	September 10th	Baseline OSVE-NoSONAR-CLOSE
CEE 07 OSVE	Sw19_253c	Sperm whale	September 10th	Baseline OSVE-XHPAS-220-DISTANT OSVE-XHPAS-220-CLOSE
CEE 08 OSVE	Sw19_254a	Sperm whale	September 11th	Baseline OSVE-XHPAS-220-CLOSE OSVE-HPAS-214-CLOSE OSVE-XHPAS-220-DISTANT
CEE 09 OSVE	Sw19_255ab[1] Sw19_255c Sw19_255d	Sperm whale	September 12th	Baseline OSVE-XHPAS-220-DISTANT OSVE-XHPAS-220-CLOSE OSVE-NoSONAR-CLOSE
CEE 10 HUS	Gm19_257a[2] Gm19_257b[2] Gm19_257c[2] Gm19_257d[2] Gm19_257e[2]	Pilot whales	September 14th	Baseline
CEE11 OSVE	Sw19_259a[2] Sw19_259b	Sperm whales	September 16th	Baseline OSVE-NoSONAR-CLOSE OSVE-XHPAS-220-CLOSE OSVE-XHPAS-220-DISTANT

[1]Two tags on the same animal. [2]Tag detached before any exposure was completed.

At the start of the trial we spent 2 days to complete installation of all equipment on-board and complete necessary training. At the end of the trial, we spent 1 day for de-mobilization. During the period of operation between August 26th and September 18th, we only had 8 short periods of interruption of the operation due to transits, bad weather or personnel transfers (table 3.2.). This was planned and expected.

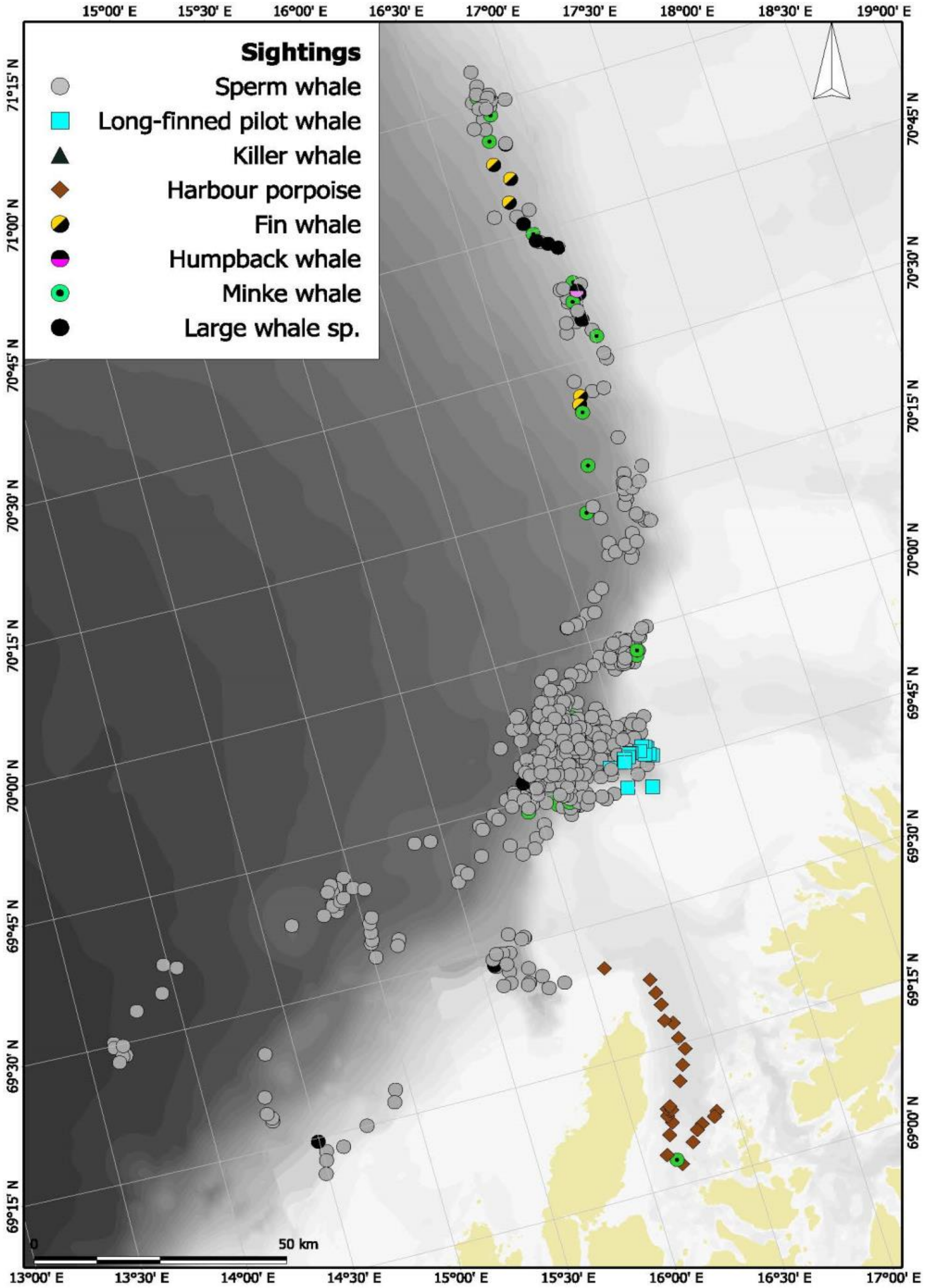


Figure 3.3 GIS plot of the marine mammal sightings made by the MMOs on HUS during 3S-2019-OPS. Locations are based on the bearing and range values recorded in Logger.

Table 3.2 Overview of weather at noon and overall activity during the 3S-2019-OPS 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
Aug.23	Harstad	Rendezvous, joint briefing				
Aug.24	Harstad	In port			Embarkment, Mobilization	No regular watches
Aug.25	Harstad-Vågsfjorden	Rain	SSW 5	3	Testing of Socrates and tags	No regular watches
Aug.26	Malangen-Bleik-Andfjord	Clouded	W 5	4	Deployed moored buoys. Testing tracking equipment. Started survey	Yellow / Green / Yellow / Red
Aug.27	Malangen – Andfjord	Partly Clouded	NW 3	2	Final test. Fully operational. Started survey	Red / Yellow / Green / Yellow
Aug.28	Andfjord – Bleik – shelf break S	Partly Clouded	E 2	1	Visually and acoustic survey for killer whales and pilot whales	Green / Green / Green / Yellow
Aug.29	Shelf edge off Stø	Fog	S 4	2	Tagged two sperm whales. Conducted CEE01.	Green / Green / Green / Yellow
Aug.30	Sheld edge Stø-Fugløy	Clouded	SW 3	3	Finished CEE I, recovered tags, surveyed northwards along shelf edge	Green / Green / Green / Yellow
Aug.31	Shelf edge off Fugløy Banks	Clouded	SSW 5	3	No detection of blackfish in operation area. Tagged sperm whales, CEE02	Green / Green / Green / Yellow
Sept.01	Fugløy bank – Malangen channel	Clear sky	E 5	3	Recovered tag, collected CTD, transit to Malangen, tagging sperm whales.	Yellow / Yellow / Green / Green
Sept.02	Malangen deep	Clear sky	SW 5	5	Tracking tagged sperm whale, preparing for CEE with frigate tonight. Tagged another sperm whale, switched focal.	Green / Green / Green / Green
Sept.03	Malangen deep	Partly Clouded	S 7	6	Conducted CEE03 with OSVE frigate, one focal and one non-focal whale. Recover tags. Transit to Harstad.	Green / Yellow / Red / Red
Sept.04	Harstad – Andfjord – Malangen	Rain	SW 5	2	Overnight port call in Harstad due to weather. Surveyed Andfjord and along shelf edge to Malangen	Red / Green / Yellow / Yellow
Sept.05.	Malangen canyon	Partly Clouded	SE 1	3	Tagged a sperm whale twice. Conducted CEE04.	Green / Green / Green / Green
Sept.06	Malangen canyon	Rain	N 7	5	Recovered tag. Too rough weather for tagging. Transit to Malangen for crew change.	Yellow / Yellow / Red / Red
Sept.07	Malangen Channel	Partly Clouded	NE 2	2	Tagged a sperm whale twice. Conducted CEE05 with OSVE.	Green / Green / Green / Green
Sept.08	Andfjord	Clouded	SW 6	4	Recovered tag. Surveyed along shelf edge and into Andfjord. Too rough weather to tag,	Yellow / Yellow / Red / Red
Sept.09	Malangen	Partly Clouded	S 4	4	Rough sea conditions. Tried tagging without success.	Yellow / Green / Red / Green
Sept.10	Malangen	Clouded	S 3	1	Tagged a sperm whale twice. Conducted CEE06. Both tags off 10min into no-sonar run. Tagged same whale again right before dark and conducted CEE07 with OSVE.	Green / Green / Green / Green
Sept.11	Bleik	Clear sky	E 3	1	Tagged a sperm whale and conducted CEE08 with OSVE	Yellow / Green / Green / Green
Sept.12	Malangen canyon	Clouded	S 3	3	Tagged 3 sperm whales with 4 tags and conducted CEE09	Green / Green / Green / Yellow
Sept.13	Off shore	Clouded	W 6	5	Recovering the six tags floating in the sea from the previous 3 CEEs	Yellow / Yellow / Yellow / Yellow
Sept.14	Malangen canyon	Clouded	W 3	3	Tagged 2 pilot whales. Tracked overnight. Tag released prematurely before CEE10.	Green / Green / Green / Green
Sept.15	Malangen-Bleik	Partly clouded	SE 4	3	Survey for blackfish. Recovered southern buoy.	Green / Green / Yellow / Green
Sept.16	Malangen	Clear sky	E 4	3	Tagged sperm whales, conducted CEE11 with OSVE	Green / Green / Green / Green
Sept.17	Malangen	Partly clouded	E 4	3	Recovered tag and northern buoy. Survey for blackfish	Green / Yellow / Yellow / Yellow
Sept.18	Malangen	Partly clouded	N 5	5	Survey for blackfish without success. Transit to Tromsø	Yellow / Green / Red / Red
Sept 19.	Tromsø	In port			De-brief, de-mobilization, celebration	No regular watches
Sept 20.	Tromsø	In port			De-mobilization, dissembarkment	No regular watches

3.2 Exposure experiments using operational sources.

Planning of the trial and the use of operational sonar sources operated from a naval combat vessel to do controlled exposure experiments to whales started in 2016 with a feasibility check. The Royal Norwegian Navy were positive to the idea, but careful planning was needed to find an area and a period where a frigate would operate over a long time period, where we could also locate whales. To assist the project in the planning, a dedicated point of contact within the Navy was appointed. An initial planning meeting was held in Bergen (close to the naval base) in April 2018, with the science team, project sponsors and the Norwegian Navy present. A final planning meeting was held in Bergen in March 2019 where final details of the operation were decided. At this meeting, the planned missile testing by OSVE off Andenes was identified as the best option for the trial, because these tests have a high priority for the Navy and the frigate was therefore expected to stay in the area for 2-3 weeks. This was also an area were 3S had operated before, and whale availability was expected to be good. However, we had worked in this area in May-June during previous trials, and now the planned period was August-September because of the frigate schedule. Sperm whales are mostly stationary in the area, and we did not expect any difficulties with whale availability. Based on the information we had, availability of pilot whales and killer whales were also expected to be good, but more uncertain.

Figure 3.4 Research vessel HU Sverdrup II (HUS, top panel) tracking a sperm whales, and KNM Otto Sverdrup (OSVE, bottom panel) approaching close during controlled exposure experiments. Photos: Saana Isojunno (top) and René Dekeling (bottom).

Three months before the trial, the cruise plan was finalized and the cruise leader gave the crew of the frigate a brief of the operation. Details of communication, navigation, and the sonar transmission schemes were discussed to assure good understanding of the importance of the strict experimental design. In addition, procedures for transfer of data from the sonar system on OSVE to the research teams after the trial was also established. During the trial we had dedicated liaisons on the frigate to facilitate communication and coordination between OSVE and HUS. They had good understanding of the science plan, but were also familiar with naval ships and operations.

Table 3.3 Overview of available OSVE data. In order to reconstruct the exposure experiment we need to supplement the tag data with navigation data (GPS position and time) and position, time and sonar settings for every transmitted ping. For exposure using HUS, this is all recorded automatically by the SOCRATES system. For most exposures runs with the frigate, high quality data were recorded by the CAPTAS sonar system on OSVE (green). For some runs the recordings were not switched on or data was corrupted from a hard-drive crash on OSVE (yellow). For those runs, we have to reconstruct the exposures using lower resolution navigation data from the bridge log on OSVE and manual records of start/stop time of runs and sonar settings, combined with tag data

CEE	RUN	Comments
CEE03	XHPAS-220-DISTANT	Sonar data and navigation data from CAPTAS system recorded every second
CEE03	XHPAS-220-CLOSE	Sonar data and navigation data from CAPTAS system recorded every second
CEE05	XHPAS-220-CLOSE	Sonar data and navigation data from CAPTAS system recorded every second
CEE05	XHPAS-220-DISTANT	Sonar data and navigation data from CAPTAS system recorded every second
CEE06	NO-SONAR-CLOSE	Navigation data from CAPTAS system recorded every second
CEE07	XHPAS-220-DISTANT	Sonar data and navigation data from CAPTAS system recorded every second
CEE07	XHPAS-220-CLOSE	Sonar data and navigation data from CAPTAS system recorded every second
CEE08	XHPAS-220-CLOSE	Sonar data and navigation data from CAPTAS system recorded every second
CEE08	HPAS-214-CLOSE	Sonar data and navigation data from CAPTAS system recorded every second
CEE08	XHPAS-220-DISTANT	Sonar data and navigation data from CAPTAS system recorded every second
CCE09	XHPAS-220-DISTANT	Sonar data corrupted/lost. Navigation data from OSVE bridge log recorded every min.
CEE09	XHPAS-220-CLOSE	Sonar data corrupted/lost. Navigation data from OSVE bridge log recorded every min.
CEE09	NO-SONAR-CLOSE	Navigation data from OSVE bridge log recorded every min
CEE11	NO-SONAR-CLOSE	Navigation data from OSVE bridge log recorded every min
CEE11	XHPAS-220-CLOSE	Sonar data corrupted/lost. Navigation data from CAPTAS system recorded every second
CEE11	XHPAS-220-DISTANT	Sonar data corrupted/lost. Navigation data from OSVE bridge log recorded every min

3.3 Sonar exposure experiments

In total 11 exposure experiment sessions (CEEs) were conducted (table 3.1). Sonar exposure experiments were conducted during 10 CEEs on sperm whales, 7 using the CAPTAS sonar system on OSVE and 3 using the SOCRATES system on HUS as the source. In total 25 runs were conducted, 4 no-sonar control runs, and 21 sonar exposure runs with source levels varying from 208 dB to 220 dB re µPa·m, and start of approach distances varying from 4 nmi to 8nmi from the focal whale. During CEE06 with sperm whales the tag detached prematurely after the no-sonar run had started. Another tag was soon after deployed on a sperm whale for CEE07, and based on photo id and drone pictures we later found out that this was the same whale. In CEE10 with pilot whales, the tag fell off before any experiment was conducted and since this was the only session on pilot whales, no sonar exposures were conducted on pilot whales.

Table 3.4 Table with experimental timeline of the controlled sonar exposure experiments (CEE). Times are based on Logger data, recorded sonar transmission times or received signals on the tag.

CEE	Focal ID	Non Focal ID	Session/run	Start_UTC	End_UTC
CEE01 HUS	Sw19_241b	Sw19_241a	BASELINE	29.08.2019 10:56:02	29.08.2019 16:43:00
			HUS-HPAS-2014-CLOSE	29.08.2019 16:43:00	29.08.2019 17:23:01
			HUS test signals	29.08.2019 18:58:00	29.08.2019 19:02:41
			HUS-HPAS-214-DISTANT	29.08.2019 19:11:00	29.08.2019 19:51:01
			HUS-MPAS-208-CLOSE	30.08.2019 03:17:00	30.08.2019 03:57:01
CEE02 HUS	Sw19_243a		BASELINE	31.08.2019 07:51:10	31.08.2019 12:35:00
			HUS-HPAS-214-DISTANT	31.08.2019 12:35:00	31.08.2019 13:15:01
			HUS-HPAS-214-CLOSE	31.08.2019 15:51:00	31.08.2019 16:31:01
CEE03 OSVE	Sw19_245a	Sw19_244a	BASELINE	02.09.2019 19:40:25	02.09.2019 22:57:55
			OSVE test signal	02.09.2019 22:57:55	02.09.2019 22:57:56
			OSVE-XHPAS-220-DISTANT	02.09.2019 23:11:23	02.09.2019 23:51:35
			OSVE-XHPAS-220-CLOSE (aborted run)	03.09.2019 01:15:00	03.09.2019 01:22:00
			OSVE test signal	03.09.2019 01:34:38	03.09.2019 01:34:44
			OSVE-XHPAS-220-CLOSE	03.09.2019 02:16:13	03.09.2019 02:54:29
CEE04 HUS	Sw19_248ab		BASELINE	05.09.2019 06:41:07	05.09.2019 10:41:00
			HUS-NoSONAR-CLOSE	05.09.2019 10:41:00	05.09.2019 11:21:01
			HUS-HPAS-214-DISTANT	05.09.2019 13:56:00	05.09.2019 14:36:01
			HUS-MPAS-208-CLOSE	05.09.2019 17:47:00	05.09.2019 18:27:01
			HUS-HPAS-2014-CLOSE	05.09.2019 20:10:00	05.09.2019 20:50:01

CEE05 OSVE	Sw19_250ab		BASELINE	07.09.2019 12:15:11	08.09.2019 00:50:00
			OSVE test signal	08.09.2019 00:00:09	08.09.2019 00:02:10
			OSVE-XHPAS-220-CLOSE	08.09.2019 00:50:21	08.09.2019 01:19:44
			OSVE test signals	08.09.2019 02:39:26	08.09.2019 02:41:29
			OSVE-XHPAS-220-DISTANT	08.09.2019 02:50:16	08.09.2019 03:30:28
			Incidental sonar detected on tag	08.09.2019 04:49:00	08.09.2019 04:50:00
CEE06 OSVE	Sw19_253ab		BASELINE	10.09.2019 09:16:07	10.09.2019 17:03:00
			OSVE test signal	10.09.2019 17:01:17	10.09.2019 17:01:57
			OSVE-NoSONAR-CLOSE (tags off during run)	10.09.2019 17:25:45	10.09.2019 18:05:45
CEE07 OSVE	Sw19_253c		BASELINE	10.09.2019 19:34:44	10.09.2019 23:07:00
			OSVE test signals	10.09.2019 19:32:34	10.09.2019 19:34:44
			OSVE test signals	10.09.2019 20:08:15	10.09.2019 20:23:56
			OSVE-XHPAS-220-DISTANT	10.09.2019 23:07:10	10.09.2019 23:50:25
			OSVE-XHPAS-220-CLOSE	11.09.2019 01:20:27	11.09.2019 01:59:55
CEE08 OSVE	Sw19_254a		BASELINE	11.09.2019 17:30:00	11.09.2019 21:42:00
			OSVE-XHPAS-220-CLOSE	11.09.2019 21:42:00	11.09.2019 22:22:00
			OSVE-HPAS-214-CLOSE	11.09.2019 23:41:00	12.09.2019 00:21:00
			OSVE-XHPAS-220-DISTANT	12.09.2019 02:00:00	12.09.2019 02:40:00
CEE09 OSVE	Sw19_255ab		BASELINE	12.09.2019 07:30:00	12.09.2019 09:00:00
		Sw19_255c	BASELINE	12.09.2019 08:03:13	12.09.2019 09:00:00
		Sw19_255d	BASELINE	12.09.2019 09:00:00	12.09.2019 15:27:00
			OSVE test signals	12.09.2019 15:27:00	12.09.2019 15:28:00
			OSVE-XHPAS-220-DISTANT	12.09.2019 16:02:00	12.09.2019 16:42:00
			OSVE-XHPAS-220-CLOSE	12.09.2019 18:05:00	12.09.2019 18:45:00
			OSVE-NoSONAR-CLOSE	12.09.2019 19:54:00	12.09.2019 20:34:00

CEE10 HUS	Gm17_257c		BASELINE	14.09.2019 15:16:19	14.09.2019 15:34:00
	Gm17_257d		BASELINE	14.09.2019 15:52:00	15.09.2019 03:20:00
	Gm17_257e		BASELINE	14.09.2019 17:05:00	14.09.2019 22:57:00
CEE11 OSVE		Sw19_259a	BASELINE	16.09.2019 09:25:21	16.09.2019 11:15:00
	Sw19_259b		BASELINE	16.09.2019 11:15:00	16.09.2019 23:30:00
			OSVE-NoSONAR-CLOSE	16.09.2019 23:30:00	17.09.2019 00:10:00
			OSVE-XHPAS-220-CLOSE	17.09.2019 02:34:00	17.09.2019 03:14:00
			OSVE-XHPAS-220-DISTANT	17.09.2019 04:40:00	17.09.2019 05:20:00

Below are maps with the tracks of HUS and the tagged whales as well as dive records from all CEEs (figures 3.5 -3.14).

Figure 3.5 CEE 01: Tracks of HUS and tagged whales Sw19_241a (non-focal whale) and Sw19_241b (focal whale) based on visual track, fastloc GPS and Argos (top panel). Dive depth versus time of Sw19_241b (lower panel). Three exposures were conducted during CEE01; HUS-HPAS-214-CLOSE, HUS-HPAS-214-DISTANT and HUS-MPAS-208-CLOSE.

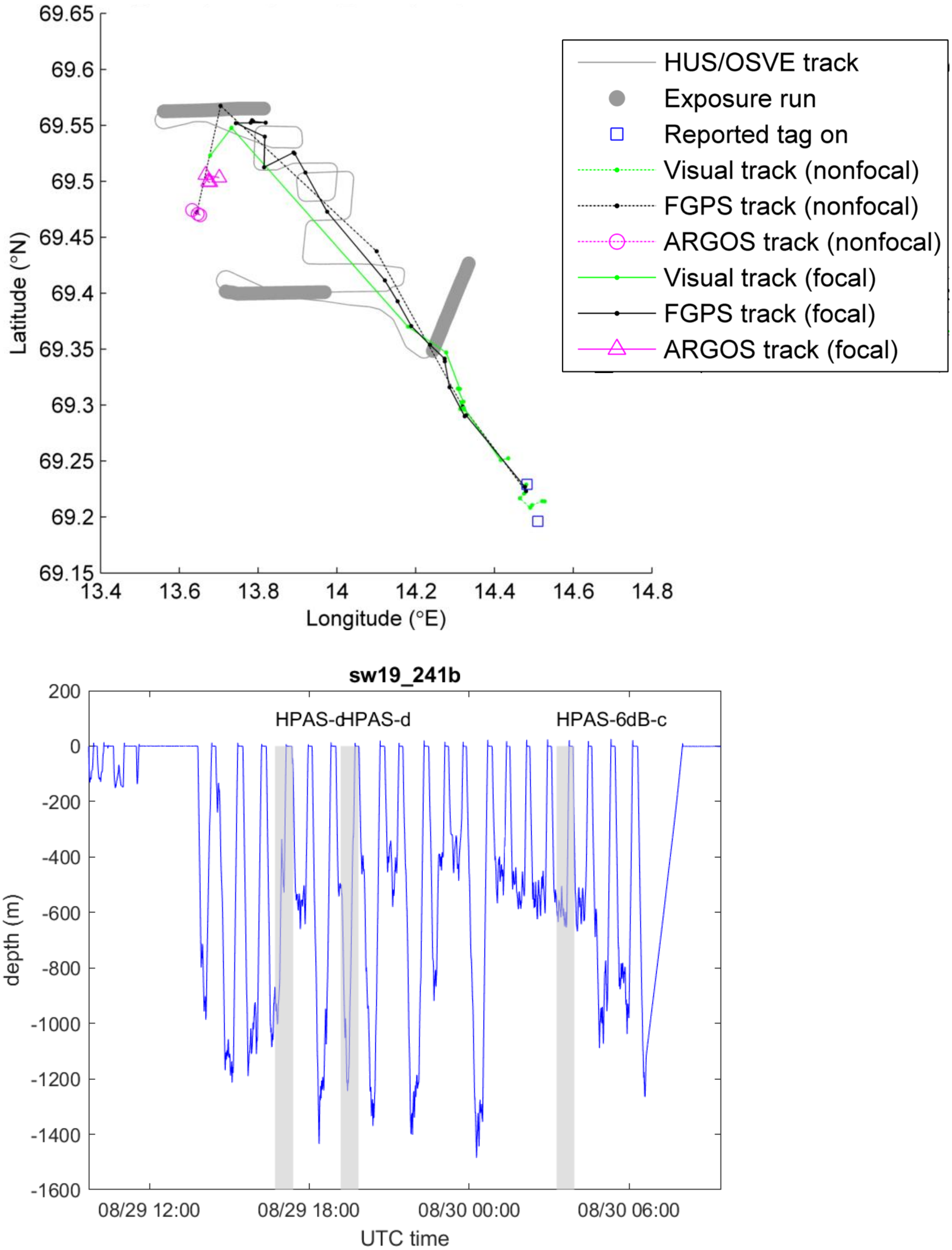
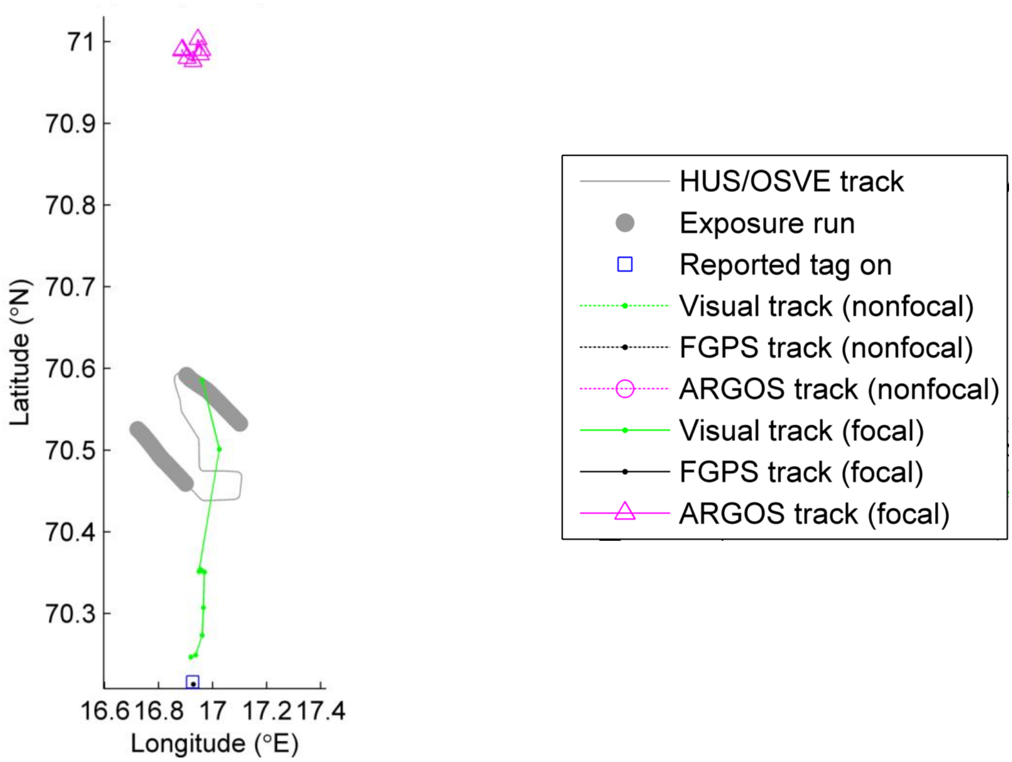


Figure 3.6 CEE 02: Tracks of HUS and tagged whales Sw19_243a (focal whale) based on visual track, fastloc GPS and Argos (top panel). Dive depth versus time of Sw19_243a (lower panel). Two exposures were conducted during CEE02; HUS-HPAS-214-DISTANT and HUS-HPAS-214- CLOSE.



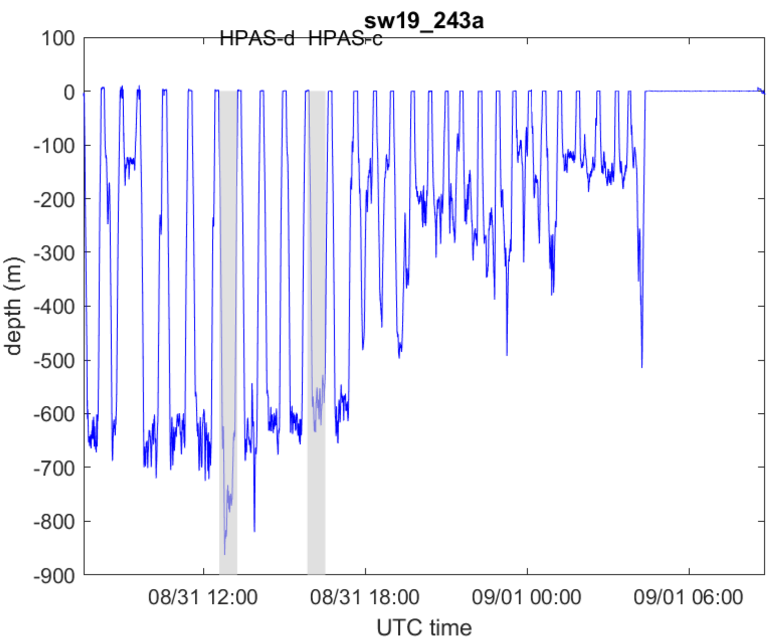


Figure 3.7 CEE 03: Tracks of OSVE and tagged whales Sw19_245a (focal whale) and Sw19_244a (non focal whale) based on visual track, fastloc GPS and Argos (top panel). Dive depth versus time of Sw19_245a and Sw19_244a (lower panel). Two exposures were conducted during CEE03; OSVE-XHPAS-220-DISTANT and OSVE-XHPAS-220-CLOSE.

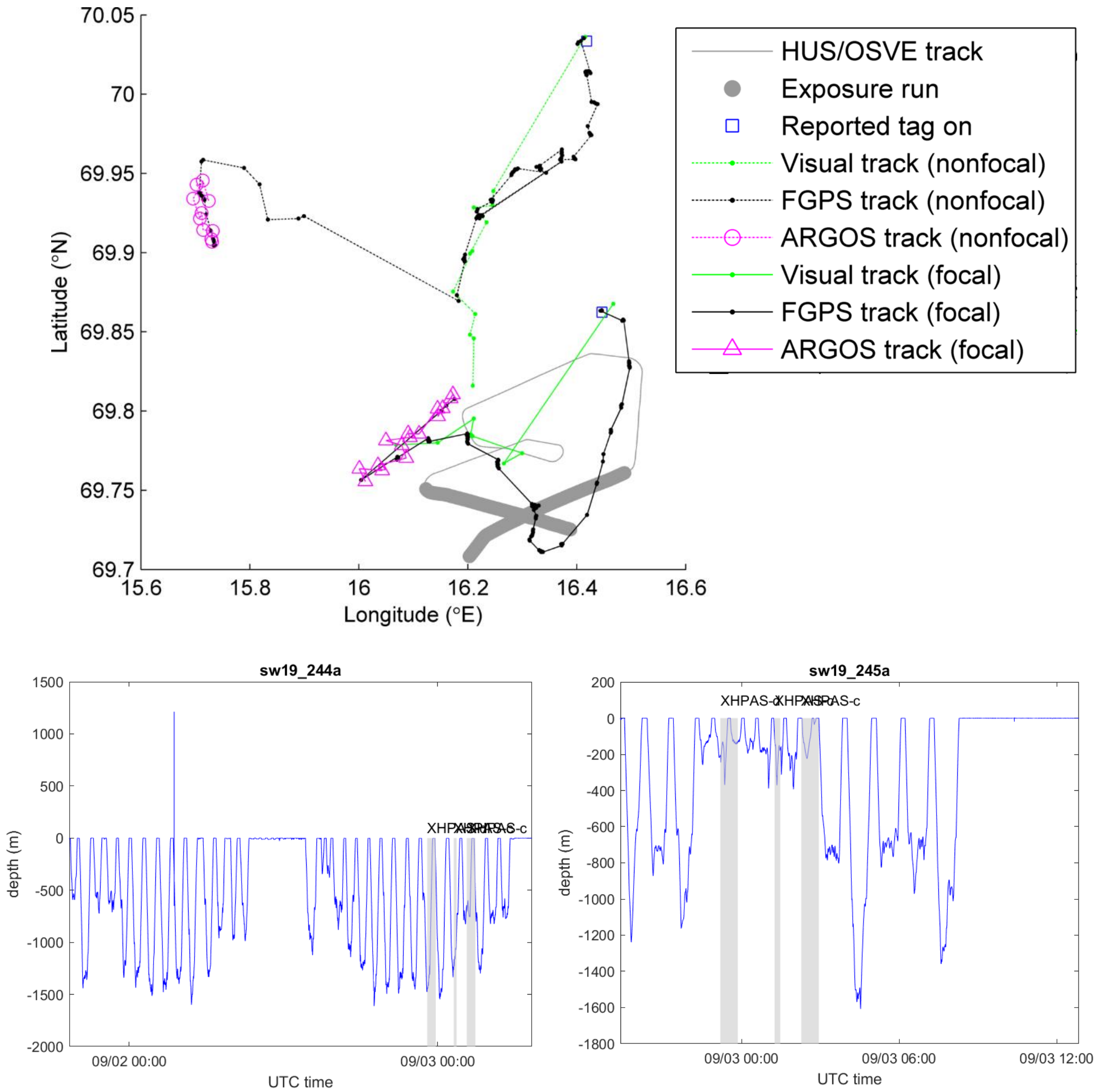


Figure 3.8 CEE 04: Tracks of HUS and tagged whales Sw19_248ab (focal whale with two tags) based on visual track, fastloc GPS and Argos (top panel). Dive depth versus time of Sw19_248ab (lower panels). Four exposures were conducted during CEE04; HUS-NoSONAR-CLOSE, HUS-HPAS-214-DISTANT, HUS-MPAS-208-CLOSE and HUS-HPAS-214-CLOSE. Tag Sw19_248a detached after the first two exposures, whereas Sw19_248b stayed attached through the entire experiment.

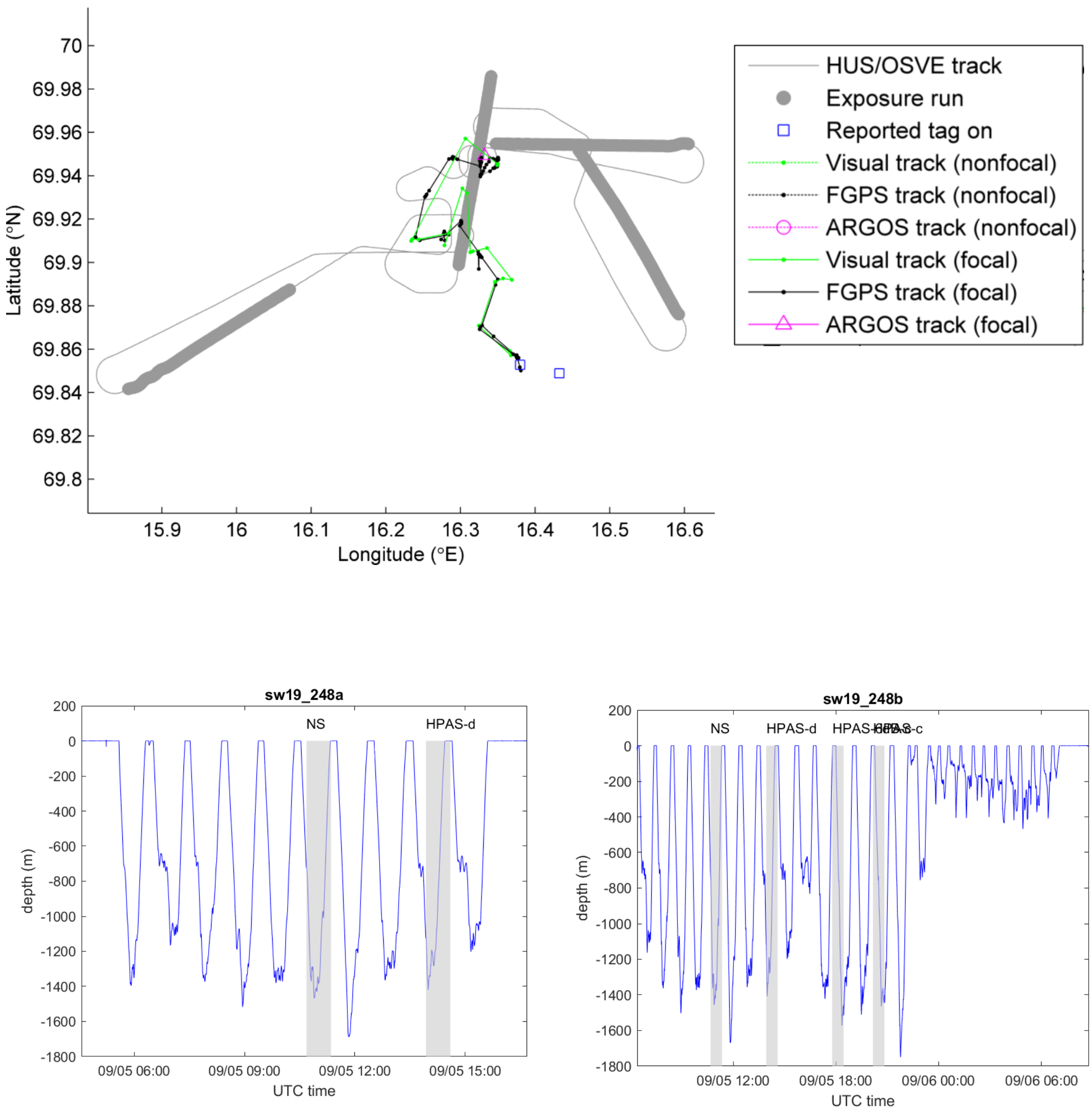


Figure 3.9 CEE 05: Tracks of OSVE and tagged whales Sw19_250ab (focal whale with two tags) based on visual track, fastloc GPS and Argos (top panel). Dive depth versus time of Sw19_250ab (lower panels). Two exposures were conducted during CEE05; OSVE-XHPAS-220-CLOSE and OSVE-XHPAS-220-DISTANT.

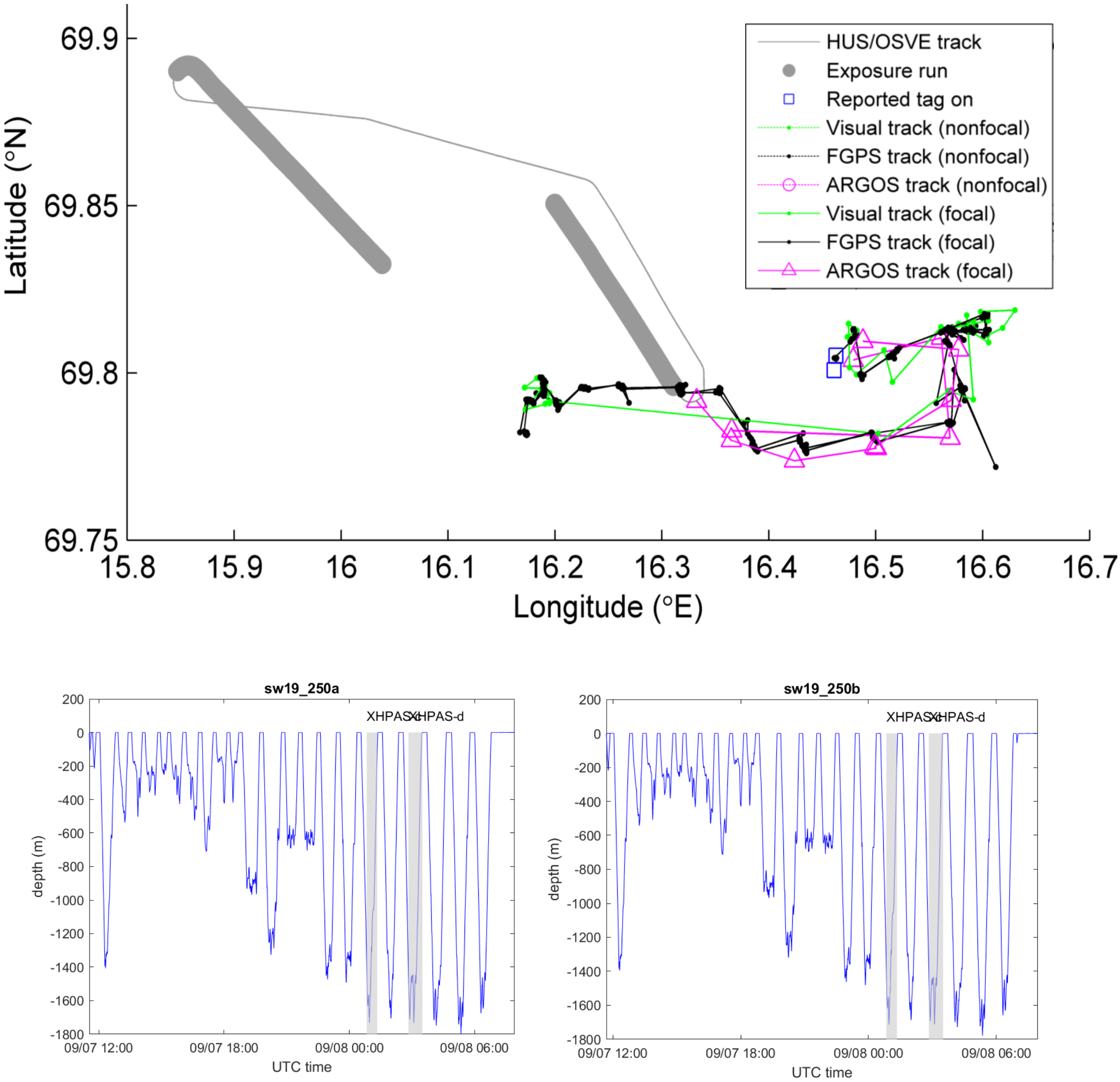


Figure 3.10 CEE 06 and CEE 07: Tracks of OSVE and tagged whales Sw19_253ab (focal whale with two tags, CEE06) and Sw_253c (focal whale, CEE07). based on visual track, fastloc GPS and Argos (top panel). Dive depth versus time of Sw19_253ab and Sw19_253c (lower panels). Only baseline data were collected during CEE06, but two exposures were conducted during CEE07; OSVE-XHPAS-220-DISTANT and OSVE-XHPAS-220-CLOSE.

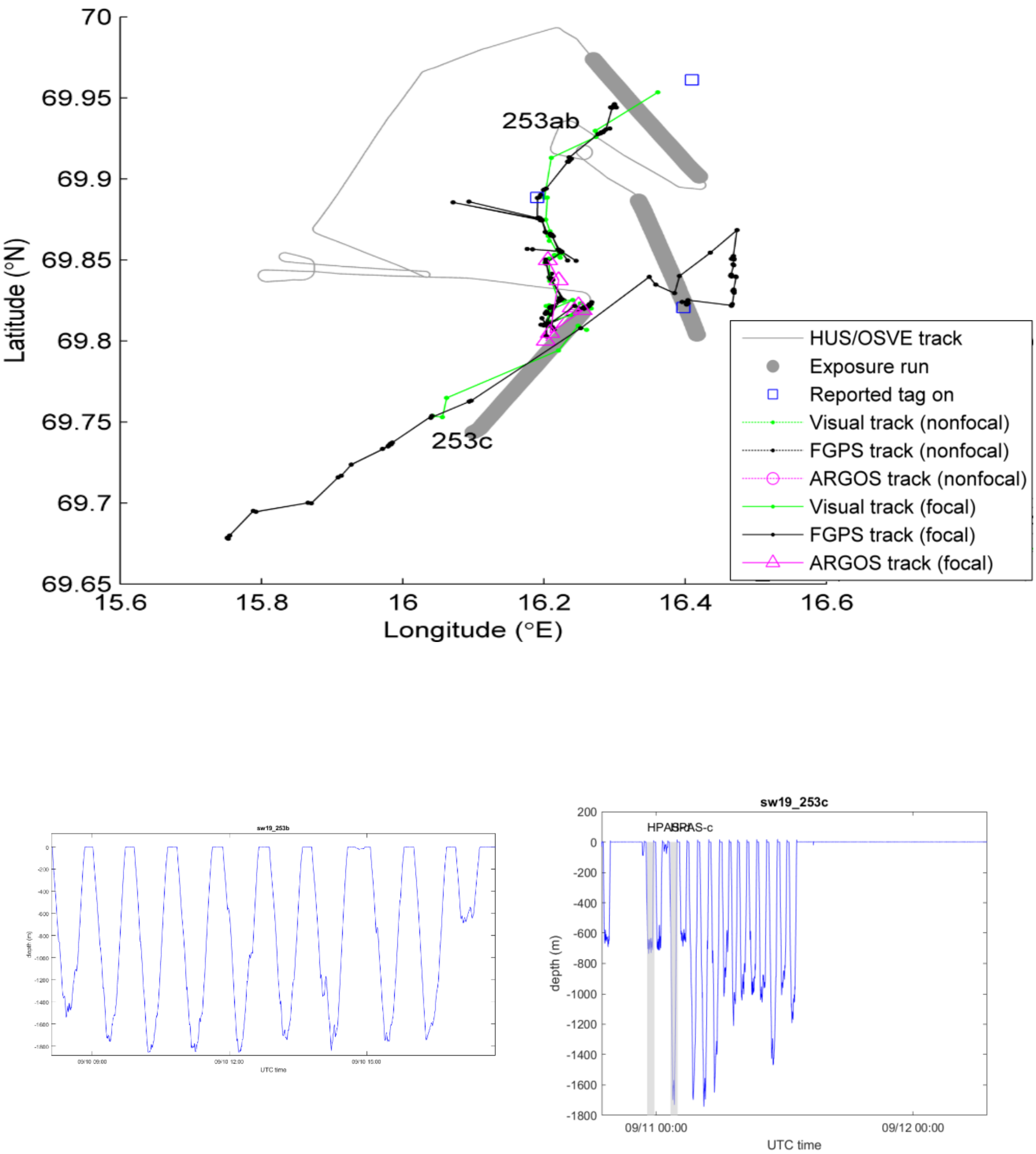


Figure 3.11 CEE 08: Tracks of tagged whales Sw19_254a (focal whale) based on visual track, fastloc GPS and Argos (top panel). Dive depth versus time of Sw19_254a (lower panels). Three exposures were conducted during CEE08; OSVE-XHPAS-220-CLOSE, OSVE-HPAS-214-CLOSE and OSVE-XHPAS-220-DISTANT. Track of source vessel OSVE not shown because data were not available yet.

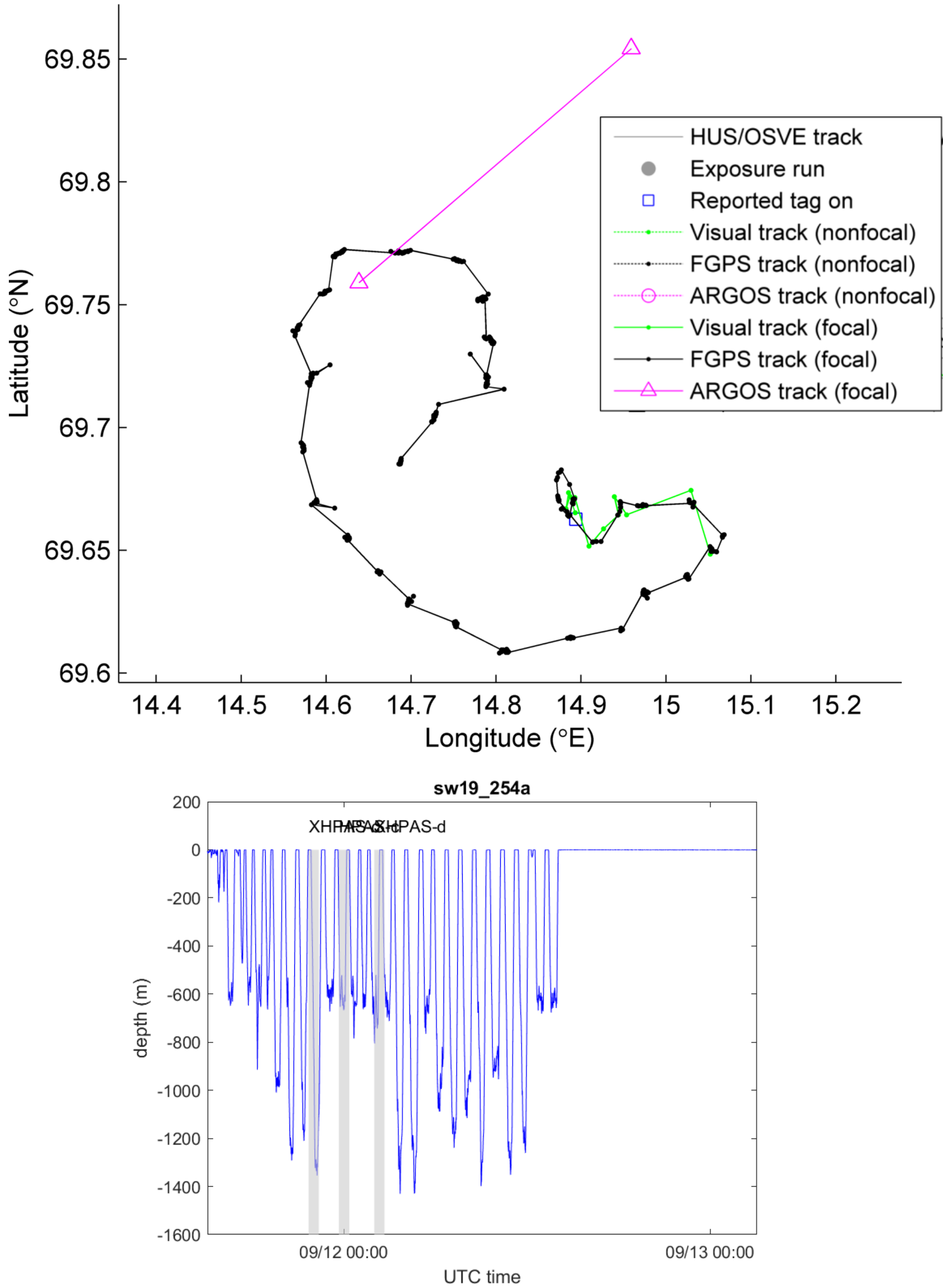


Figure 3.12 CEE 09: Tracks of tagged whales Sw19_255ab (focal whale with two tags), Sw19_255c and Sw19_255c (non focal whales) based on visual track, fastloc GPS and Argos (top panel). Dive depth versus time of Sw19_255b and Sw19_255c (lower panels). Dive records from Sw19_255a and Sw19_255d are not shown. Three exposures were conducted during CEE09; OSVE-XHPAS-220-DISTANT, OSVE-XHPAS-220-CLOSE and OSVE-NoSONAR-CLOSE. Track of source vessel OSVE not shown because data were not available yet.

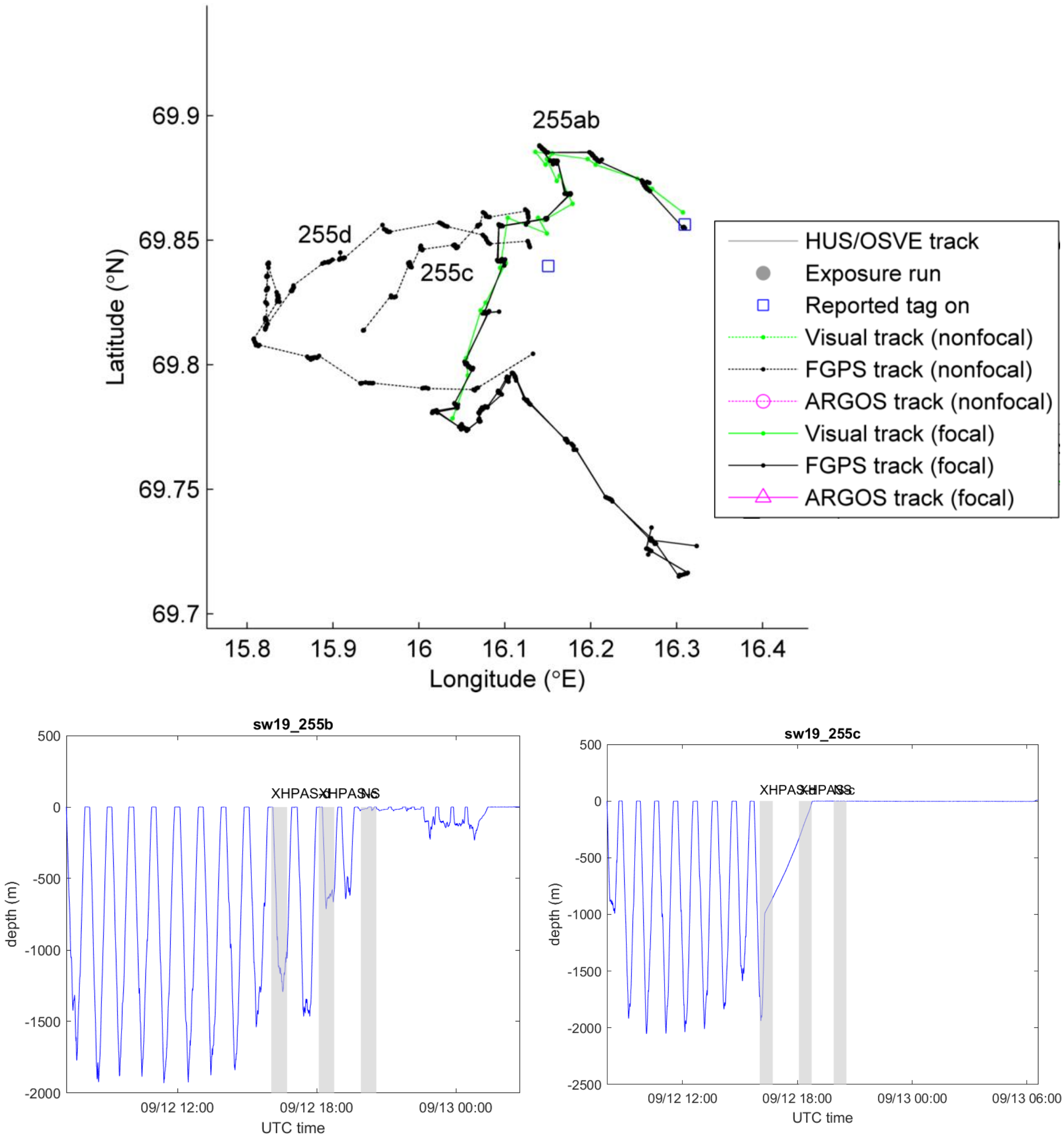


Figure 3.13 CEE 10: Tracks of tagged whales Gm19_257a, b, c, d and e (all from the focal group) based on visual track, fastloc GPS and Argos (top panel). Dive depth versus time of Gm19_257c and Gm19_257d (lower panels). Dive records from Gm19_257a,b and e are not shown. No exposures were conducted during CEE10 due to premature tag release, but 20 hrs of baseline data were collected.

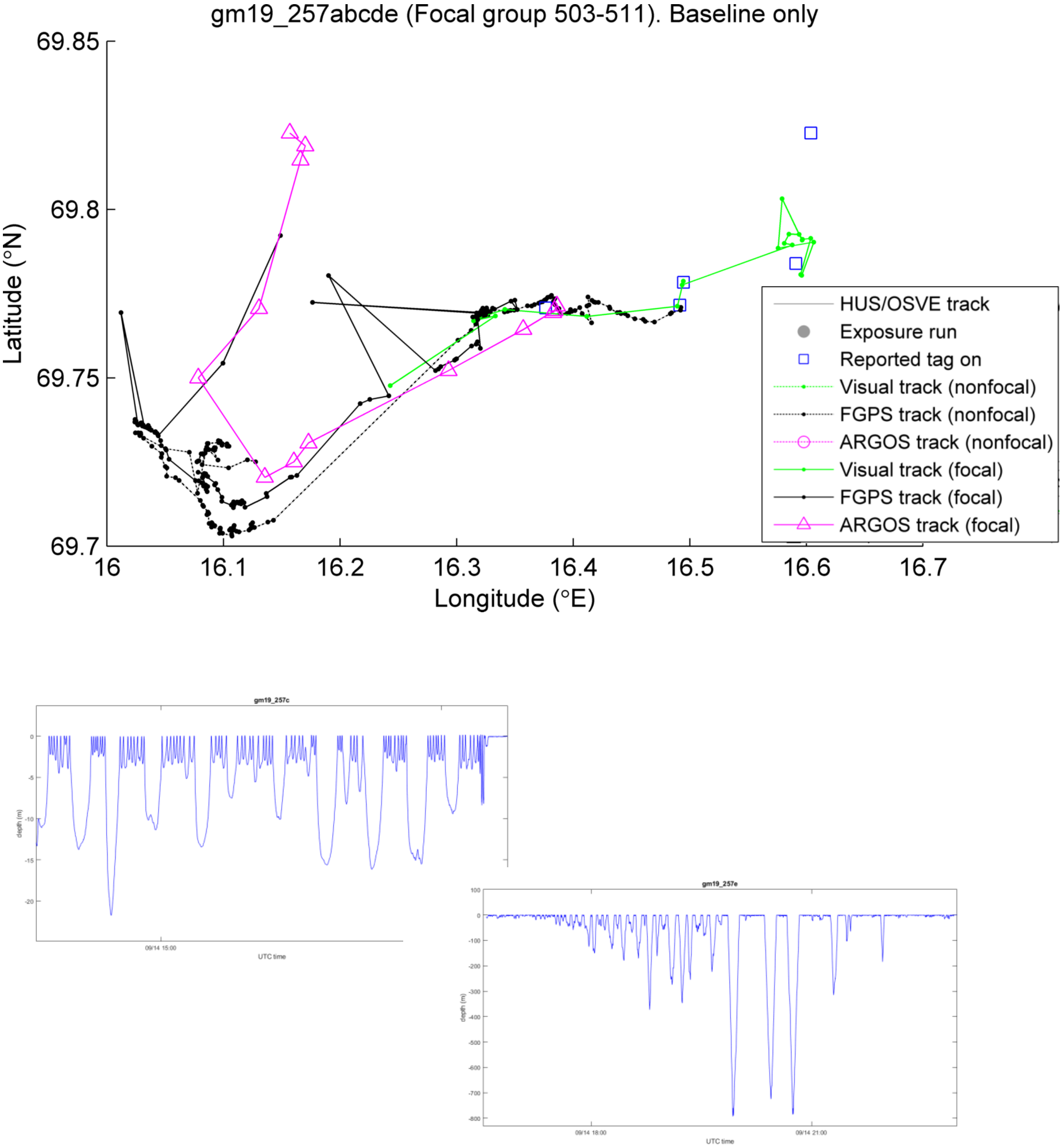
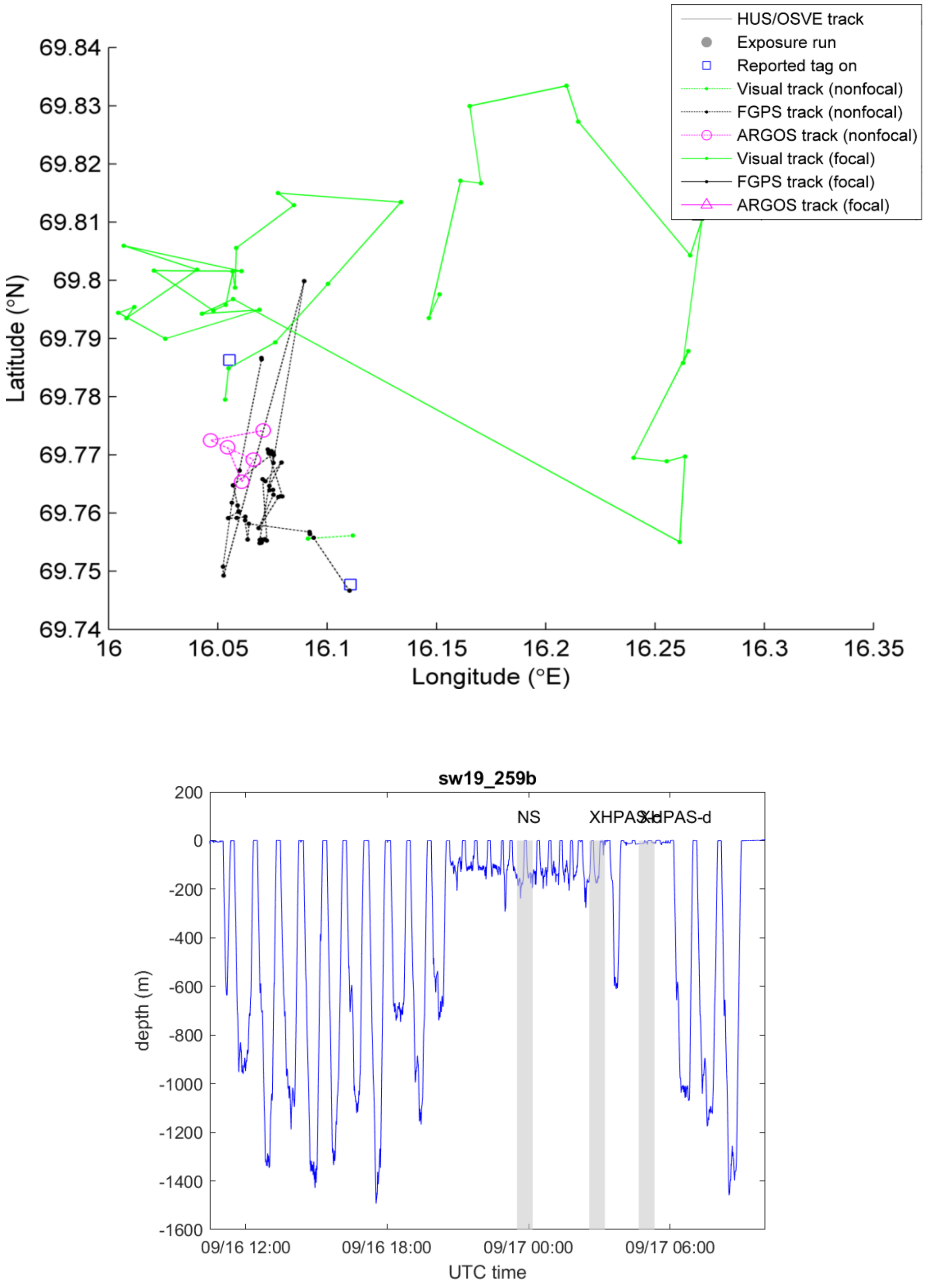


Figure 3.14 CEE 11: Tracks of tagged whales Sw19_259a (non-focal whale) and Sw19_259b (focal whale) based on visual track, fastloc GPS and Argos (top panel). Dive depth versus time of Sw19_259b (lower panels). Tag record from Sw19_259a is not shown (tag released before any exposures). Three exposures were conducted during CEE11; OSVE-NoSONAR-CLOSE, OSVE-XHPAS-220-CLOSE and OSVE-XHPAS-220-DISTANT. Track of source vessel OSVE not shown because data were not available yet.



3.4 Visual effort

In all phases of the operation when we were either searching for target whales, tagging whales or tracking tagged whales, marine mammal observers on the MMO deck on HUS were making visual observations of focal whales and any other whales sighted. Sightings were entered into the Logger software. Whale locations were calculated using the position and gyro heading of the vessel, and the range estimate and bearing measurement of the sighting. Of all range estimates, 11% and 26% were calculated based on the reticle count of the big eye binoculars and hand-held binocular, respectively. When reticles could not be used to make a sighting, e.g. due to poor weather conditions (sea state, swell, showers) or when land was visible on the horizon, the ranges were estimated by eye. Of all range estimates, 62% were reported as estimates by eye, although these were often guided by binocular observations.

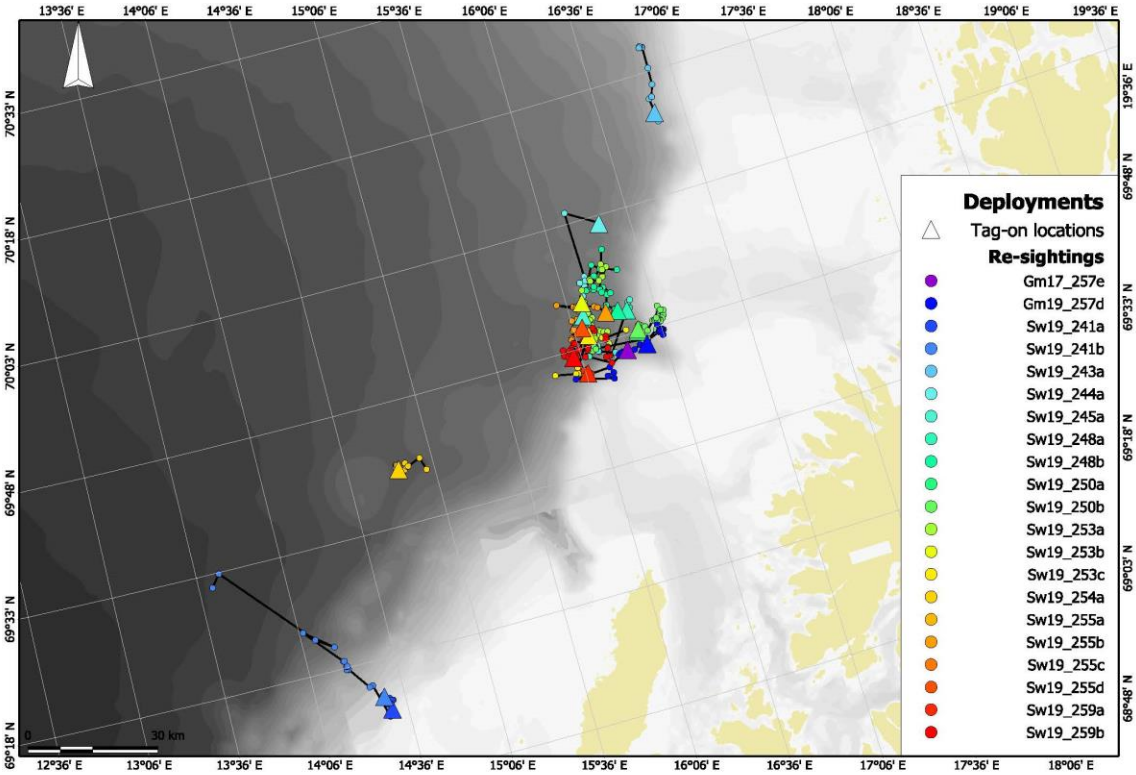


Figure 3.15 Tracks of tagged whales based on visual re-sightings made by the MMOs on HUS. Locations are based on the bearing and range values recorded in Logger.

A total of 467 sperm whale and 16 long-finned pilot whale sightings were recorded, excluding re-sightings (figure 3.3). Sightings of minke whale, harbor porpoise, fin whale, humpback whale, sei whale, killer whale, and a possible blue whale were also recorded. Horizontal tracks of the tagged whales consisted of an additional 509 location re-sightings, a median of 26 fixes per deployment (figure 3.15). Excluding re-sighting data, average group sizes were 1 for sperm whales (max 2), and 9.3 for pilot whales (max 25).

From the Logger database an experimental timeline was created based on event data entered into Logger (table 3.4). All on-effort events for each day are entered into an excel sheet, with the timing and data (UTC) from the effort form/comments. Experiment timing and timing of tag on/off was also checked with the Socrates log or the tag data itself, respectively.

3.4.1 Tracking in the dark

In the 3S-2019-OPS trial, there were substantial periods of darkness. The periods of darkness changed from 23:00-03:00 to 21:00-05:00 over the course of the four-week sea trial. Weather conditions, such as clear sky and sunshine versus a cloudy sky, influenced the light conditions as well. Visual observation was limited during sunset and sunrise, and not an option during nighttime. This affected both the search and tag phases of the experiment, since both of these phases had to be postponed until daylight. The ability to do sufficient mitigation during sonar exposures was decided on a case-by-case basis, depending on weather and light conditions, which continuously changed.

The tracking phase was also adapted at night. In the dark, VHF tracking from the OBS deck, in combination with acoustic tracking, were the most important tools because they could be used to fix the position of the focal whale in order to set up the experiment. Acoustic tracking using Delphinus is mostly useful if it is known which acoustic track to follow. We therefore established a procedure to use target motion analysis to get cross-bearing locations based on both the VHF signal from the tag, and match that with acoustic tracks, to follow the focal whale in the dark to set up the exposure experiments:

- When the animal surfaces and you hear a VHF reception (beeps), prioritize the tasks (especially if there are only 2-3 people on the MMO deck). Priority one is to get the initial bearing into Logger as soon as possible. Enter “999” as the resighting number, and enter “9000m” as the range. Don’t wait too long, otherwise your ability to do target motion analysis is lost.

- Call Socrates on the radio and tell them the animal is at the surface at the observed bearing, and ask them to turn the ship towards the whale to reach a 45 degree offset — either side is ok but port side is preferred.

- Continue to enter bearings into Logger, don’t wait for the turn to finish.

- Enter a final bearing when the VHF-signal stops. The bearings can give you a cross-bearing fix. Put the cursor on the fix and give that information to Socrates. Be aware that Logger gives you the absolute bearing and range to the cursor position (not the relative bearing).

- Provide the position of the cross bearing to Sverdrup, so that they can set up the experiment.

Figure 3.16 Example of target motion analysis on the logger display using the VHF signal from the tag and the DF-Horten directional receiver. A cross-bearing position (red dot) was made based on two bearings (orange lines) made before and after a turn of the ship (green line). This was considered to be a rough position of the focal whale, and based on this we could guide the acoustic tracking to choose the correct acoustic track of the focal whale, and set up the geometry of night time exposure experiments.

3.4.2 Data Management

The Logger program works with an Access database to log positions, monitoring effort, tracking and sightings. Data is entered in real time from the observation deck, and a backup is created at the end of every observer rotation. Data is then quality assured and checked by the lead MMOs. The data for the effort, sightings, re-sightings, VHF detections, and overall comments are transferred from Access into Excel, and each line is individually checked. For example, any corrections entered into the comments section are entered into the corresponding line of data, and a note of the correction is entered into that individual data point’s comments section inside brackets. Additionally, the accuracy of the reticles versus distance compared to the conversion sheets for big eyes and binoculars is checked individually. Below is a 5 step protocol to manage the Logger data:

1. Create a backup after every watch:
   a) go to the folder on the Logger computer that contains the database. There should be a shortcut on the desktop.
   b) copy the access database

c) paste copy of the access database onto dataserver 3s_2019(\\Datastorage) and rename with date and shift and initials of who made the backup.

2. Transfer access database into excel database to check the data
    a) this transfer only needs to be done one time, after that see 3.
    b) copy the logger database from the logger computer
    c) open a new excel file
    d) choose ‘Data’-tab in Excel
    e) choose ‘From Access’
    f) open the Access database from the backup folder
    g) import the logger database into an excel file
    h) select the box ‘Enable selection of multiple tables’
    i) select the relevant forms from the access database (comments, effort, lookup (only one time), tracker-**re**sighting, tracker**si**ghting, VHF)
    j) select ‘Table’ and it will automatically switch as well to New worksheet
    k) data will be imported when you click ‘ok’; NOTE: this might take a while.
    l) rename the sheets according to the forms in Access, database is imported.
3. Import new data input from logger access database into the ‘mother’ excel logger database
    a) copy new lines from access per form (comments, effort, tracker-**re**sighting, trackersighting, VHF) NOTE: check that you really open the right field and not recopy the previous field. Especially with trackerREsighting and trackerSighting.
    b) paste new lines in the ‘mother’ excel logger database
    c) delete extra line of heading cells automatically pasted in between old and new data
4. Check ‘mother’ excel logger database
    a) add 3 columns to excel logger database (headers: watch, checked by, delete)
    b) add watch number (1 or 2) for every line in ‘watch’ based on the timestamps
    c) add initials who checked the lines
    d) add a ‘x’ when a line can be deleted from original access database, don’t delete lines from the excel file.
    e) look at comments file for known errors that need correcting
    f) try to change as little as possible
    g) when you do change something, state what you’ve changed between square brackets [ ] in the comments column, try to be as short as possible
    h) check the accuracy of the imported data for effort, sightings, and resightings. Check reticles versus distance and compare to the conversion sheets for big eyes and binoculars.
5. Create experiment timeline in new sheet
    a) add all events, look up the timing and data (UTC) from the effort form/comments.
    b) get experiment timing from Socrates
    c) timing of tag on/off can also be checked with the tag data itself.

3.5 Acoustic effort

3.5.1 Passive acoustic detection and tracking

Delphinus acoustic array was towed extensively while searching, tagging and tracking sperm whales. In total 418 hours of data have been recorded, collecting almost 2 TByte of acoustic data (table 3.5).

Since 2017 the UHF data suffers 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 MF data also suffers from the same electronic interference, but for the MF data the effect was much less significant.

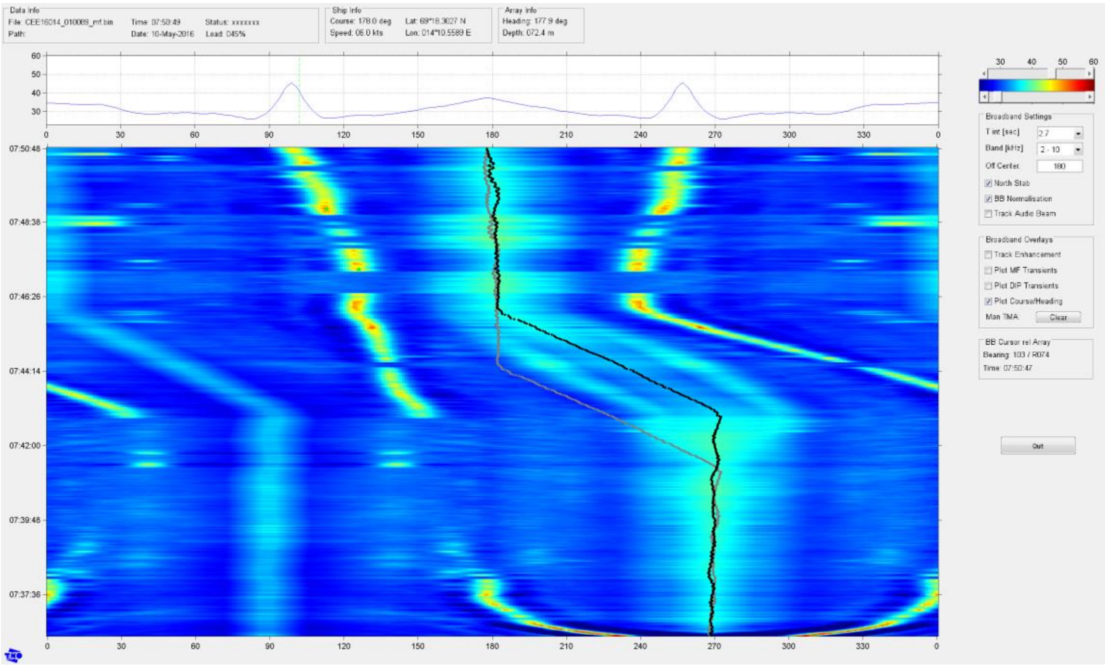


Figure 3.17 Screenshot of the Carcharodon broadband display showing an Amplitude-Bearing plot (top) and Bearing-Time plot (bottom). This display was mainly used to determine the bearing of the sperm whale vocalizations. The main beam is the track of H.U. Sverdrup, making a 90-degree turn around 07:44. 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.

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 3.17 and 3.18).

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 3.19). 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 H.U. Sverdrup, the tracks of the tag boats and other boats using AIS, acoustic detections and bathymetry (figure 3.20). 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 3.21).

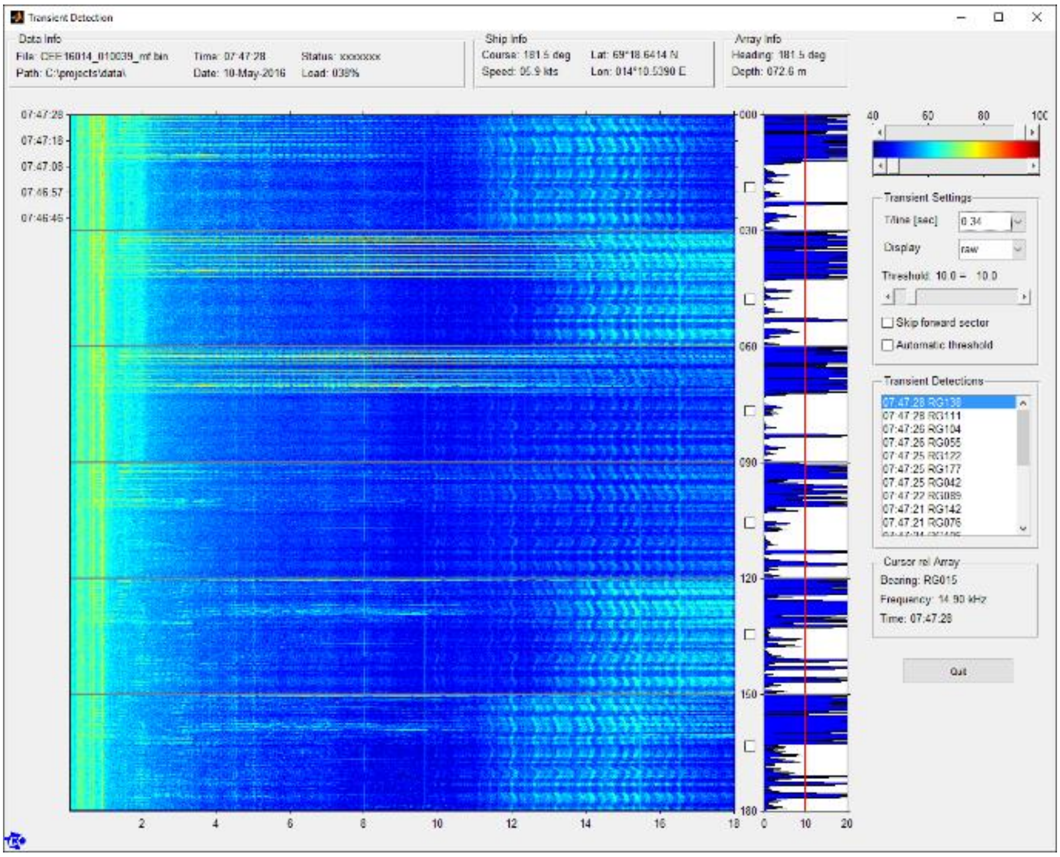


Figure 3.18 Screenshot of the Carcharodon transient detection display showing six time-frequency plots for six horizontal bearing sectors. This screen was mainly used for the initial detection and classification of sperm whale vocalizations.

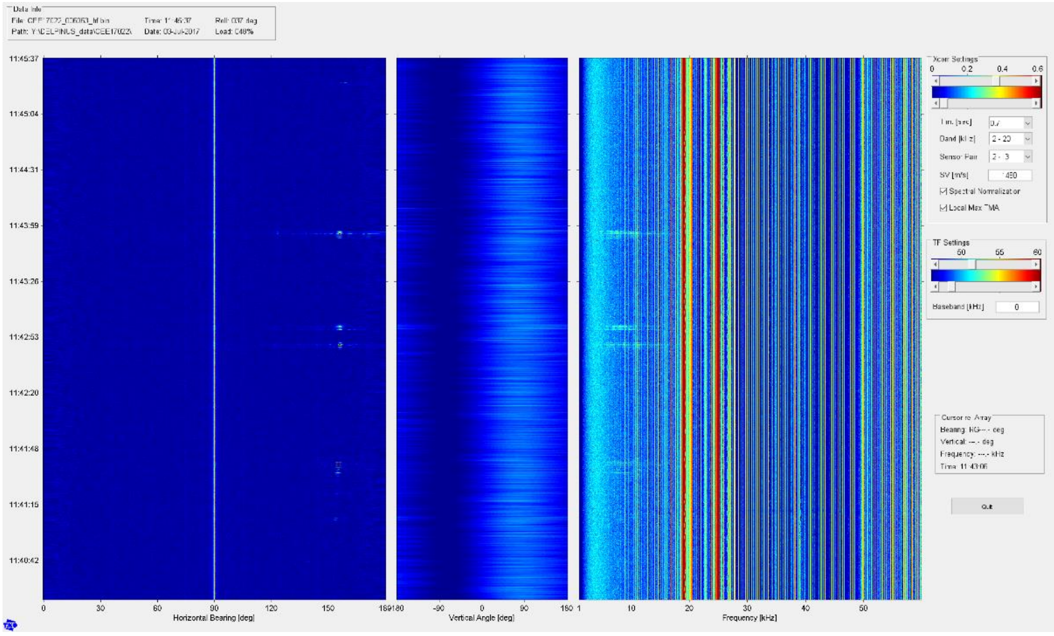


Figure 3.19 Screenshot of Thetis showing a horizontal bearing-time plot (left), vertical angle-time plot (middle) and time-frequency plot (right). The right panel shows serious electronic interference in the UHF data.

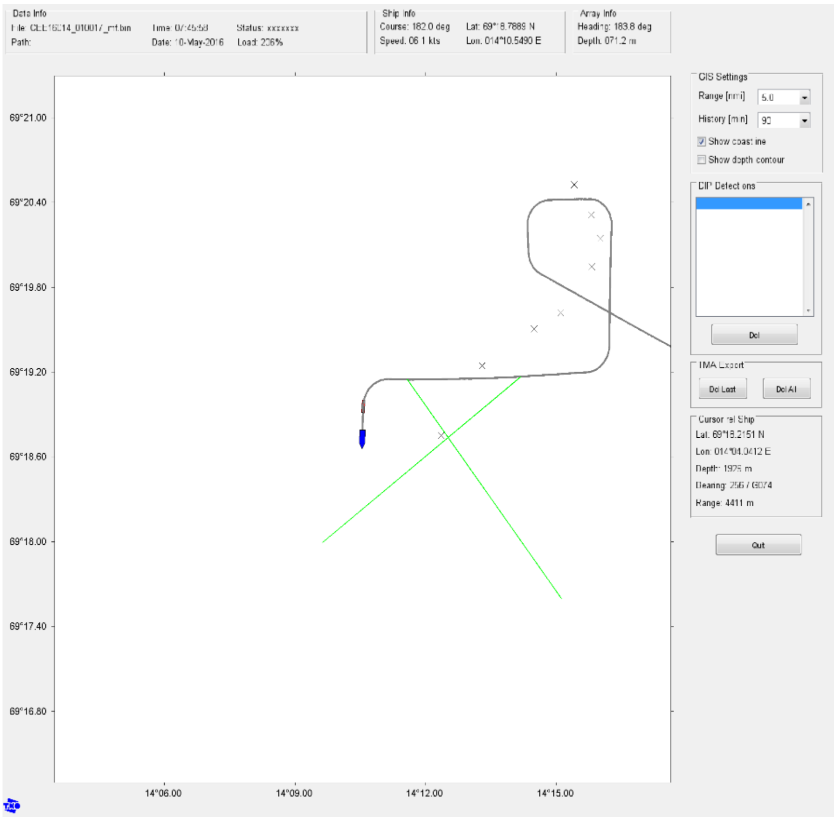


Figure 3.20 Screenshot of the Carcharodon GIS or TMA display. Own ship (track) and array (track) are depicted by the blue ship symbol and red box on the grey line. Bearings of the detected whale vocali-zations are shown in blue (Thetis) and green (Carcharodon). The estimated whale location is marked by the cross (x), which is then exported to the second GIS display at the marine mammals observer station (figure 3.21).

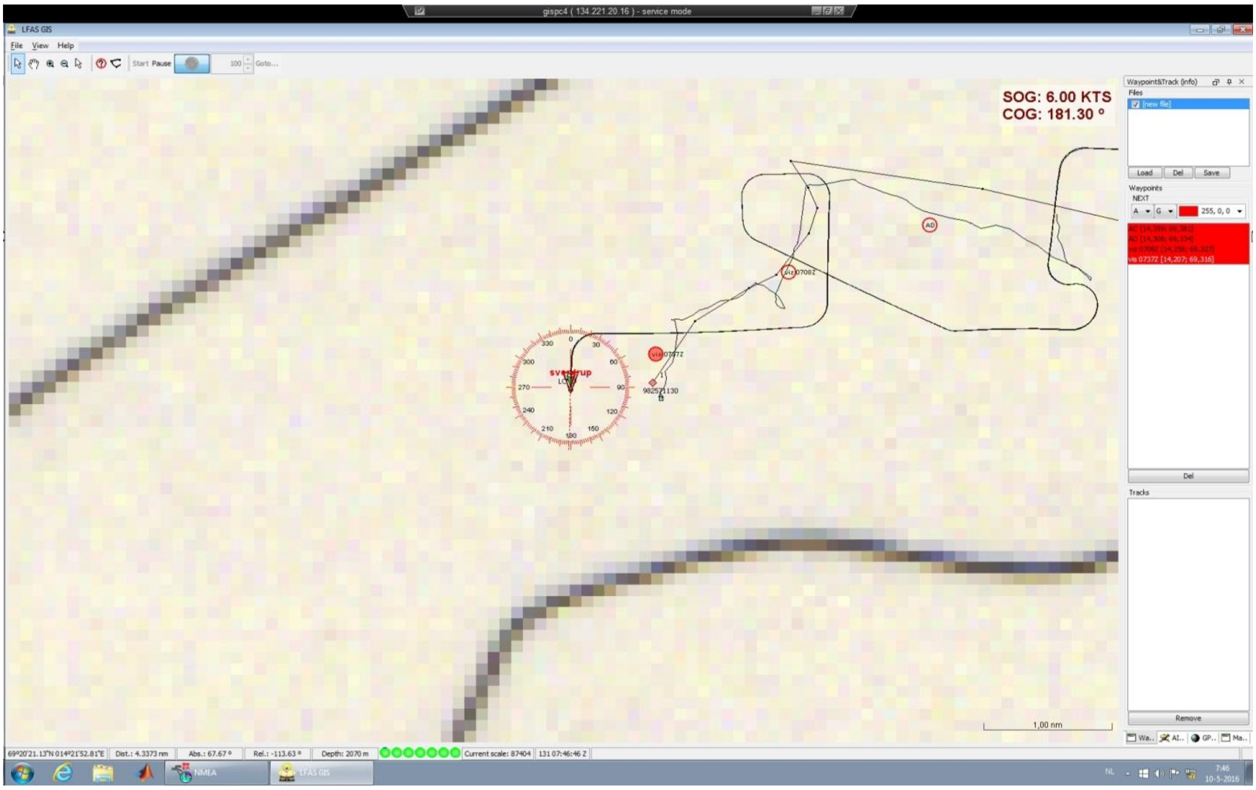


Figure 3.21 GIS display from the Delphinus system showing the estimated position of acoustic detections of sperm whales (pink dot). Black lines are the sailed track of the Sverdrup. The AIS position of the tag boat is also shown in this display (green square).

At the acoustic station, when the Delphinus array was operated, the number of acoustic sperm whale tracks on the time-bearing plot of the Carcharodon display (e.g. figure 3.17) was logged (best-estimate, minimum and maximum value) every 15 minutes. This information was used to estimate the overall sperm whale density (figure 3.2).

Table 3.5 Overview of acoustic recordings and transmissions (Delphinus and SOC) during 3S-2019-OPS.

Exp Name	**Sys**	**Date (start time)**	**Start Time (UTC)**	**Stop Time (UTC)**	**Duration [HH:MM]**	**Summary**
Minky Dinky	Soc	25-08-2019	20:00	22:00	02:00	Test of Socrates
CEE19001	Delp	26-08-2019	20:56	22:56	02:00	Survey Andfjord.
CEE19002	Delp	27-08-2019	13:36	14:23	00:47	Survey Malangen
CEE19003	Delp	27-08-2019	14:33	21:51	07:18	Survey Malangen + boxing and tracking of SW
CEE19004	Delp	27-08-2019	21:52	04:00	06:07	Survey during transit Malangen -> Andfjord.
CEE19005	Delp	28-08-2019	04:15	18:12	13:56	Survey Andfjord (inshore and offshore).
CEE19006	Delp	28-08-2019	18:24	13:06	18:42	Survey west of Andenes for Gm and Oo. Tagged SW.
CEE19007	Delp, Soc	29-08-2019	13:30	09:24	19:54	Socrates exposure runs SW CEE001.
CEE19008	Delp	30-08-2019	11:08	11:05	23:56	Search for Gm and Oo.
CEE19009	Delp, Soc	31-08-2019	11:27	11:29	24:01	Socrates exposure runs SW CEE002
CEE19010	Delp	01-09-2019	14:17	19:33	29:15	Search for and tagging SW.
CEE19011	Delp	02-09-2019	19:33	07:31	11:57	Frigate exposure runs SW CEE003
CEE19012	Delp	04-09-2019	13:58	08:49	18:51	Search for and tagging SW.
CEE19013	Delp, Soc	05-09-2019	09:15	07:48	22:33	Socrates exposure runs SW CEE004
CEE19014	Delp	06-09-2019	08:14	18:05	09:50	Search for SW to tag, but weather to bad.
CEE19015	Delp	07-09-2019	06:28	07:05	24:36	Frigate exposure runs SW CEE005
CEE19016	Delp	08-09-2019	07:15	16:55	09:39	Transit to new area, but weather too bad for tagging.
CEE19017	Delp	09-09-2019	06:17	21:20	15:02	Tagging attempts of SW but no joy.
CEE19018	Delp	09-09-2019	21:21	05:38	32:17	Frigate exposure runs SW CEE006-7
CEE19019	Delp	11-09-2019	11:47	05:53	18:06	Frigate exposure runs SW CEE008
CEE19020	Delp	12-09-2019	05:54	23:14	17:20	Frigate exposure runs SW CEE009
CEE19021	Delp	12-09-2019	23:14	06:04	06:49	Tag recovery
CEE19022	Delp	14-09-2019	00:49	06:08	05:18	Search for PW or KW
CEE19023	Delp	14-09-2019	06:28	12:35	06:07	Search for PW or KW
CEE19024	Delp	15-09-2016	06:26	02:13	19:46	Search for PW or KW
CEE19025	Delp	16-09-2019	02:13	02:14	00:01	Array connection error.
CEE19026	Delp	16-09-2019	02:18	09:28	31:10	Frigate exposure runs SW CEE010
CEE19027	Delp	17-09-2019	15:59	14:17	22:18	Search for PW or KW
Total					17 days 09:48	

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

3.5.2 Acoustic Moorings

Similar to the 3S-2017 trial, acoustic recorders were deployed 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 (figures 3.1 and 3.2). Furthermore, the same locations have been used in the 3S-2017 trial allowing for a comparison of the data. This time two recorders were mounted on each mooring for a total of four acoustic recorders.

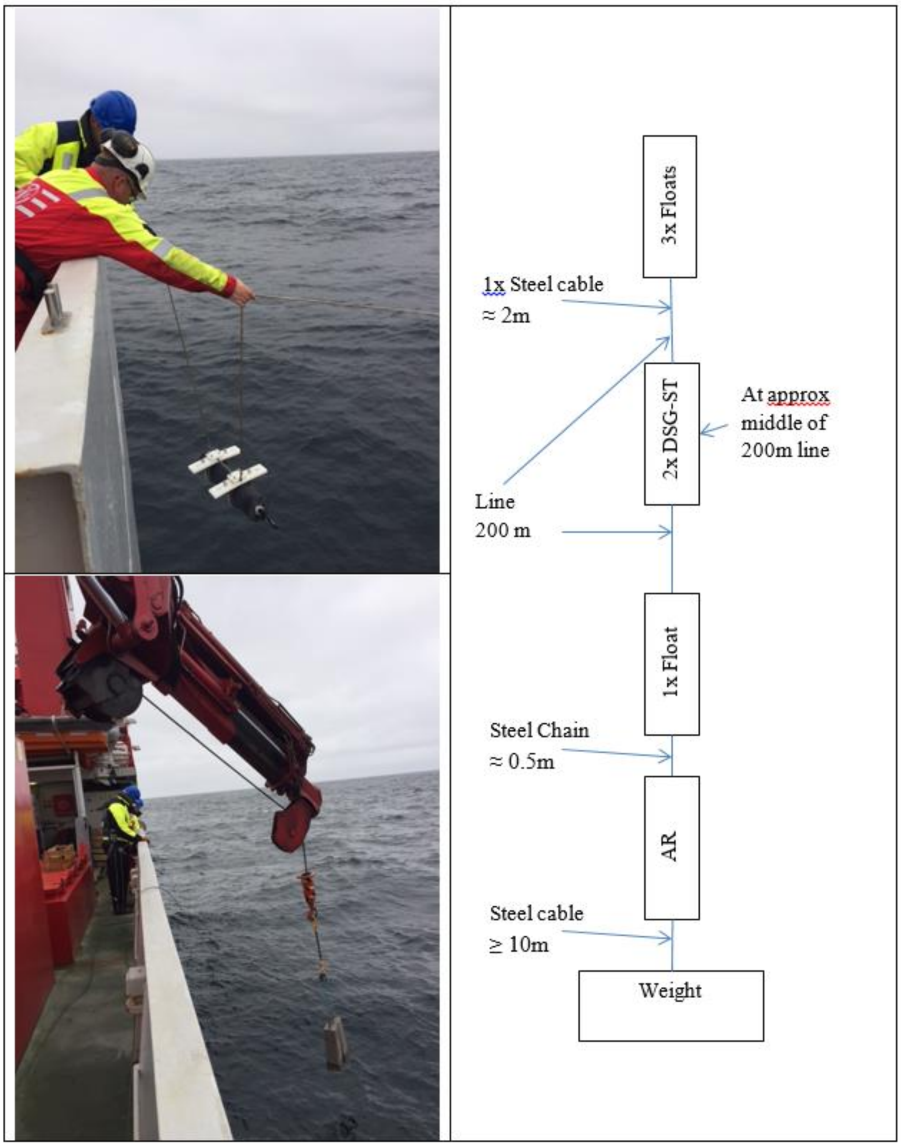


Figure 3.22 Overview of the mooring setup (right) used for the acoustic recorders during the 3S-trial in 2019 and 2 pictures from the deployment of the northern mooring. Photos: Frans-Peter Lam.

Table 3.6 Overview of deployment, recovery and recording settings for the two buoy positions.

Recording Location	**North**		**South**	
Recording Name	**CAS3-806121498**	**CAS4-1543553062**	**CAS6-1678020614**	**CAS6-201650198**
Recorder s/n	806121498 (SMRU)	1543553062 (TNO3)	1678020614 (TNO4)	201650198 (TNO2)
Deployment Time	26-08-2019 07:38Z	26-08-2019 07:38Z	26-08-2019 13:02Z	26-08-2019 13:02Z
Recovery Time	17-09-2019 13:16Z	17-09-2019 13:16Z	15-09-2019 ≈13:00Z	15-09-2019 ≈13:00Z
Deployment Position	70º00,115N / 016º29,846E	70º00,115N / 016º29,846E	69º28,556N / 015º38,769E	69º28,556N / 015º38,769E
Deployment Area & Depth	Northern Buoy (West of Tromso) water depth around 1270m.	Northern Buoy (West of Tromso) water depth around 1270m	Southern Buoy (North-West of Andenes), water depth around 1300m	Southern Buoy (North-West of Andenes), water depth around 1300m
Deployment Set-up	Mooring, see Figure 3.22	Mooring, see Figure 3.22	Mooring, see Figure 3.22	Mooring, see Figure 3.22
Recording Start	25-08-2019 ≈19:10Z	25-08-2019 ≈18:00Z	26-08-2019 ≈08:33Z	26-08-2019 ≈08:29Z
Recording Stop	08-09-2019 14:19Z Too early for unknown reason!!!	17-09-2019 14:00Z	15-09-2019 ≈15:00Z	15-09-2019 ≈15:00Z
Recording Interval	Continuous	Continuous	Continuous	Continuous
Recording Settings	Fs=144kHz, Gain=high, X3compression=on	Fs=96kHz, Gain=high, X3compression=on	Fs=144kHz, Gain=high, X3compression=on	Fs=96kHz, Gain=high, X3compression=on
Remarks	Clock offset at recovery: DSG-ST = GPS + 00:00:03	Clock offset at recovery: DSG-ST = GPS – 00:00:21	Clock offset at recovery: DSG-ST = GPS – 00:00:18	Clock offset at recovery: DSG-ST = GPS – 00:00:33

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

During the 3S-2019-OPS trial three out of the four deployed recorders worked very well and provided us with continuous acoustic recording of the study area. However, the fourth recorder (sn 806121498) stopped recording 9 days earlier. The reason for the premature stop is unknown.

For the southern buoy a total of 20 days of data was recorded and for the northern buoy this was 22 days and 5 hours. Figure 3.23 shows a spectral (time-frequency) overview of both recordings. In both recordings we can already detect several of the CEE sonar transmissions runs executed during the trial. Furthermore, sonar transmissions by the OSVE which was not part of the of the CEE experiments is visible around September 7th Further analysis is needed to show if we can detect changes in the click rates of the present sperm whales and if these recorded data can be a helpful tool in determining long range effects of sonar exposures.

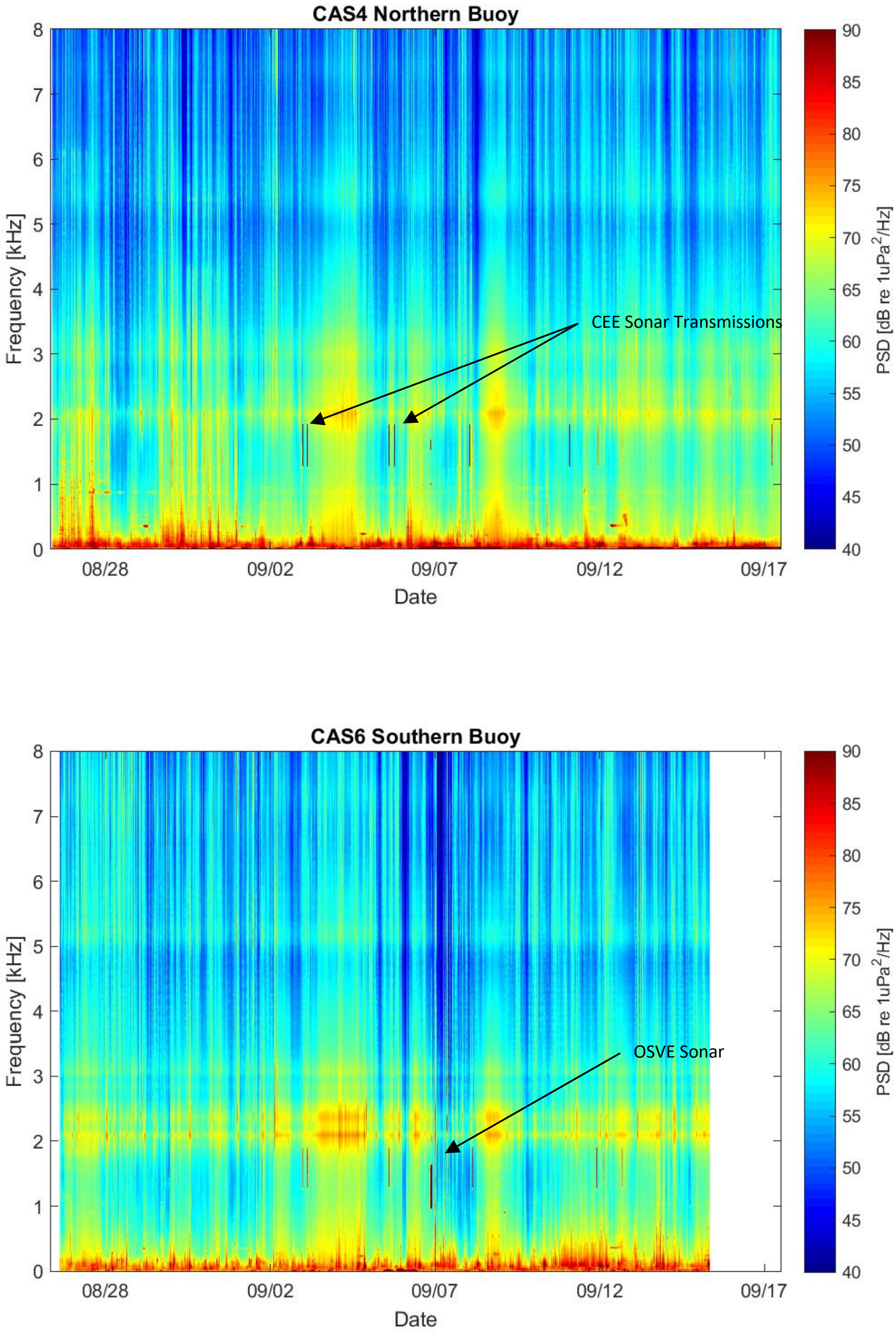


Figure 3.23 Long term spectral average overviews of the Southern (top) and Northern (bottom) buoys. Visible are several of the CEE sonar transmission runs and an unintended exposure from OSVE around September 7th.

3.6 Tags and tagging

3.6.1 Improvements to the mixed-DTAG design and performance

The mixed-DTAG is a suction-cup attached whale tag that can be attached using poles or the ARTS launcher. It is slightly larger than the DTAGv2 but uses the same suction cups and fits in the same robot. The mixed-DTAG contains a Sirtrack GPS logger and a Wildlife Computer SPOT Argos transmitter in addition to the regular DTAG sensors (triaxial accelerometer sensor, triaxial magnetometer sensor, stereo acoustic sensors and pressure sensor). The goal of this sensor combination was to enable the "Range-vs-Received Level" study with both focal subjects (tracked from HUS with visual sightings of position recorded) and non-focal subjects that would not be followed by HUS. The ARGOS transmitter helps tag recovery, particularly when whales are outside of VHF range from HUS when the tag detaches. Combining the capabilities of the stereo DTAGv3 (made available by University of Michigan) with GPS or visual recording of the whale's position enables calculation of a continuous 3D dead-reckoned track of each whale's movement (Wensveen et al. 2015).

Figure 3.24 Testing the buoyancy of the 8 Mixed-DTAGs and 1 standard DTAGv3 that were available for the trial.

During the 3S-2017 trial (Lam et al. 2018b) we had discovered several technical issues with the previous version of the Mixed-DTAG, though many core elements of the tag functioned well including retention on the whale using the DTAGv2 suction cups and good functionality of the release system. These issues were worked on substantially after the 2017 trial, including during dedicated baseline trials in summers of 2018 (Azores and Sicily) and 2019 (northern Norway, see appendix D), which led to several changes in the hardware and procedures designed to improve performance and robustness of the Mixed-DTAG system.

During the 3S-2019-OPS trial reported here, the performance of the redesigned Mixed-DTAG was found to be greatly improved. The main improvements were stronger and more visible housings, fully functional GPS loggers, double-power VHF transmitters with better range and the total number of mixed-DTAGs available. There were fewer tag failures than in previous trials and no tags were lost despite several of the tags being left to float at sea for extended periods. However, some new unexpected issues, particularly with the data recorded by the DTAG core units, were identified (table 3.7).

Table 3.7 Summary of the changes to the mixed-DTAG since 3S-2017, outcome during the 3S- 2019-OPS trial reported here, and new issues encountered during the 3S-2019-OPS trial.

Changes to the tags and tag recovery equipment and findings related to these upgrades	
Housing	More housing materials available: e.g. softer and more flexible for normal use and harder and thicker for ARTS.
	Different colours including brighter ones available. These new colours were confirmed to be highly visible in the drone videos.
	Extra counterweight and flotation added so that tags floated more upright.
→ outcome	No housing failures were found in the 3S-2019-OPS trial.
SPOT	New stiffer antennas to avoid contact with whale skin.
	Changes in the delay from ‘dry’ reading in the salt water switch from 0.5-3.0s.
→ outcome	Good transmissions when tag was floating (upright position) except when a long transmission delay (3s) was set. On-animal performance was variable. Likely dependent on tag orientation and placement. However, on-animal locations were not a project priority.
Goniometer	The goniometer provides a direction to the ARGOS transmitter, and was added as a tool to enable a backup for tag recovery in case of VHF failure.
→ outcome	Good performance on a small boat but less so on Sverdrup (interference?). Tag recovery works well but is slower than with VHF. OK for a backup system.
VHF	New double power VHF transmitters were added to some tags to improve on-animal performance. Range tests during the baseline trial demonstrated that a greater range is obtained using the double powered transmitters.
	Antenna inclination angle was increased to 30° so that it was sticking further up and away from the whale skin.
→ outcome	Double power transmitters had better range during on-animal tracking. It comes at the cost of battery life.
D3 core	Magnetometer issue in earlier trials was solved by removing a device with a strong magnet from Sverdrup.
	USB GPS timing dongle was useful to accurately synchronize the DTAG clock. Helpful for obtaining accurate range from time-of-flight data.
→ outcome	Good performance of the magnetometer was obtained for most tag deployments (but see below for some data issues with the D3 cores).

GPS	We switched to new Sirtrack dataloggers (F5G 234C) as the previous version was no longer available. Tests confirmed that performance of the F5G 234C FastGPS loggers was similar to older FastlocGPS loggers. Some differences in sensitivity between individual loggers.
	Analysis by Sirtrack engineers found sudden clock shifts due to degaussing the tags on Mobhus during the 2017 trial. Many GPS fixes from 3S-2017 recovered.
→ outcome	We obtained very good GPS locations for all whales for which tagged were placed sufficiently high on the body.
Availability	We prepared more tags than in previous trials, and had spares of most components, including VHF transmitter batteries.
→ outcome	This large number of Mixed-DTAGs (n=8 core units) and spares available resulted in no availability issues. Though no tags were lost during this trial, issues with data recording in some of the core units meant that we had tags available for up to three nonfocal whales.
New tag issues encountered	
D3 core unit	Several new issues were found which varied from unit to unit: 1 broken magnetometer, depth errors (single spikes or periods of noise, time offsets), and memory issues leading to a few corrupted data files. None of these issues were clearly associated with deployments during the trial and most seemed to already exist a priori, though they were not revealed by the extensive testing we did with each core unit prior to deployment. Alex Shorter at U Michigan provided us with substantial support and advice during the trial. We recommend long test recordings be made to check for these sorts of problems, as they were not apparent from the short test recordings.
VHF	Some potted VHF batteries had cracked and had started to corrode. The problem was caught in time before VHF failure could occur, and batteries of several transmitters were replaced successfully during the trial. The double-powered transmitter caused batteries to drain more quickly, which was difficult to monitor with the current design – we recommend a rechargeable VHF system be developed for further improvement.

3.6.2 Tagging effort

There were 19 mixed-DTAGs deployed on sperm whales using the cantilever pole, and 5 tags were deployed on pilot whales using the hand held pole (table 3.8). All tags were deployed from MOBHUS. For sperm whale deployments, most of the mixed-DTAGs stay attached until the programmed release, which was generally long (table 3.8), whereas for the pilot whale deployments, none of the tags stayed attached until the planned release. Premature release of the tags was a major reason why we did not manage to conduct any sonar exposure experiments with pilot whales. Suction cup attached tags tend to release prematurely when attached to pilot whales, but this problem might be greater for the bigger mixed-DTAG compared to regular DTAGv3. However, one of the tag deployed during CEE10 on pilot whales (Gm19_257c) was a standard DTAGv3, and it too released prematurely after less than one hour on the whale.

Figure 3.25 Successful deployments of mixed-DTAGS to a sperm whale with the cantiliver pole (upper panel) and pilot whale with the hand held pole (lower panel). Some sperm whales were double-tagged as a precautionary measure against early release Photos: Saana Isojunno

Table 3.8 DTAG deployment table

Deployment	Logger Sighting number	Tag-on Time (UTC)	Tag-on position	Tag-off Time (UTC)	On-animal hours	Tag type, method	Animal's reaction to tagging	Experiment	Notes
Sw19_241a *Non-focal*	58	29/08/2019 08:32:44	69˚11.771N 14˚30.608E	30/08/2019 08:04	23.48	M-Dtag cantilever	1 Arch-out	CEE1 HUS HPAS-close HPAS-far HPAS-6db close	Detached 3.5 hours after release after time: one suction cup was blocked with skin. Diving synchronously with sw19_241b GPS: Obs300819_113946_Tag65370 ARGOS PTT 183279: ArgosData_2019_08_30_12_28_19
Sw19_241b *Focal*	59	29/08/2019 09:43:14	69˚13.479N 14˚28.968E	30/08/2019 08:04	22.35	M-Dtag cantilever	1 Arch-out	CEE1 HUS HPAS-close HPAS-far HPAS-6dB close	Diving synchronously with sw19_241a GPS: Obs300819_115348_Tag65365 ARGO PTT 183276: ArgosData_2019_08_30_12_29_49
Sw19_243a *Focal*	112	31/08/2019 07:32:51	70˚12.98N 16˚55.61E	01/09/2019 04:28	20.90	M-Dtag cantilever	1 Arch-out	CEE2 HUS HPAS-close HPAS-far	No GPSs data on-animal GPS: Obs010919_105217_Tag65348 ARGOS PTT 183278: ArgosData_2019_09_01_15_23_08
Sw19_244a *Non-focal*	201	01/09/2019 19:20:04	70˚02.011N 16˚25.094E	03/09/2019 05:57	34.62	M-Dtag cantilever	1 Arch-out Rolled side	CEE3 OSVE XHPAS-Distant XHPAS-close XHPAS-Distant	Possible breaches (n=3) at 11:45 02/09/2019 GPS: fastgps_export_id_0001387_190904223210 ARGOS PTT 161601: ArgosData_2019_09_03_19_30_04
Sw19_245a *Focal*	226	02/09/2019 19:22:41	69˚51.741N 16˚10.545E	03/09/2019 08:18	12.92	M-Dtag cantilever	0	CEE3 OSVE XHPAS-Distant XHPAS-close XHPAS-Distant	GPS: Obs030919_171814_Tag65370 ARGOS PTT 183279: ArgosData_2019_09_03_19_25_43
Sw19_248a *Focal*	246	05/09/2019 04:33:54	69˚50.933N 16˚25.954E	05/09/2019 15:49	10.25	M-Dtag cantilever	1 Small tail-slap	CEE4 HUS No-sonar HPAS-Distant HPAS-6dB close HPAS-close	It detached before programmed. Double tag attachment (sw19_248b) GPS: Obs050919_225844_Tag65370 ARGOS PTT 183279: ArgosData_2019_09_05_23_22_38
Sw19_248b	246	05/09/2019 06:23:40	69˚51.169N 16˚22.792E	06/09/2019 07:02	24.47	M-Dtag cantilever	2 Large	CEE4 HUS No-sonar	Double tag attachment (sw19_248a) GPS: fastgps_export_id_0001387_190906090305

Focal							tail-slap	HPAS-Distant HPAS-6dB close HPAS-close	ARGOS PTT 161601: ArgosData_2019_09_06_17_17_44
Sw19_250a *Focal*	285	07/09/2019 11:32:14	69°48.049N 16°27.669E	08/09/2019 06:49	19.27	M-Dtag cantilever	1 Turn sideways, side fluke-out	CEE5 OSVE HXPAS-close HXPAS-distant	Double tag attachment (sw19_250b) Drone footage with both tags. GPS: Obs080919_100114_Tag65370 ARGOS PTT 183279: ArgosData_2019_09_08_15_53_17
Sw19_250b *Focal*	285	07/09/2019 11:41:33	69°48.310N 16°27.769E	08/09/2019 06:56	19.23	M-Dtag Cantilever	1 Turn sideways, side fluke-out	CEE5 OSVE HXPAS-close HXPAS-distant	Double tag attachment (sw19_250a) Drone footage with both tags. GPS: fastgps_export_id_0001387_190908084609 ARGOS PTT 161601: ArgosData_2019_09_08_15_50_38
Sw19_253a	357	10/09/2019 04:38:55	69°57.666N 16°24.565	10/09/2019 17:27	13.8	M-Dtag Cantilever	1 Small tail-movement	CEE06 NoSonar-close	Double tag attachment (sw19_253b) Drone footage with both tags. Detached before programmed due to a breach. GPS: Obs100919_215428_Tag65348 ARGOS PTT 183278: ArgosData_2019_09_11_04_58_28
Sw19_253b	357	10/09/2019 08:07:42	69°53.314N 16°11.418E	10/09/2019 17:27	9.32	M-Dtag Cantilever	1 Fluke strike, then fluke out	CEE06 NoSonar-close	Double tag attachment (sw19_253a) Drone footage with both tags. Detached before programmed due to a breach. GPS: Obs100919_220944_Tag65370 ARGOS PTT 183279: ArgosData_2019_09_11_05_00_42
Sw19_253c *Focal*	409	10/09/2019 18:54:30	69°49.237N 16°10.495E	11/09/2019 14:08	18.22	M-Dtag Cantilever	2 Short strong response: banana back and strong tail swipe	CEE7 OSVE HPAS-distant HPAS-close	It released 8 hours later than programmed for unknown reasons. Same whale as sw19_253a/b as suction cup marks seen on drone footage GPS: Obs130919_100021_Tag65365 ARGOS PTT 183276: ArgosData_2019_09_13_14_44_48
Sw19_254a *Focal*	454	11/09/2019 15:04:27	69°39.757N 14°53.636E	12/09/2019 14:12	23.12	M-Dtag Cantilever	1 Tail up	CEE8 OSVE XHPAS-close HPAS-close XHAPAS-distant	GPS: Obs140919_015924_Tag65370 ARGOS PTT 183279: ArgosData_2019_09_14_15_55_22

Sw19_255a *Focal*	469	12/09/2019 07:08:15	69°51.378N 16°18.574E	13/09/19 01:07	18.99	M-Dtag Cantilever	1 Side roll Short dive	CEE9 OSVE XHPAS-distant XHPAS-close No sonar	Double tag attachment (sw19_255b) GPS: fastgps_export_id_0001457_190913071812 ARGOS PTT 183277: ArgosData_2019_09_13_14_34_42
Sw19_255b *Focal*	469	12/09/2019 07:11:41	69°51.378N 16°18.574E	13/09/2019 00:52	17.68	M-Dtag Cantilever	1 Minor turn Moved away and fluked	CEE9 OSVE XHPAS-distant XHPAS-close No sonar	Double tag attachment (sw19_255a) GPS: fastgps_export_id_0001458_190913054030 ARGOS PTT 36685: ArgosData_2019_09_13_14_16_49
Sw19_255c *Non-focal*	?	12/09/2019 08:03:13	69°50.375N 16°09.044E	12/09/2019 16:18	8.23	M-Dtag Cantilever	1 Side roll Fluked out	CEE9 OSVE XHPAS-distant XHPAS-close No sonar	GPS: fastgps_export_id_0001456_190913065902 ARGOS PTT 161599: ArgosData_2019_09_13_14_40_21
Sw19_255d *Non-focal*	?	12/09/2019 08:34:16	69°50.375N 16°09.044E	13/09/2019 16:46	8.18	M-Dtag Cantilever	1 Side roll Defecation Dove-under	CEE9 OSVE XHPAS-distant XHPAS-close No sonar	GPS: fastgps_export_id_0001456_190913065902 ARGOS PTT 36683: ArgosData_2019_09_13_14_43_04
Sw19_259a	557	16/09/2019 09:25:21	69°44.865N 16°06.634E	16/09/2019 15:30	6.08	M-Dtag cantilever	2 Fluke raise high upside-down Moved away	CEE11	GPS: fastgps_export_id_0001386_190916192334 ARGOS PTT 36683: ArgosData_2019_09_17_03_09_35
Sw19_259b *Focal*	558	16/09/2019 10:28:45	69°47.18N 16°03.32E	16/09/2019 08:57	23.54	M-Dtag cantilever	1 Fluke up Shallow dive	CEE11 OSVE No sonar XHPAS-close XHPAS-distant	GPS: fastgps_export_id_0001456_190917101632 ARGOS PTT 161599: ArgosData_2019_09_17_15_27_55
Total (n=19)					**334.65 hours**			**OTTO=6 SOCRATES=3**	
Gm19_257a	503	14/09/2019 10:40	69°47.042N 16°35.457E	14/09/2019 10:43	0.05	M-Dtag pole	1 Tail flinch	CEE10	Tag off likely after a breach.
Gm19_257b	503	14/09/2019 11:27	69°49.364N 16°36.229E	14/09/2019 11:36	0.17	M-Dtag Pole	1 Fast swim down	CEE10	Could be a poor tag placement.
Gm19_257c	503	14/09/2019 14:46:19	69°46.706N 16°29.675E	14/09/2019 15:34	0.8	Dtag3 pole	1 Flinch	CEE10	Tag on with only 3 suction cups. 1 was reversed.

Gm19_257d	503	14/09/2019 15:21:54	69˚46.294N 16˚29.484E	15/09/2019 03:20	11.98	M-Dtag Pole	1 Flinch	CEE10	Slipped off. GPS: fastgps_export_id_0001457_190915044052 ARGOS PTT 183277: ArgosData_2019_09_15_07_10_36
Gm17_257e	503	14/09/2019 16:34:34	69˚46.248N 16˚22.281E	14/09/2019 22:57	6.37	M-Dtag pole	1 Flinch	CEE10	Slipped off. GPS: fastgps_export_id_0001458_190915060052 ARGOS PTT 36685: ArgosData_2019_09_15_15_03_47
Total (n=5)					**19.37 hours**				

3.7 Environmental data

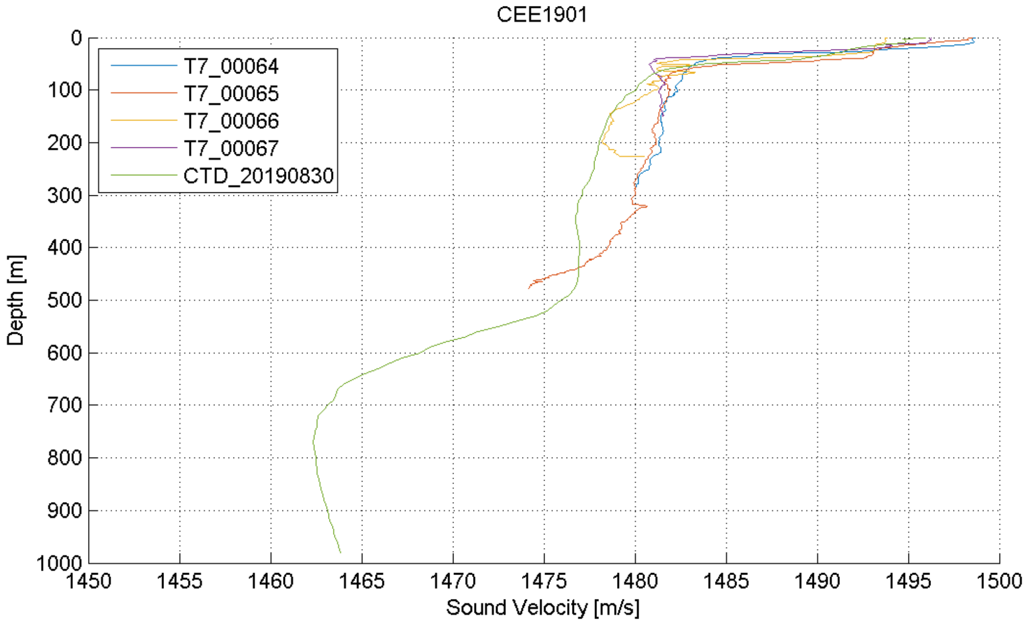
Measurements of sound propagation conditions were made in connection with the sonar exposure experiment. The DTAG contain two hydrophones, which measured the sound levels received by the animal during the sonar exposures. However, in order to understand the response of the animal, it is important to 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 from both HUS (table 3.9) and OSVE (table 3.10). After each exposure experiment a more accurate Conductivity Temperature Depth (CTD) measurement was conducted using SAIV STD/CTD SD204 from HUS (Table 3.9). Figures 3.26-3.34 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 XBTs & CTDs collected from HUS during 3S-2019-OPS. Latitude and longitude are provided in degrees and decimal minutes.

Exposure Experiment	XBT Name	Date & Time (UTC)	Max Depth [m]	Latitude	Longitude
CEE01	T7_00064.EDF	29-08-2019 19:31:32	280	69 24.0180N	13 50.7270E
	T7_00065.EDF	29-08-2019 19:48:35	470	69 24.0542N	13 57.2330E
	T7_00066.EDF	30-08-2019 03:25:51	220	69 33.7841N	13 36.8979E
	T7_00067.EDF	30-08-2019 03:42:08	150	69 33.8691N	13 43.1400E
	CTD_20190830	30-08-2019 10:22:16	980	69 33.8890N	13 41.2230E
CEE02	T7_00068.EDF	31-08-2019 14:10:04	240	70 27.8266N	17 06.4157E
	T7_00069.EDF	31-08-2019 16:14:00	245	70 33.5830N	17 01.2718E
	T7_00070.EDF	31-08-2019 16:18:27	760	70 33.1538N	17 02.5352E
	CTD_20190901	01-09-2019 13:13:00	1000	70 28.9960N	16 51.8800E
CEE03	T7_00071.EDF	02-09-2019 23:29:23	260	69 48.3764N	16 26.4481E
	CTD_20190903	03-09-2019 13:17:00	700	69 45.6140N	16 21.8540E
CEE04	T7_00072.EDF	05-09-2019 11:01:25	650	69 56.5297N	16 19.1749E
	T7_00073.EDF	05-09-2019 14:24:50	330	69 52.4536N	16 00.5521E
	T7_00074.EDF	05-09-2019 18:08:18	710	69 57.2539N	16 28.2308E
	T7_00075.EDF	05-09-2019 20:31:08	760	69 54.9722N	16 31.5475E
CEE05	T7_00076.EDF	08-09-2019 05:58:51	760	69 46.4414N	16 12.1632E
CEE06-07	T7_00077.EDF	11-09-2019 00:04:58	760	69 52.0557N	16 29.7228E
CEE08	T7_00078.EDF	11-09-2019 23:59:21	760	69 36.0168N	14 52.8759E
CEE09	T7_00079.EDF	12-09-2019 17:17:17	760	69 47.8101N	16 05.6410E
CEE10	-	-	-	-	-
CEE11	T7_00080.EDF	17-09-2019 04:18:36	760	69 46.3530N	16 15.5030E
	CTD_20190917	17-09-2019 10:41:00	1210	69 45.6190N	16 05.9410E

Table 3.10 Overview of XBTs collected from OSVE during 3S-2019-OPS. Latitude and longitude are provided in degrees and minutes; Depth is provided in meter; Time is given as date in September followed by time in hours and minutes zulu time (UTC)

Date/Time September	**XBT Name**	**TYPE**	**Lat**	**Long**	**Depth**
022337Z	0901	T7	6944N	01622E	1000
030135Z	0902		6946N	01618E	1000
080104Z	0903	T7	6949N	01615E	1750
112334Z			6956N	01619E	
110130Z	0905	T7	6948N	01624E	1800
112205Z	0906	T7	6938N	01502E	2000
120005Z	0907	T7	6935N	01455E	2000
120420Z	0908	T7	6936N	01433E	2000
121620Z	0909	T7	6949N	01544E	2100
121824Z	0910	T7	6846N	01549E	2000
122030Z	0911	T7	6940N	01550E	2000
170255Z	0912	T7	6942N	01612E	1000
170500Z	0913	T7	6945N	01549E	1000



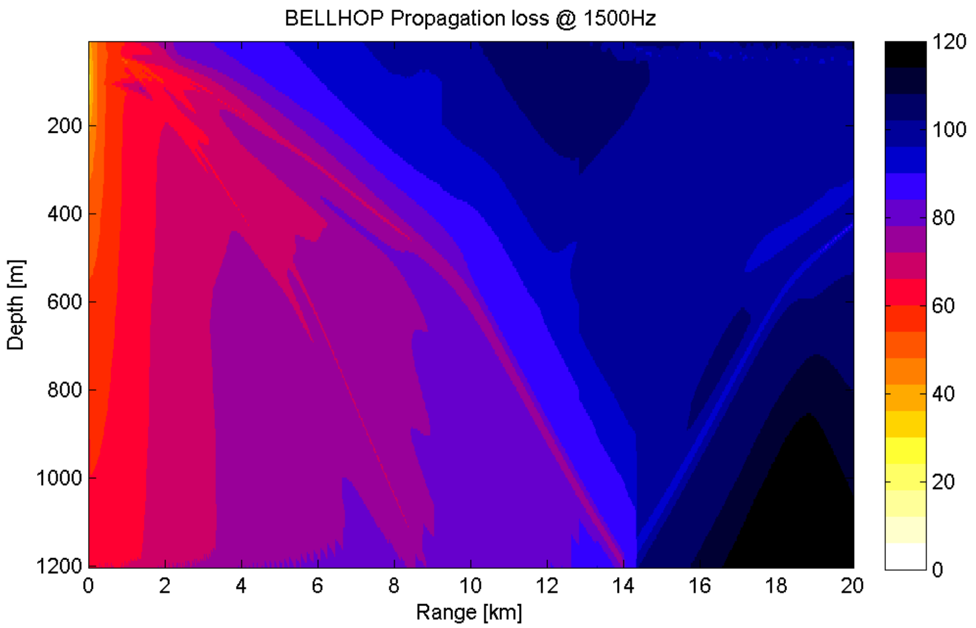
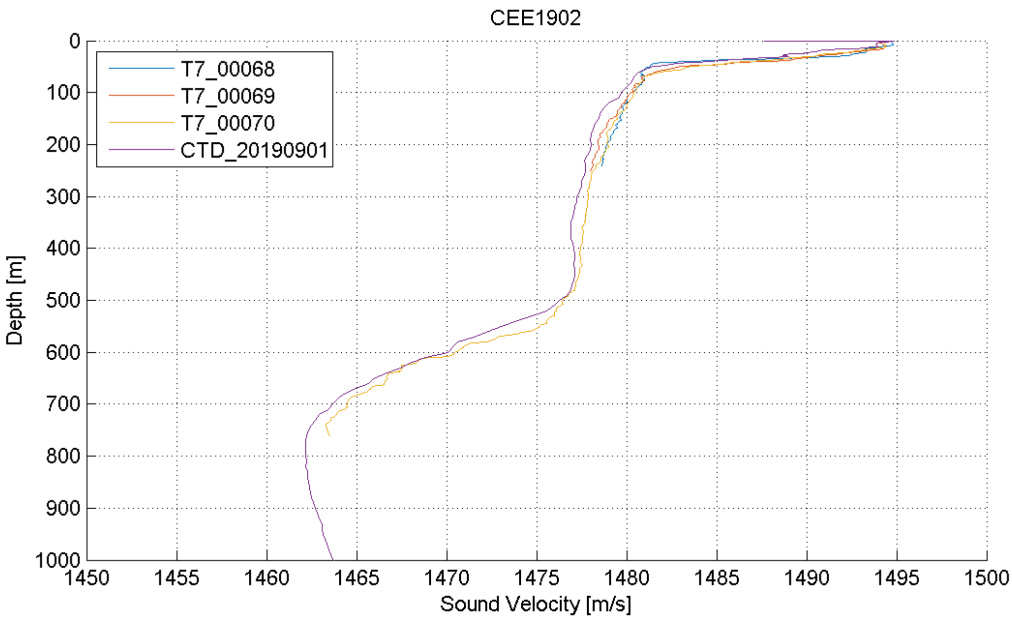


Figure 3.26 Sound Speed Profiles (SSPs) as measured by the XBTs and CTD for exposure experiment CEE01 (top). Using the measured CTD SSP the propagation loss is modelled (bottom).



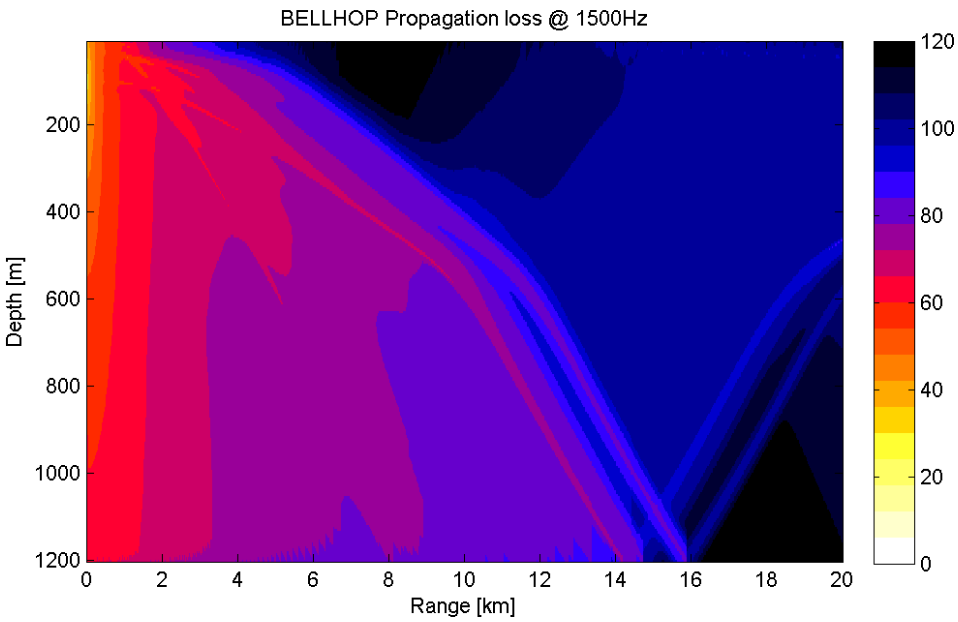
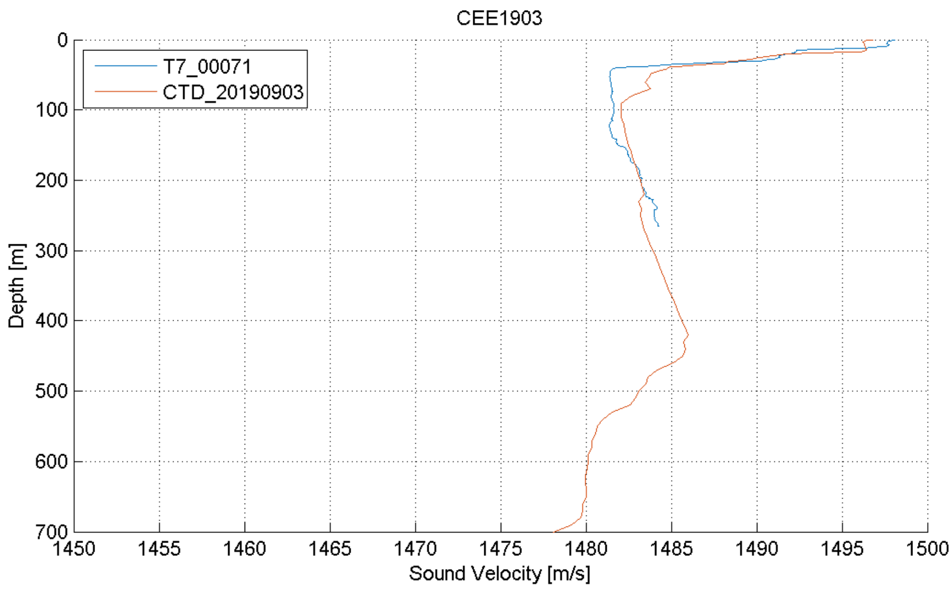


Figure 3.27 Sound Speed Profiles (SSPs) as measured by the XBTs and CTD for exposure experiment CEE02 (top). Using the measured CTD SSP the propagation loss is modelled (bottom).



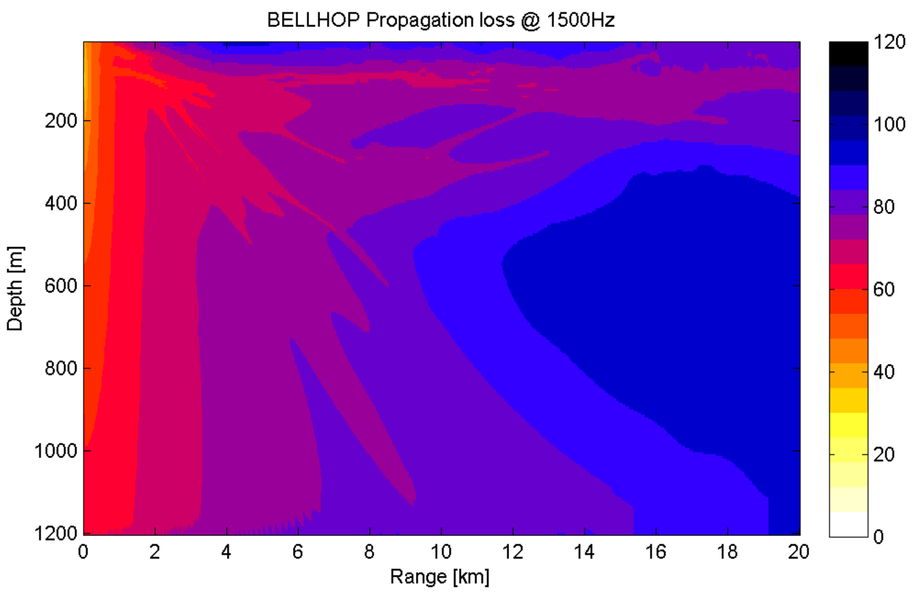
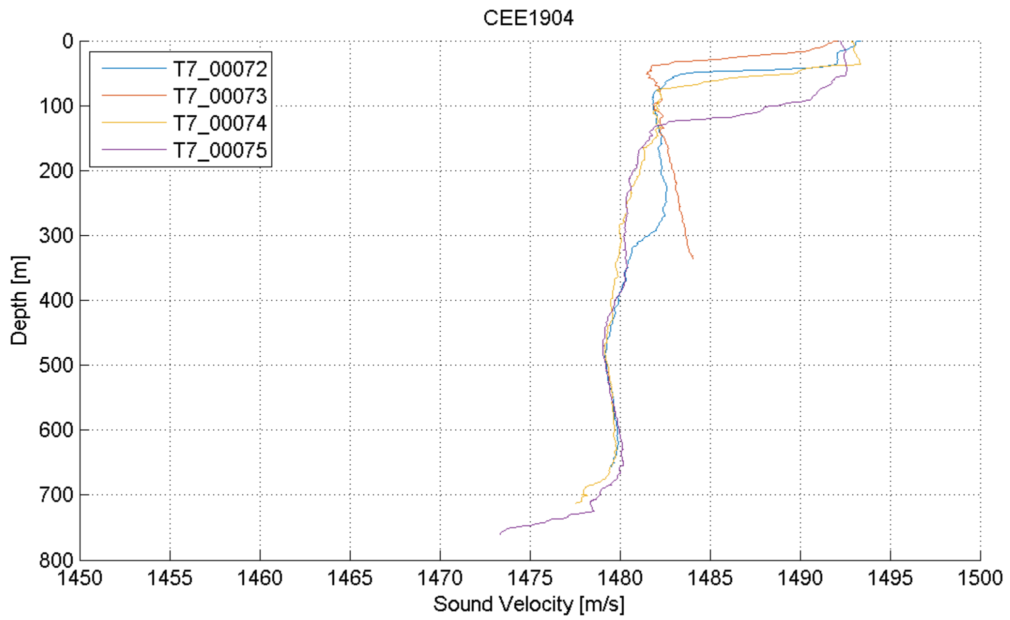


Figure 3.28 Sound Speed Profiles (SSPs) as measured by the XBT's and CTD for exposure experiment CEE03 (top). Using the measured CTD SSP the propagation loss is modelled (bottom).



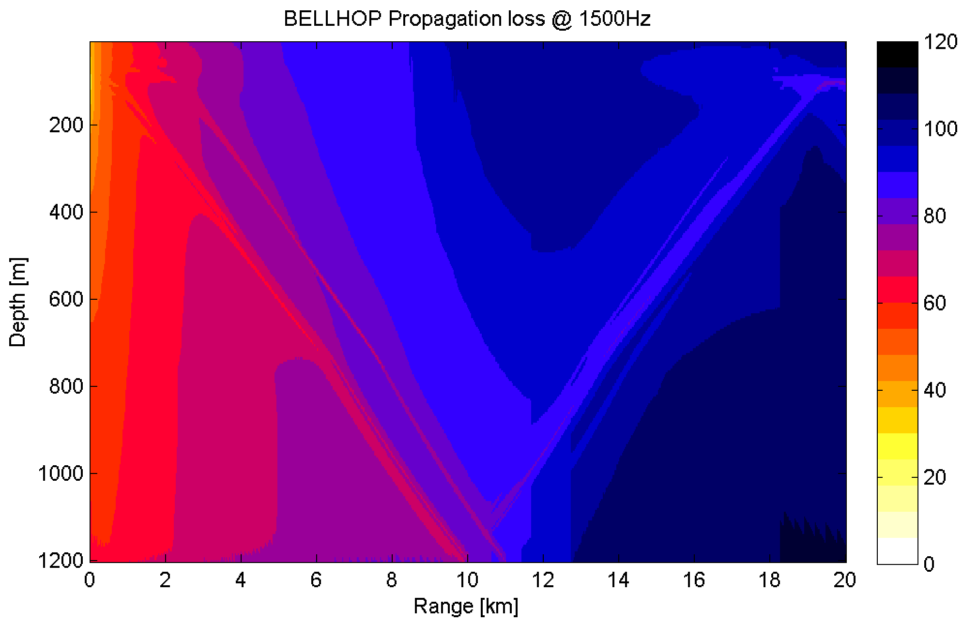
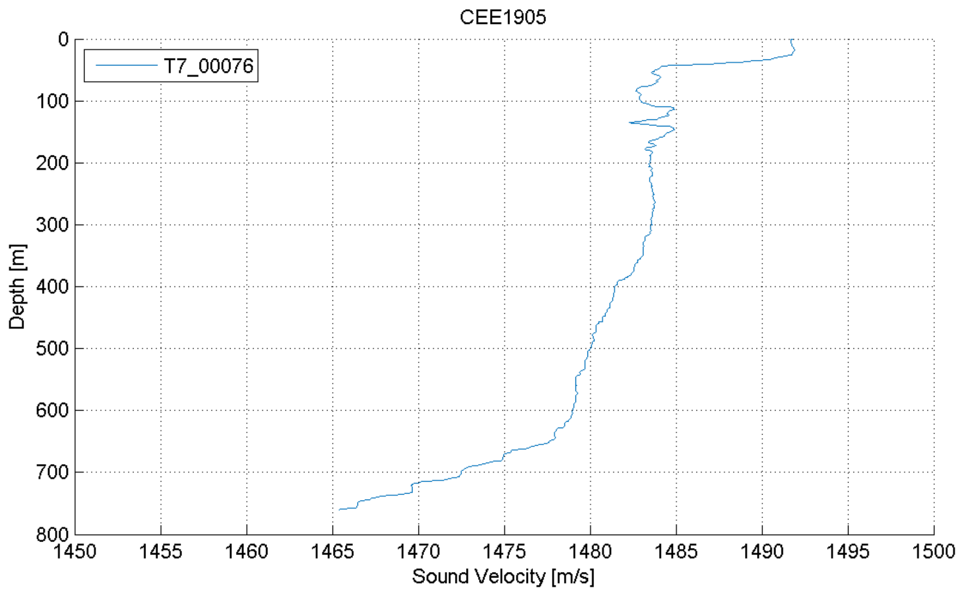


Figure 3.29 Sound Speed Profiles (SSPs) as measured by the XBTs and CTD for exposure experiment CEE04 (top). Using the measured CTD SSP the propagation loss is modelled (bottom).



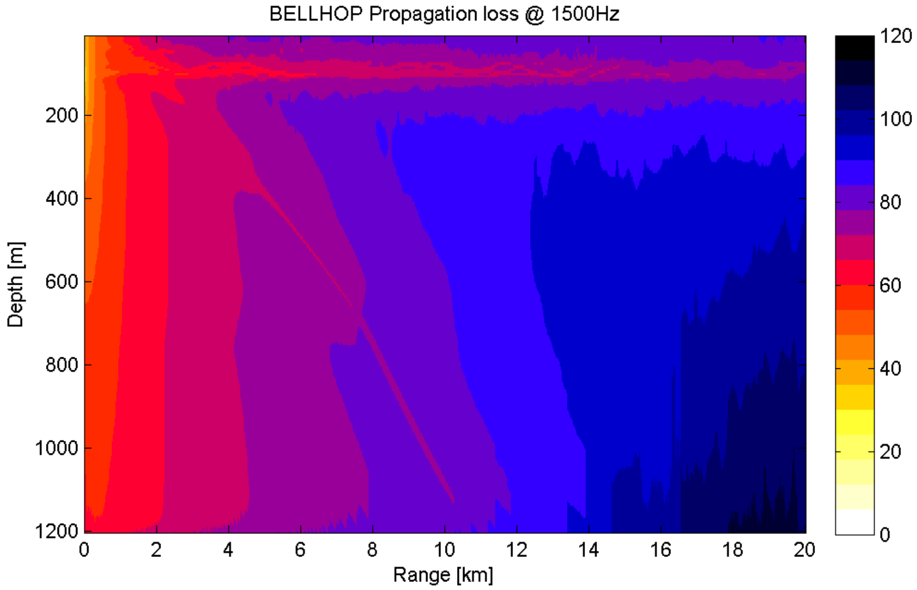


Figure 3.30 Sound Speed Profiles (SSPs) as measured by the XBTs and CTD for exposure experiment CEE05 (top). Using the measured CTD SSP the propagation loss is modelled (bottom).

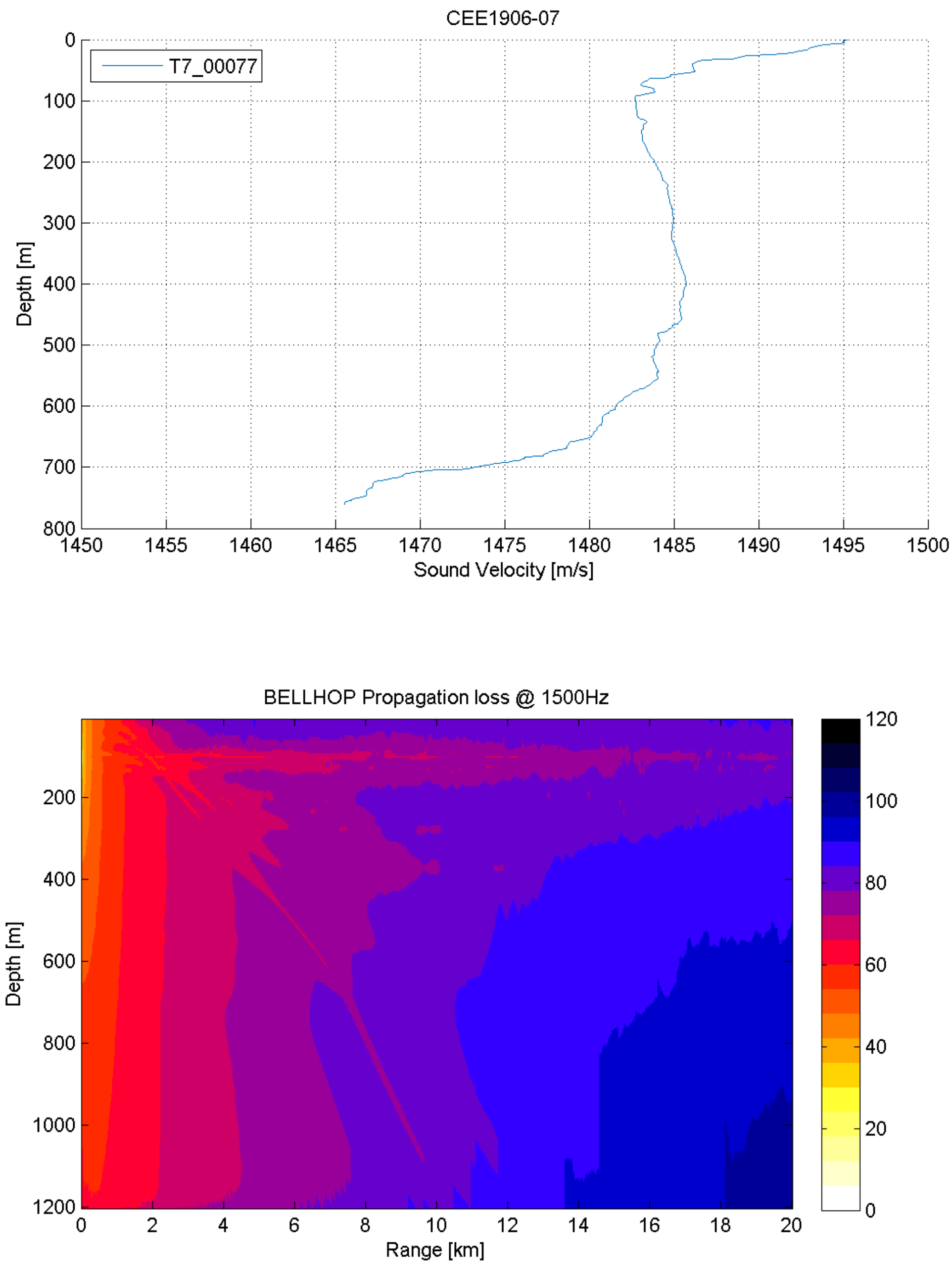
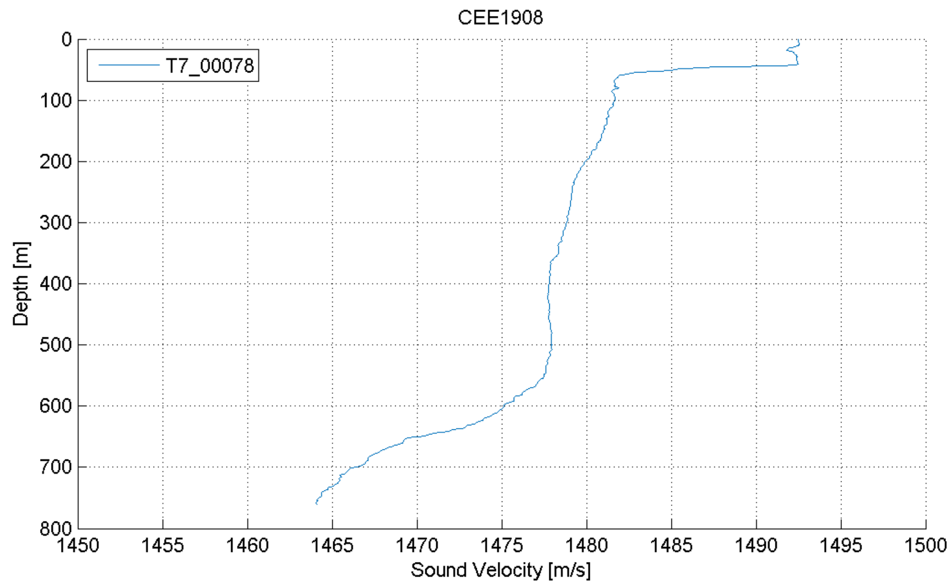


Figure 3.31 Sound Speed Profiles (SSPs) as measured by the XBTs and CTD for exposure experiment CEE06-07 (top). Using the measured CTD SSP the propagation loss is modelled (bottom).



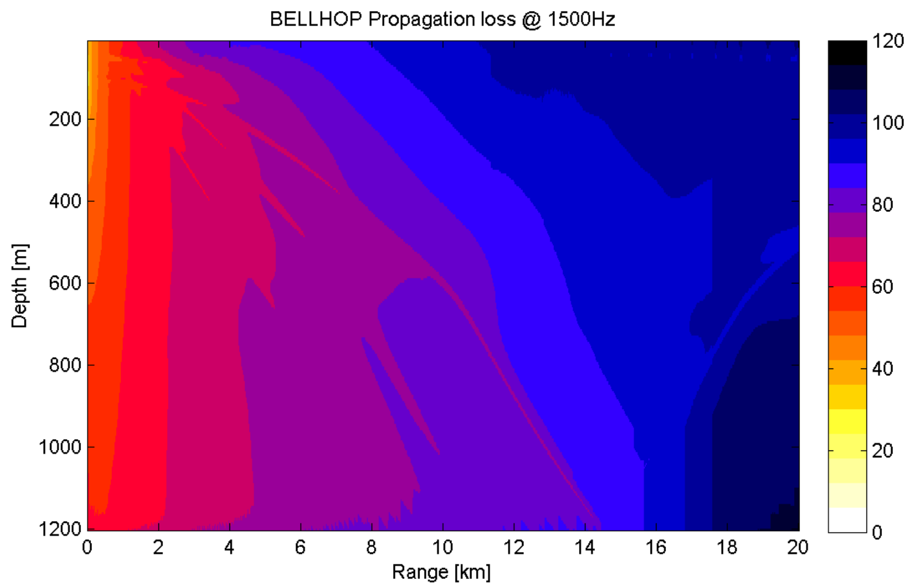


Figure 3.32 Sound Speed Profiles (SSPs) as measured by the XBTs and CTD for exposure experiment CEE08 (top). Using the measured CTD SSP the propagation loss is modelled (bottom).

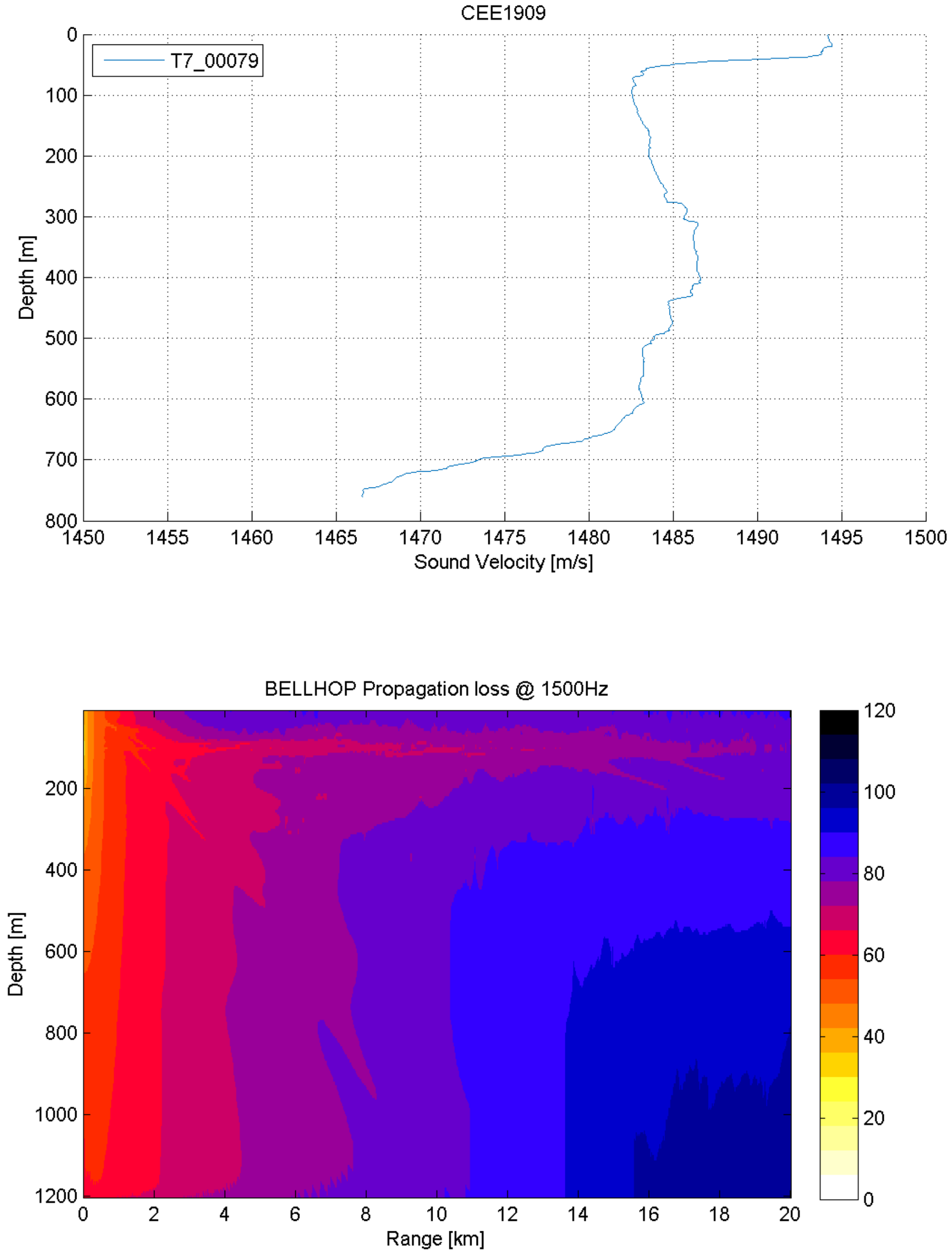


Figure 3.33 Sound Speed Profiles (SSPs) as measured by the XBTs and CTD for exposure experiment CEE09 (top). Using the measured CTD SSP the propagation loss is modelled (bottom).

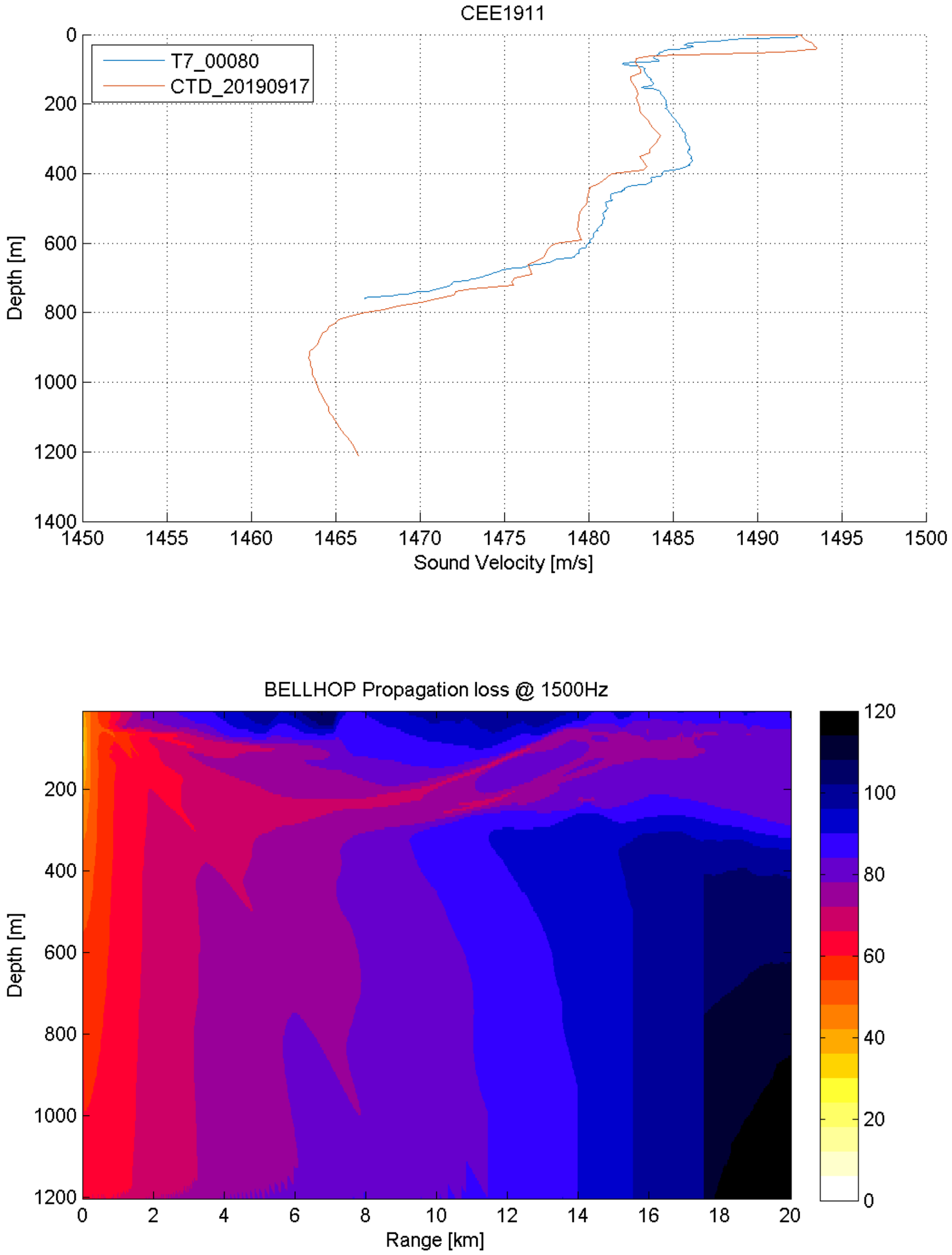


Figure 3.34 Sound Speed Profiles (SSPs) as measured by the XBTs and CTD for exposure experiment CEE11 (top). Using the measured CTD SSP the propagation loss is modelled (bottom).

3.8 Using drones to track tagged whales

A DJI Phantom 4 unmanned aerial vehicle (UAV) was employed to observe and record near-surface behavior, and as a platform from which to collect photogrammetry data. UAV photogrammetry allows for high precision estimation of distances within images obtained by overflying the subject with a UAV equipped with a camera and high accuracy altimeter (Dawson *et al.* 2018). It can be used to estimate a variety of morphometric characteristics of individual animals, as well as distances between multiple animals captured in the same image. The overhead viewpoint afforded by the UAV also allows for the observation of near surface behaviors which are difficult or impossible to observe from surface observation platforms (Torres *et al.* 2018) with little or no disturbance to the subject likely to occur (Christiansen *et al.* 2016).

The primary aim concerning the UAV was to observe near surface behavior in long-finned pilot whales and/or killer whales before, during and subsequent to sonar exposures, looking for changes in group spacing in response to sonar exposure. However, no exposures were conducted with these species during the trial due to short tag retention times.

Figure 3.35 Video frame captured during the flight conducted on 10th September 2019 showing excellent potential for body condition estimation; the animal is well centered in the frame, the body is flat and close to the surface and its full outline is clearly visible. Photo: Alec Burslem

In the absence of pilot and killer whale experiments, UAV flyovers were attempted opportunistically on sperm whales with the aim of obtaining body condition estimates, which can then be used to cross validate those obtained by modelling body density from DTAG records. Overflights were attempted whenever weather conditions were within acceptable limits (see UAV protocol, appendix D) and tagged whales could be approached without affecting the experimental protocol of the primary cruise objectives.

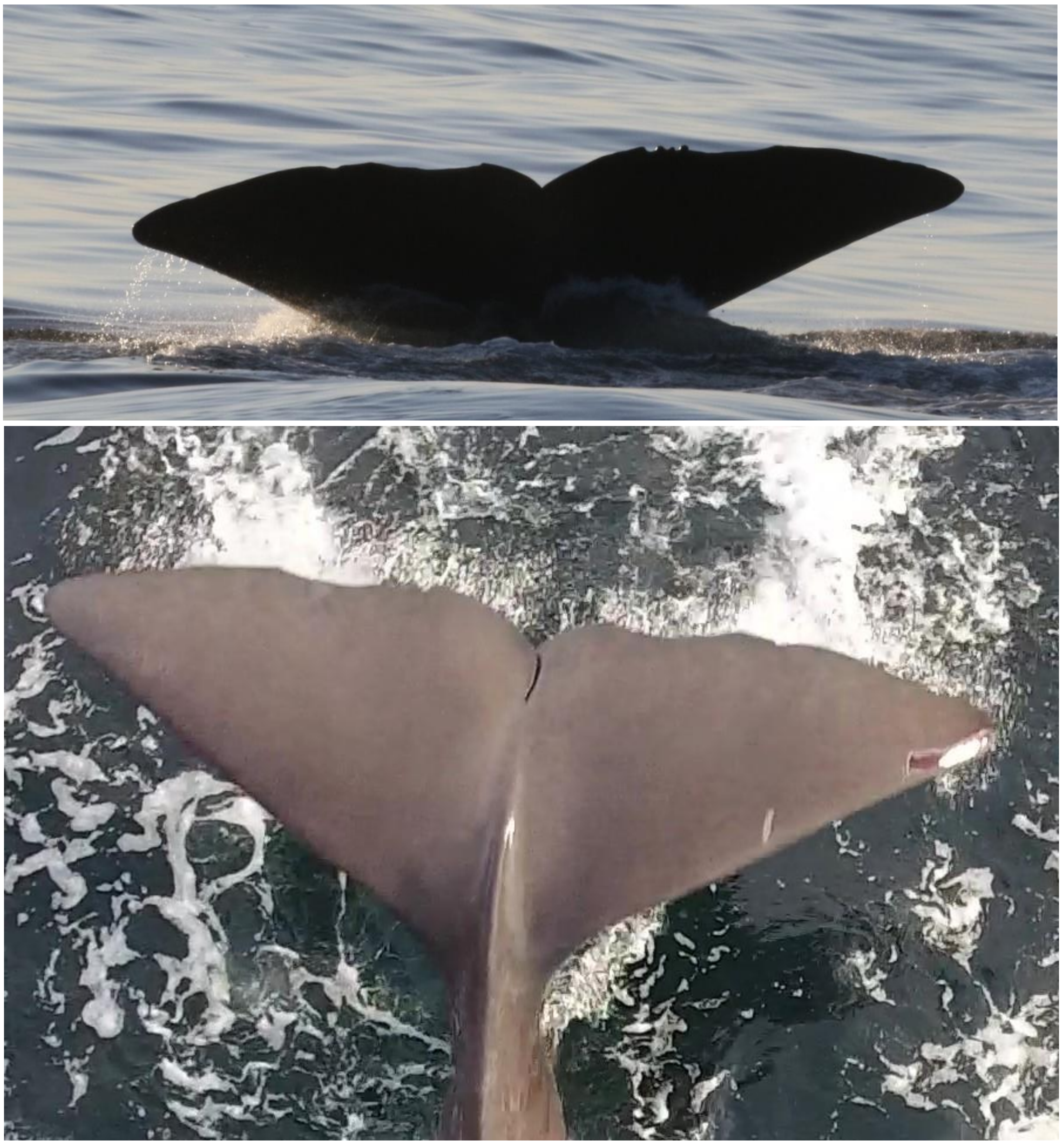


Figure 3.36 Fluke shot taken from MOBHUS of Sw19_253ab tagged in the morning of 10/09/2019. The whale's aspect relative to the photographer is around 0° (top panel). Part of a video frame captured during the second flight on 11/09/2019, showing the same features as above (lower panel). The whale's aspect relative to the drone is around 180°. Photos: Jackie Bort (top), Alec Burslem (bottom).

Four UAV flyovers were attempted on three days over the course of the trial (table 3.11), and all were successful in locating the target whale on the first attempt, 3 on tagged whales and one on an untagged whale. On all occasions the UAV remained above the target whale until it fluked out. High quality UAV imagery suitable for body condition estimation were captured in all flights (figure 3.35) and no responses to the UAV were observed. Fluke-out at the end of each surfacing period was observed in all flyovers and was accompanied by clearly visible defecation on two occasions.

Figure 3.37 Part of a video frame captured of Sw19_253ab during the flight conducted on 10/09/2019 showing tag placement (upper panel). Part of a video frame captured during the second flight conducted on 11/09/2019 (lower panel), showing signs of a previous tag attachment matching the location of the tags in the upper panel. Photos: Alec Burslem

Table 3.11 UAV flight log for the 3S-2019-OPS trial

Species	**Sperm whale**	**Sperm whale**	**Sperm whale**	**Sperm whale**
Date	08/09/19	10/09/19	11/09/19	11/09/19
Datasheet approx time (Local UTC+2)	07 45	10 58	08 00	09 45
Sea State	1	1	2	2
Visibility	Good	Very Good	Good	Good
Wind (m/s)	3.1	4	5	2.7
Tag dataset(s)	250 a&b	253 a&b	NA	253c
Resight ID	285	357	NA	357 (initially recorded as 409)
Pilot	AB	AB	AB	AB
Recorder	PM	PM	PM	PM
Assisting	LM	SI	LM	LM
Calves	0	0	0	0
Response[1]	0	0	0	0
Notes	Tagged sperm whale photogram metry, logging. Fluke up and defecation clear. Rotated UAV 180 to check polarizer	High wind warning, Good photogramme try. No Defecation. Boat photogramme try. Some irregularities on return flight	Non tagged whale, good photogrammetry, boat flyover. Defecation? Video Corrupted	Tagged whale, good photogrammetry. Good light.
Video Filename(s)	05_52_a. mov 05_52_b. mov	08_54_45_ a.mov	01_0803a.mov	02_0743a.mov
Flight Log Hard Copy Image	datasheet _0745.jpg	datasheet_ 1058.jpg	datasheet_2019_09_11. jpeg (IMG_20190911_1828 10152.jpg on central server)	datasheet_2019_09_11. jpeg (IMG_20190911_1828 10152.jpg on central server)

[1] 0 = No response; 1 Low response - Brief and mild, e.g. fast dive, change in speed or orientation; 2: Moderate Response – More forceful reaction but not prolonged, e.g. breach, tail slap; 3: Strong response – continued forceful reaction, multiple tail slaps/breaches/trumpet blows or sustained flight.tail slap; 3: Strong response – continued forceful reaction, multiple tail slaps/breaches/trumpet blows or sustained flight.

Pictures taken from the UAV could also be used for photo identification purposes (figure 3.36). When reviewing the data captured on 11th September 2019 it became apparent that the whale in question bore marks suggestive of a previous tagging: four circular marks arranged in a tight square, corresponding to the positions of the suction cups on the mixed DTAG (figure 3.37). Cross-referencing these images with those of tag placement and flukes taken during previous tagging attempts and UAV flights confirmed that it was the same animal tagged 10th September 2019, having been retagged later the same day after a breach removed both tags. This revealed that data for this animal spanned a greater range of time than previously thought and prevented the data being treated as independent replicates in subsequent analyses.

3.9 Photo identification effort

During tagging a person in the tag boat (MOBHUS) was always dedicated to take pictures of the tagging process. Once a tag was deployed on a whale, the tag boat stays with the whale for some time to take pictures of the tag placement and pictures of the animal's body that can be used for identification purposes. The dorsal fin and fluke are most useful for that, because they tend to have scars and other features that can be used to re-identify the whale. Photo identification was mainly used retrospectively in the analysis of the CEE data to assure that a tagged animal had not been tagged before, in which case it should not be treated as an independent sample.

Figure 3.38 Example of successful deployments of tags on sperm whales using the cantilever pole, along with a fluke photo used for photo-identification; whale Sw19_259b on 16 September 2019. Photo credits: Saana Isojunno.

Figure 3.39 Example of successful deployments of tags on sperm whales Sw19_241b on 29 August 2019 using the cantilever pole (left), with matching fluke (middle) and dorsal fin (right) photographs that can be used for photo-identification. Photos: Saana Isojunno

Table 3.12 List of photo id and tag placement pictures collected during the trial

Date	**DTAG ID**	**File location of photo id pictures** \\ PhotoID_sw\Sperm whales\	**File location of tag placement pictures (tag nickname)** \\TagPlacementPhotos\
8.29.19	Sw19_241a	20190829-SI-Canon7D-tag-on-Silvertop	20190829-SI-sw19_241a(SilverTop)
8.29.19	Sw19_241b	20190829-SI-Canon7D-tag-on-Bruno	20190829-SI-sw19_241b(Bruno)
8.31.19	Sw19_243a	20190831-SI-Canon7D-tag-on-YoungBuoy	20190831_SI_sw19_243(YoungBuoy)
9.3.19	Sw19_244a	NA	NA
9.3.19	Sw19_245a	NA	NA
9.5.19	Sw19_248ab	20190905-JB-Canon7D-tag-on-Silvertop&Liv	20190905_JB_sw19_248ab(Liv&SilverTop)
9.8.19	Sw19_250ab	20190907-SI-Canon7D-tag-on-Silvertop&Liv	20190907_JB_sw19_250ab(SilverTop&Liv)
9.10.19	Sw19_253ab	20190910_JB_Canon7D_tag-on-YoungBuoy, 20190910_SI_Canon7D_tag-on-YoungBuoy&SilverTop	20190910_JB_sw19_253ab(YoungBuoy&SilverTop)
9.10.19	Sw19_253c	NA	NA
9.11.19	Sw19_254a	20190911_JB_Canon7D_tag-on-SilverTop	20190911_JB_sw19_254a(SilverTop)
9.12.19	Sw19_255ab	20190912_SI_Canon7D_tag-on-BumbleBee_SunFlower	20190912_SI_sw19_255ab(BumbleBee&Sunflower)
9.12.19	Sw19_255c	20190912_SI_Canon7D_tag-on-LadyBird	20190912_SI_sw19_255c(LadyBird)
9.12.19	Sw19_255d	20190912_SI_Canon7D_tag-on-LordChristmas	20190912_SI_sw19_255d(LordChristmas)
9.14.19	Gm19_257d	PhotoID_Gm\PhotoID\gm19_photoID_2_tagged_Bumblebee	20190914_LH_gm19_257d(BumbleBee)
9.14.19	Gm19_257e	PhotoID_Gm\PhotoID\gm19_photoID_3_tagged_Sunflower	20190914_JB_gm19_257e(Sunflower)
9.16.19	Sw19_259a	20190916_SI_Canon7D_tag-on-LordChristmas	20190916_SI_sw19_259a(LordChristmas)
9.16.19	Sw19_259b	20190916_SI_Canon7D_tag-on-Ladybird	20190916_SI_sw19_259b(Ladybird)

4 Discussion

4.1 Outcome of the trial

The trial had two primary tasks (1 and 2), and six secondary tasks (3-8):

1) Tag sperm whales with Mixed-DTAG and expose them to PAS at different levels and ranges using the CAPTAS source on OSVE.

✓ *We deployed 20 tags on 15 sperm whales and conducted 10 controlled exposure experiments with 25 runs. Using the frigate (OSVE) with the operational CAPTAS source we conducted 7 CEEs with 16 exposure runs. This task is considered achieved very successfully (section 3.1-3.3).*

2) Tag pilot whales or killer whales with Mixed-DTAG and expose them to PAS and CAS using the SOCRATES source on HUS.

o *We deployed 5 tags on pilot whales but all tags released prematurely and before any CEEs could be conducted. This task is therefore considered not achieved (section 3.1). However, we stress that this primary task was given significant priority. In total, we estimate that 7 to 10 days of ship time were fully dedicated to this task, and we collected 20 hours of baseline data on pilot whales. The primary reason why no CAS experiments were conducted is that the weather conditions were rough in the initial period when this task was the highest priority and no pilot/killer whales were found in the protected fjords were conditions were better. Furthermore, when weather was acceptable, we struggled to find target species in the main operation area. When we finally did find them in acceptable weather conditions, the behavior of the tagged pilot whales led to early tag release.*

3) Tag sperm whales with Mixed-DTAG and expose them to PAS at distant ranges (close and distant) using the SOCRATES source on HUS, but mimicking the OSVE transmission scheme.

✓ *In addition to the exposures conducted with the sonar on OSVE, an additional 3 CEEs were conducted with 9 exposure runs using the SOCRATES source on HUS as the source. This task is considered achieved (section 3.1 and 3.3).*

4. Collect data using moored passive acoustic sensors in the study area.

✓ *Two stations with 2 Loggerhead recorders on each were deployed and recovered successfully. Three of the four recorders worked very well and provided us with continuous acoustic recording of the study area. The southern buoy recorded a total of 20 days of data and the northern buoy recorded 22 days and 5 hours of data. This task is considered achieved (section 3.5.2).*

5. Collect baseline data of target species.

✓ *We managed to deploy 24 tags to 20 different animals (15 sperm whales and 5 pilot whales), and collect 355 hours of tag data. In the pre-exposure period and in sessions were no exposures were conducted we collected 120 hours of baseline data on sperm whales and 20 hours of baseline data on pilot whales. This task is consider achieved (section 3.1 and 3.3).*

6. Collect information about the environment in the study area (CTD and XBT).

✓ *5 CTDs and 17 XBTs were collected from HUS and 13 XBTs were collected from OSVE. This task is considered achieved (section 3.7).*

7. Collect acoustic data using towed arrays.

✓ *The Delphinus acoustic array was towed extensively while searching, tagging and tracking sperm whales. In total, 418 hours of data have been recorded, collecting almost 2 TB of acoustic data. This task is considered achieved (section 3.5).*

8. Collect sightings of marine mammals in the study area.

✓ *A total of 467 sperm whale and 16 long-finned pilot whale sightings were recorded, excluding re-sightings. Sightings of minke whale, harbor porpoise, fin whale, humpback whale, sei whale, killer whale, and a possible blue whale were also recorded. This task is considered achieved (section 3.4).*

Thus, all tasks except task 2 were achieved successfully. Overall, the 3S-2019-OPS trial is considered to be successful. We expect that the data collected will be sufficient to answer the questions related to the effect of animal to sonar range well. However, despite significant effort to try to achieve task 2, the question of the effect of CAS on pilot whales and killer whales cannot be answered with the data collected. Additional field effort will be required to achieve this.

4.2 Collaboration with the Royal Norwegian Navy

The 3S3-project is funded by military authorities from US, UK, The Netherlands and France, and except for an in-kind contribution from FFI there is no financial support from Norwegian military authorities, despite the fact that the trial happened in Norwegian waters. However, the direct support of the Royal Norwegian Navy (RNoN) during the 3S-209-OPS trial in making the frigate OSVE available is a major contribution and the RNoN is considered a full partner in the 3S project, along with other sponsors.

Naval vessels always have a tight schedule and early planning was essential to get our activity into their sailing schedule. It was critical for coordination in the planning phase to have a dedicated point of contact within the Navy. During the operation dedicated liaisons on the frigate were essential to coordination and communication between the trial managers on HUS and the command chain on OSVE.

The exposure experiments were conducted according to a strict geometrical design. The OSVE initially approached HUS on an intercept course, with both vessels towing a long array and thus having restricted maneuverability. Strict coordination bridge to bridge was therefore essential to maintain safety and experimental design. This worked very well because of the professional behavior of the navigators on both vessels. Use of open maritime VHF and AIS on both vessels also made this coordination easier.

Most of the experiments involving the frigate were executed in the dark, because OSVE was more available during night times. This added a challenge with the current technology used to track whales, which is mostly based on visual observations. The permits to conduct experiments on animals also require that we do not risk injury to the focal animal, or any other animals in the area. A safety zone around the source vessel was therefore established during active transmissions from both HUS and OSVE. If an animal entered the safety zone, the sonar would be shut down. In the dark, this safety zone was monitored using infrared optical equipment on the frigate. The operators reported that this worked fine, they detected many whales, but never close enough to initiate shut down.

The 3S project is open science involving close collaboration with academia and military research organizations. Results will be published in unrestricted public reports and papers. All issues concerning restrictions on the use of data from the experiments involving a naval combat vessel and an operational sonar system were therefore carefully sorted out beforehand. Data from the combat system on OSVE are restricted, but the only data that is needed for the analysis is the position, time and sonar settings of each transmitted pings. As long as OSVE sailed with AIS on during the CEEs, navigation data is unrestricted, and the sonar transmission scheme were specified by the experimental design. A procedure was set up where the Navy extracted data from the combat system, and FFI removed all sensitive information before releasing the necessary data to the open science process as unrestricted. Getting access to the data from the frigate has taken more time than expected which has delayed the analysis. For some of the CEE runs we also have to use lower quality data, because logging was not activated, or data was corrupted and lost.

The partners and sponsors of the 3S project have all expressed gratitude that the close collaboration between the RNoN and FFI allowed for this type of experimentation with operational systems. What we achieved during the 3S-2019-OPS trial is to collect a unique dataset, which would be difficult to collect elsewhere. The crew on OSVE and our naval point of contact always appeared professional and correct, both in the planning and execution phase of the operation.

4.3 Hot wash up de-brief

On the final day of the trial we did a hot wash up de-brief with the science team on HUS. The aim was to summarize the trial and have an open discussion on how to improve future fieldwork. We compiled a wish list for future 3S trials, based on this years’ experience. This list (below) will be considered when planning future trials, but cost benefit analysis and financial limitations of future trials also need to be considered. At the end of the de-brief, we had a short brain storming session about ideas for future research for 3S (3S4). The notes below are from a brainstorming session, and not the product of a thorough consideration of science need, nor necessarily the priority of the 3S project managers.

4.3.1 SOCRATES source

- Increase the power of Socrates source by adding a few dB (~3dB). An increase up to 3dB seems feasible by improving different components (e.g. amplifiers and tow cable). It could be explored what gain can be achieved against what cost. The cost ia estimated to be in the order of 100-200 kEuro, but that should be checked more carefully.

4.3.2 Tags

- A rechargeable and high-power VHF is recommended as the best improvement of the mixed-DTAG, especially in the context of the having some VHF transmitters fail during this trial
- The primary function of the Argos sensor was to recover the tags after release. To get on-animal Argos, the setting was changed to a 3-sec delay. This worked well at least with some animals. However, the manual did not specify that this setting meant that the transmitter had to be dry for 3 seconds. The result was significantly fewer fixes of tags floating in the water. Based on this, it is recommended to include a testing procedure in the protocol whenever settings are changed.
- The mixed-DTAG core units were received one day before departure, some extra days for testing the units would be preferred.
- There were problems with the depth sensors of the DTAG core units after dives >1800 m. The core units were pressure tested in the lab before being shipped, but problems might occur only when all components of the tag are mounted together inside the mixed-DTAG housing. It might be an option to do a depth pressure test at sea with the CTD. Alternatively, a test with the entire tag, not only the core unit, in the pressure tank before departure could be considered.

4.3.3 Tagging

- When tagging sperm whales, it is essential to be close to the animal when it surfaces to be able to manoeuvre close to the whale before it starts on a new long dive. The acoustics team with the Delphinus system can follow the animal based on its acoustic behaviour, and this is of great value. The visual observers are essential when the animal is at the surface. However, when the animal ascends, clicks stop and the expected surface location has to be estimated. It might be good to go back to the data and see if there is a certain pattern that might help predict surfacing location (distance from last clicks to surface location, time between last clicks and surfacing).
- Communication between MOBHUS and MMOs on HUS can be improved to aid tagging.

- When tagging in rough sea conditions, it can be difficult to see whales at the surface. Clear directions from HUS are helpful for MOBHUS. E.g. a relative bearing from HUS is useful.
- In 2019, the boat driver was wearing a radio helmet. This helped radio communication between HUS and MOBHUS a lot, but the other two tag team members on board MOBHUS could not hear the radio conversation. This caused delay in information transfer. A second helmet (or connection to speaker on board) might be considered.
- A better VHF radio on the OBS deck is needed (higher antenna placement, more power). SOCRATES and the bridge of HUS had less difficulties with radio contact with MOBHUS (antenna was higher placed and more transmitted power).
- A tablet of acoustic and visual tracks of target whales, similar to what they have on OBS deck, would be an advantage for the tag-team as well.
- In general, good preparation beforehand of the team members on all stations and knowing what information is useful and what isn't is recommended. A protocol on the tagging procedure can be a good start point.
- Consider a study on the marks and wounds made by the suction cups using drones. Under what conditions are lesions seen? E.g. only when the tags are pulled off by a breach, or also when the release are activated?

4.3.4 Tracking of tagged animals

- The visibility during twilight and thus the number of hours of difficult visual conditions due to darkness was underestimated in the planning. We were therefore not sufficiently prepared to do tracking in the dark.
- Tracking in the dark using acoustic tracking in combination with target motion analysis (TMA) based on the automatic direction finder tracking the VHF transmitter on the tag was an essential tool which was developed during the trial, but could be improved.
- We recommend to analyse the tag data to test the accuracy of VHF based TMA.
- It is recommended to work towards a better performance of the automatic direction finder system on board of HUS (DF-Horten). From MOBHUS the direction finder worked well. Double (high) power VHF and a rechargeable VHF system are recommended to improve the tracking system.

4.3.5 Marine Mammal Observers

- It is recommended to have more binoculars with reticles on the OBS-deck. Two more angle boards might be useful as well.
- Having more dedicated MMO's on the OBS deck is useful (especially with Pilot whales). It is also recommended that the lead MMO is not also member of the tag team.

4.3.6 Drone

- Our first attempt to use drones (UAV) to track whales and take photos were successful and encourage future use of this technology.

- It would be an advantage if the tag teams could bring and operate the drone, to save time and risk having to swap crew on MOBHUS.
- Drones with longer flight times and better noise protection to enable flights from HUS would be a great advantage.

4.3.7 3S4 – future research questions for 3S

- CAS versus PAS studies on more species (including pilot whales).
- Masking effect by CAS
- Longer duration exposure, more closely mimicking how the Navy does its operations, looking at habituation, sensitization (instead of extrapolation from exposure duration less than one hour to hours or even days). Killer whale might be a good species for this, or humpback whales. How long do these species stop feeding?
- Looking into effects of seismic activities, although this obviously needs another type of funding (JIP?).
- Investigate the effect of multiple sources (e.g. using both a Frigate source and Socrates) at the same time.
- Are there signs of any long-term habituation to 1-2 kHz sonar in sperm whales looking back to 3S data over the last 10-12 years?

4.4 3S3 publication plan

We have now completed all data collection under the 3S3-project and are making good progress on our analysis of the core deliverables. So far two major papers have been published to report on the results of the data collected under 3S3 (Wensveen et al. 2019 and Isojunno et al. 2020). Wensveen et al. (2019) reported that bottlenose whales in a pristine environment responded at similar levels to both close and distant sonar, indicating that for this species in that habitat behavioral responses were not significantly modified by range to the source. This paper was supported by propagation modelling in Von Benda-Beckmann et al. (2019) in order to optimize estimates of received levels for whales with satellite tags (without acoustic recording). Isojunno et al. (2020) recently reported that received sound energy predicts sperm whale responses to both intermittent and continuous navy sonar, and that responses to CAS and PAS were similar as long as the received sound exposure level were similar. Further publications are currently in preparation to address the severity of behavioral responses in sperm whales exposed to CAS and PAS (Curé et al. in prep) and potential masking of sperm whales exposed to 1-2 kHz CAS and PAS (von Benda-Beckmann et al. In prep, Isojunno et al. In prep).

The analysis of the data from the 3S-2019-OPS trial will mainly be achieved through a quantitative analysis of response threshold and response intensity (Wensveen et al. in prep), and more descriptive analysis using severity scoring (Curé et al. In prep). The quantitative analysis might be split up into separate analysis of response threshold and response intensity in the end. In addition to the papers, we also plan to deliver a data report describing all data from 3S3 (Kvadsheim et al. In prep). All analysis and publications are expected to be achieved by the end of the project (Dec 2002), although the on-going COVID19 crisis might lead to some delay.

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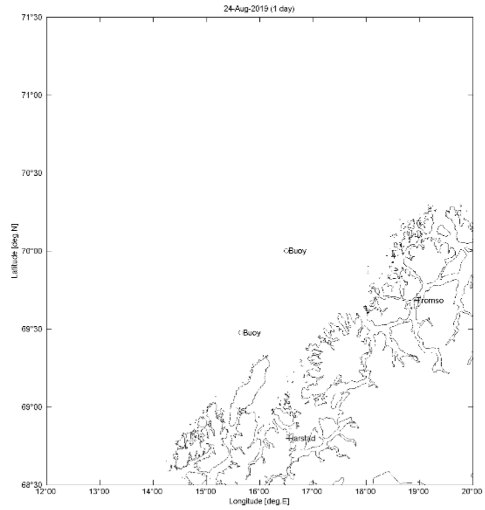
A Data inventory

Table A.1 Data inventory of the central server of 3S-2019-OPS

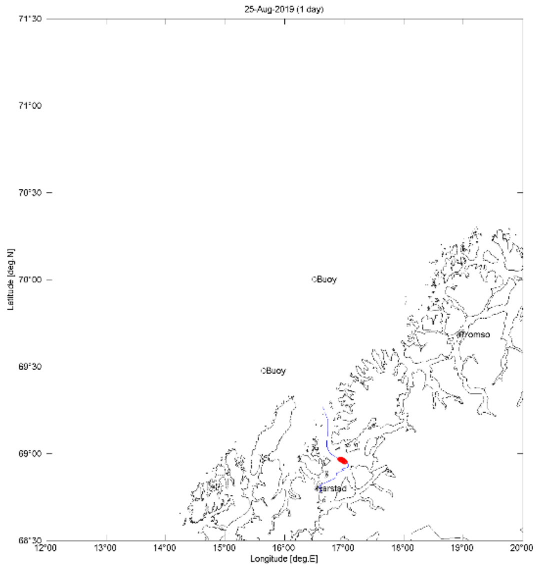
Folder	Summary of content
3S-19_CTD_XBT	XBT profiles including sound speed profiles and raw XBT data for use in MK21 program. All CTD casts, CTD log and SD200W program to read data files.
acousticDataAndResults	Screenshots of TNO PAM systems Sound example from mooring with OSVE exposure and SW clicks.
Argos	All ARGOS datafiles from Spot logger.
Bridge Log	Daily order 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
Cruise report	Previous 3S cruise reports and 3S-2019 cruise report outline.
Daily Orders	Daily work plans that we put up daily to inform the team about weather, work area, etc
Documents	TNO events log book, TNO summary information about acoustic recordings and number of whales clicking.
GPSlogs	Raw NMEA logs from GPS on TNO container.
Logger	Daily backups of raw logger database Checked_data logger files that will be imported back into Access to create MASTER database. Screenshots of Logger.
MDTAGs	Raw DTAGv3 data (.dtg, .swv, .xml) and meta data (cal and prh). Data files from Fastloc GPS deployments Logbook kept by tag technicians, dtag prep protocol, etc
pictures and videos	All photos organised by Cruise Highlights, Photo ID data and fun pics.
Sit Reps	Situation reports sent to Norwegian Naval Command.
SocratesLogs	Log files of SOCRATES II source. Times of transmissions in the transmission log file in each subfolder.
TrialOverviewPictures	Plots of daily sailing tracks
UAV	AUV video data and protocol
OSVE data	Navigation data, bathy drops and sonar transmission log from the frigate

B Daily sail tracks

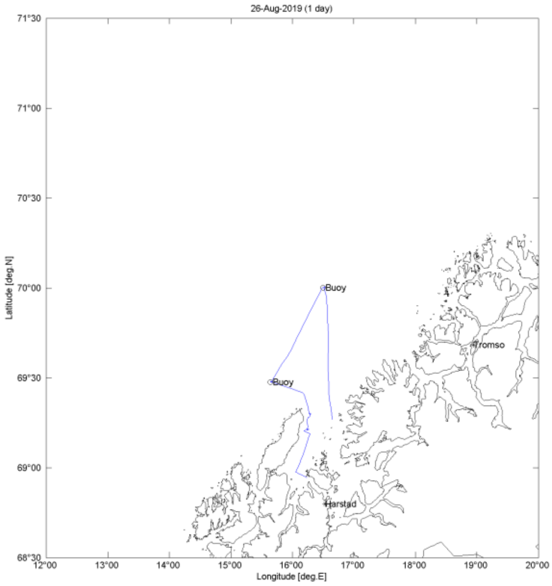
August 24th – Mobilization in Harstad.



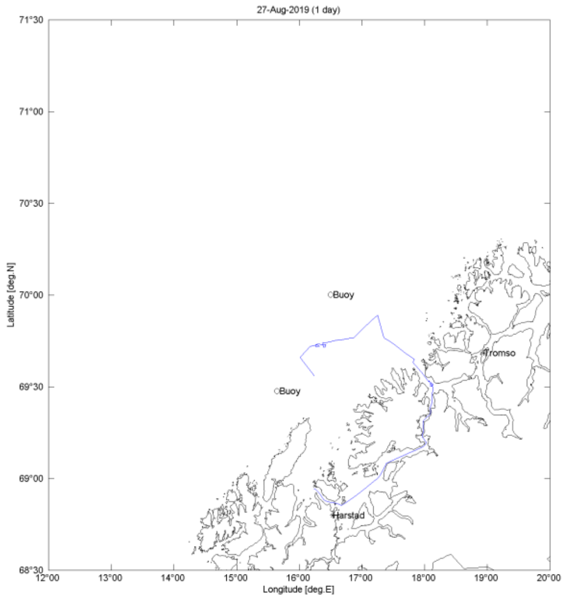
August 25th – Testing of SOCRATES and tags. Position of HUS sonar transmissions in red



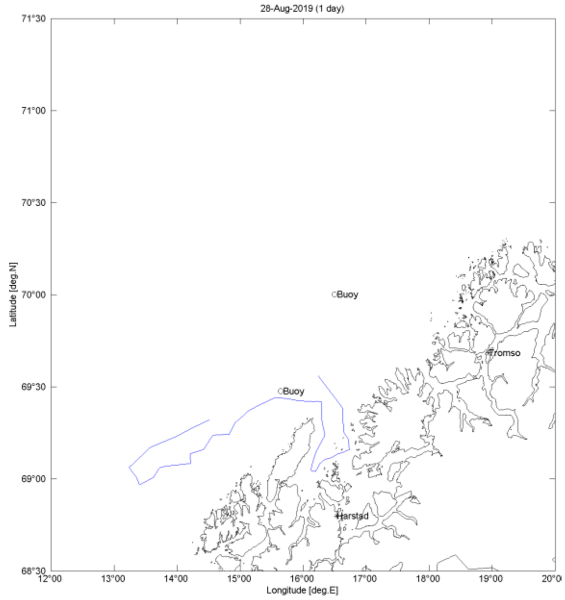
August 26th– Deployed moored buoys. Testing VHF tracking equipment. Started survey



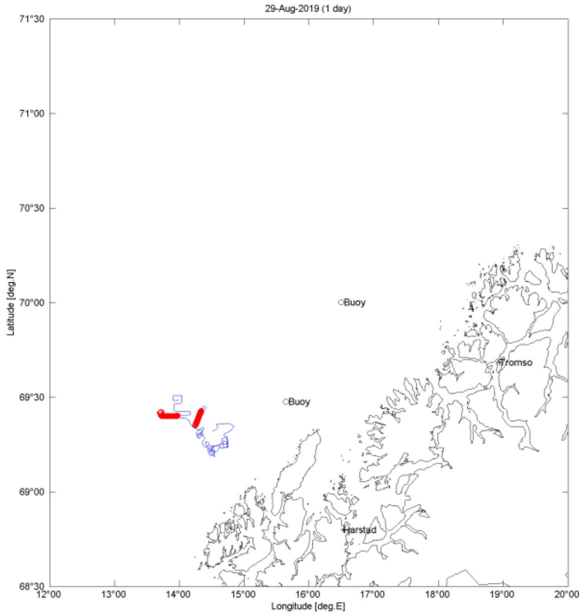
August 27th – Final tests. Fully operational. Started survey for pilot/killer whales



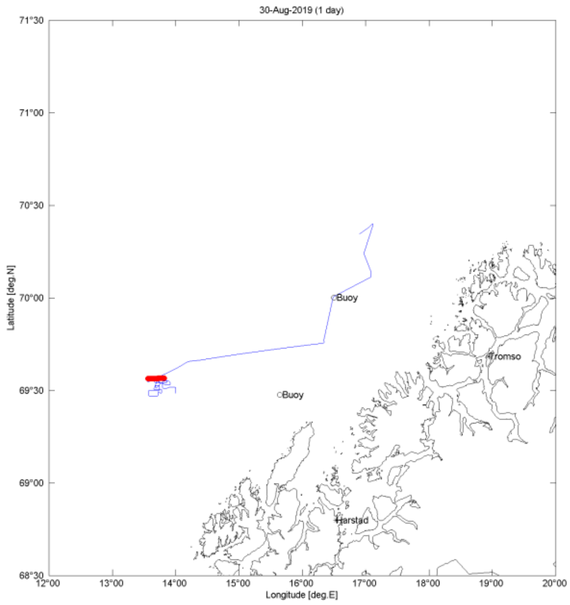
August 28th – Visual and acoustic survey for killer whales and pilot whales.



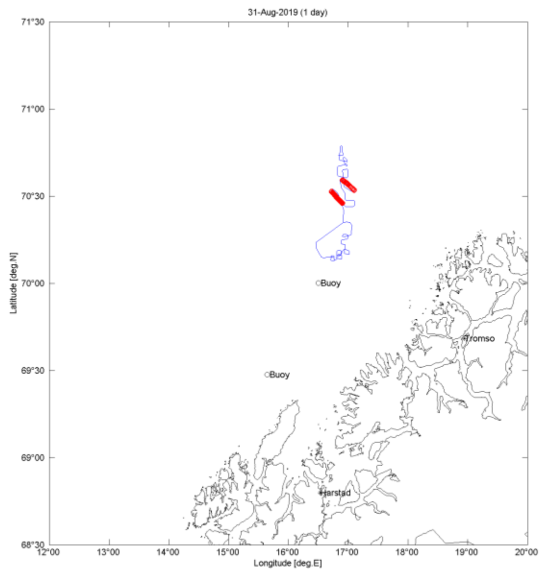
August 29th – Tagged two sperm whales. Conducted CEE01 with HUS



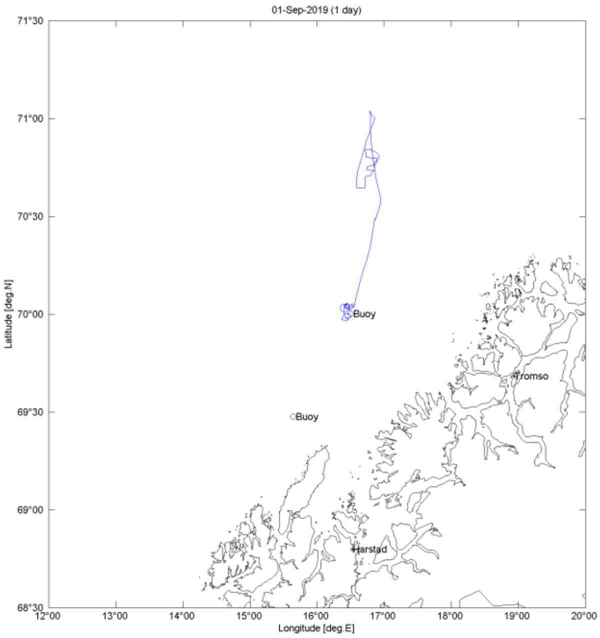
August 30th - Finished CEE I, surveyed northwards along shelf edge for pilot/killer whales



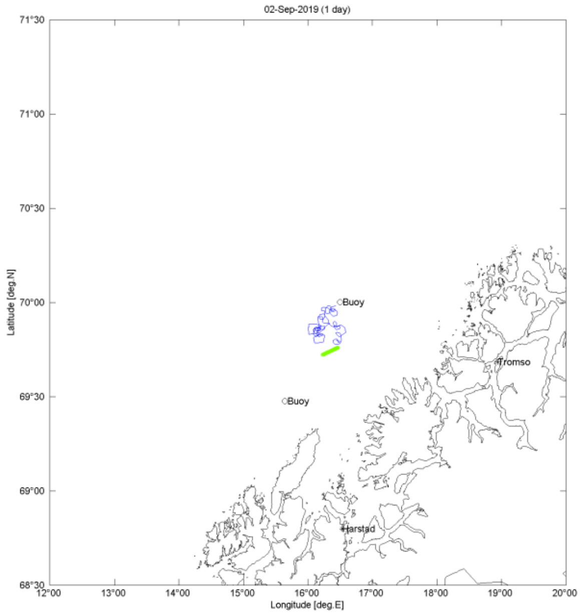
August 31st - No detection of blackfish in operation area. Tagged sperm whales, conducted CEE02 with



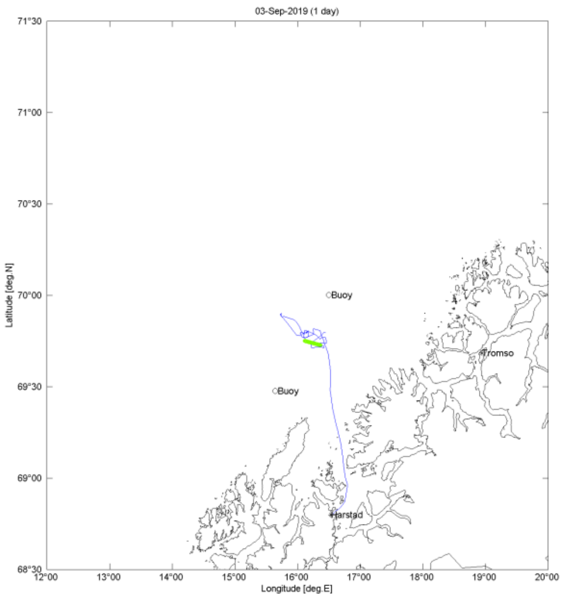
September 1st - Recovered tag, collected CTD, transit to Malangen, tagging sperm whales.



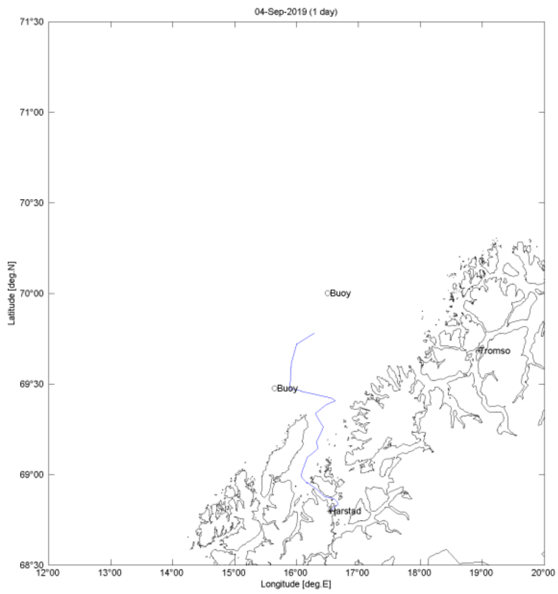
September 2nd - Tracking tagged sperm whale, CEE3, OSVE sonar transmission in green.



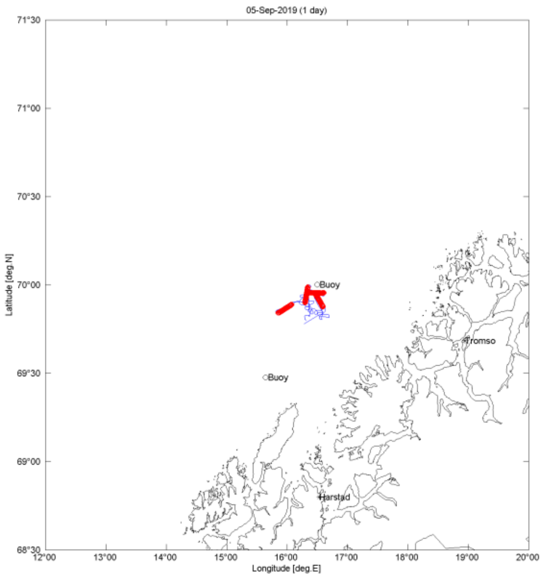
September 3rd - Conducted CEE03 with OSVE. Recover tags. Transit to Harstad.



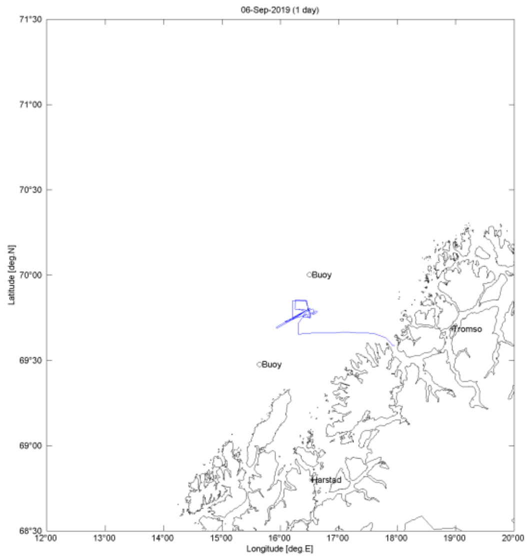
September 4th - Overnight port call in Harstad due to weather. Surveyed for pilot whales/killer whales through Andfjord and along shelf edge to Malangen.



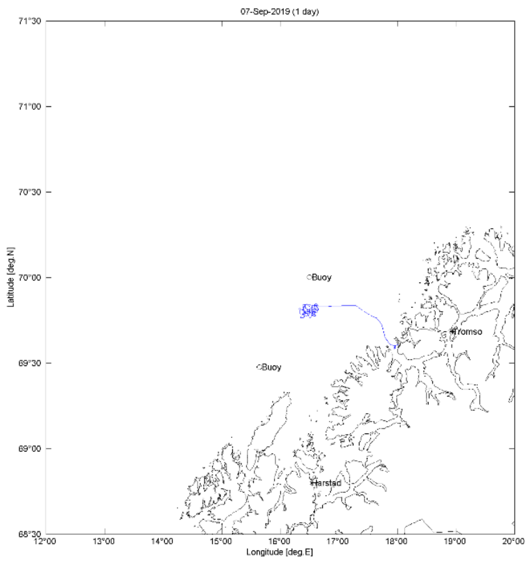
September 5th - Tagged a sperm whale, conducted CEE04 with HUS



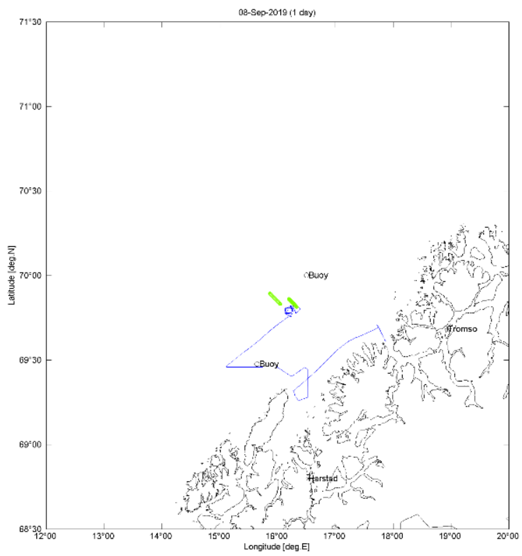
September 6th - Recovered tag. Too rough weather for tagging. Transit to Malangen for personell transfer.



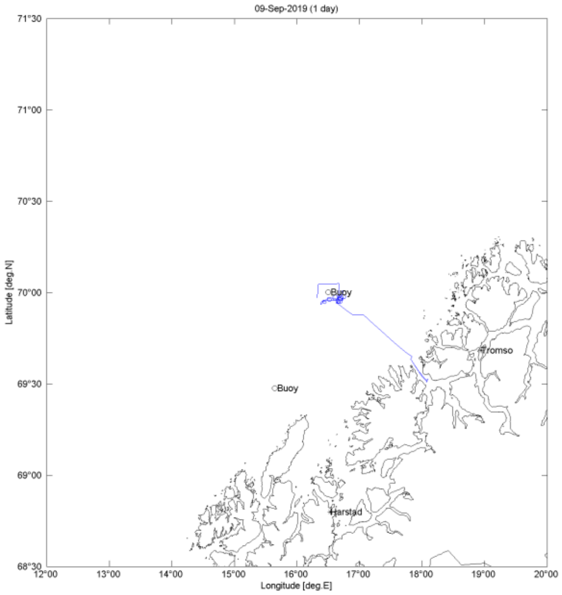
September 7th – Survey through Malangen, tagged a sperm whale.



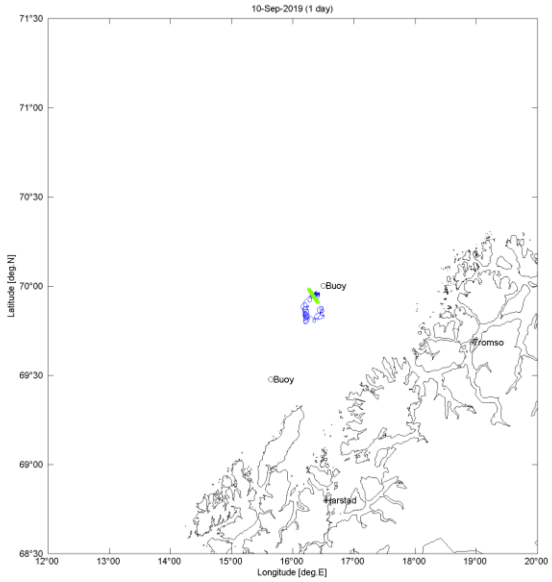
September 8th - Conducted CEE05 with OSVE. Surveyed along shelf edge and into Andfjord for pilot/killer whales. Too rough weather to tag,



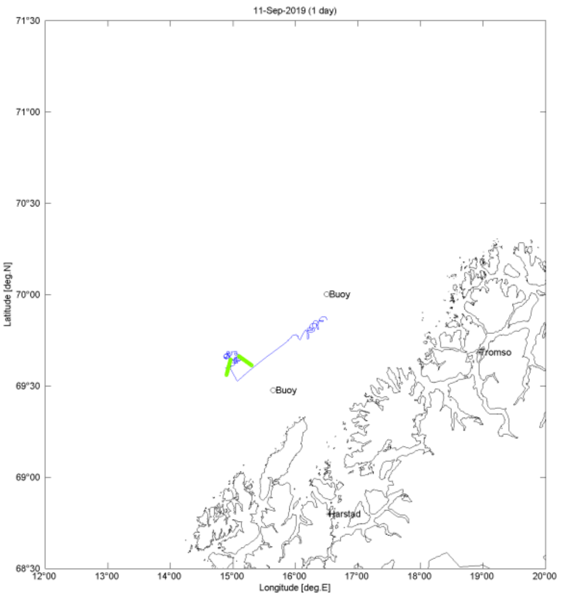
September 9th - Rough sea conditions. Tried tagging without success.



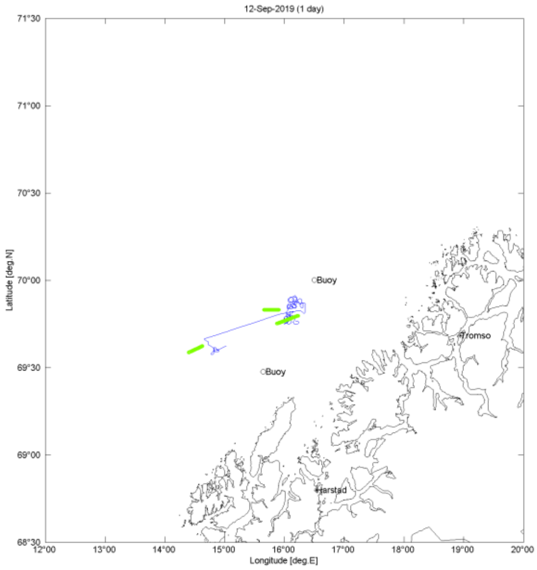
September 10th - Tagged a sperm whales Conducted CEE06. Both tags off 10min into no-sonar run. Tagged again right before dark and conducted CEE07 with OSVE.



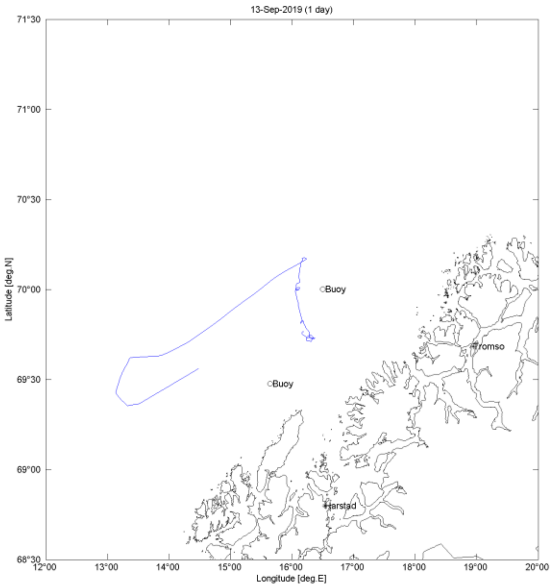
September 11th - Tagged a sperm whale and conducted CEE08 with OSVE



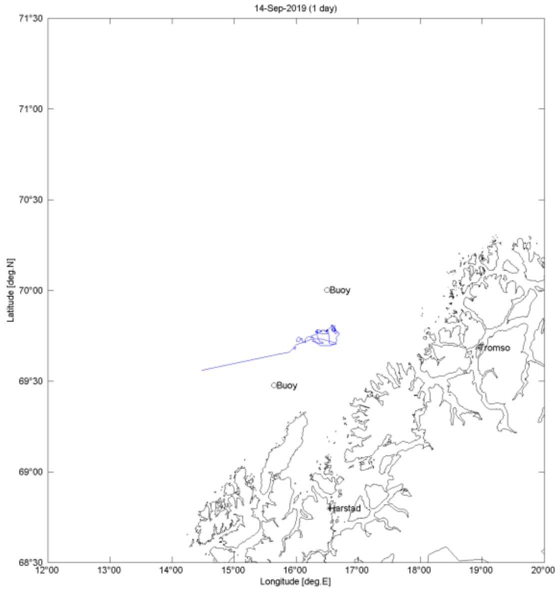
September 12th – Finished CEE08, transited north, tagged 3 sperm whales and conducted CEE09 with OSVE.



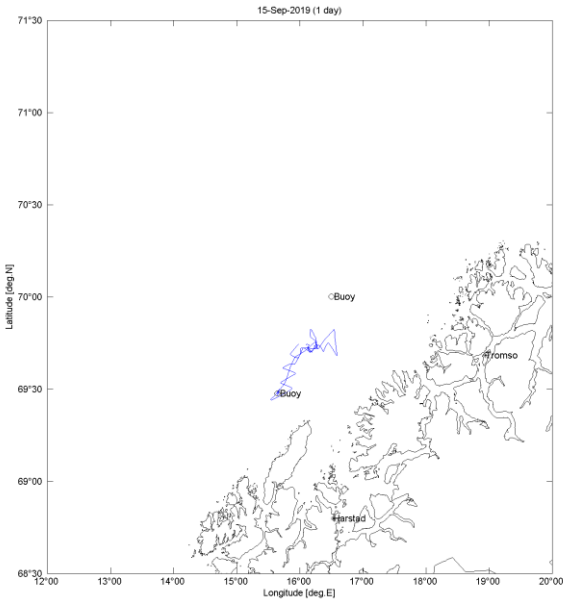
September 13th - Recovering the six tags floating in the sea from the previous 3 CEEs



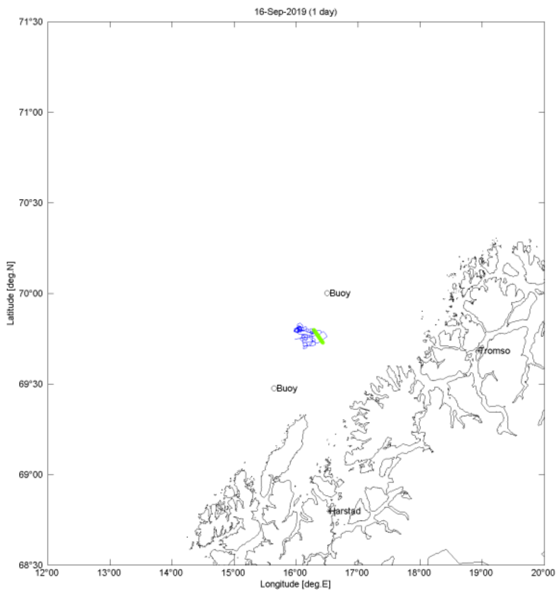
September 14th - Tagged 5 pilot whales, tracked overnight, all tags released prematurely before CEE10.



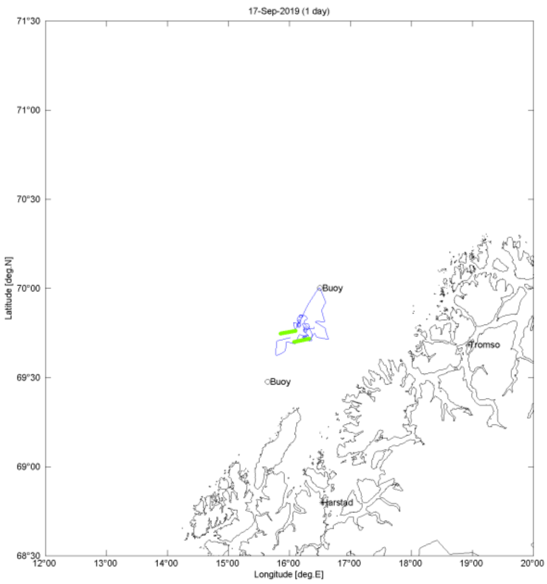
September 15th - survey for blackfish. Recovered southern buoy.



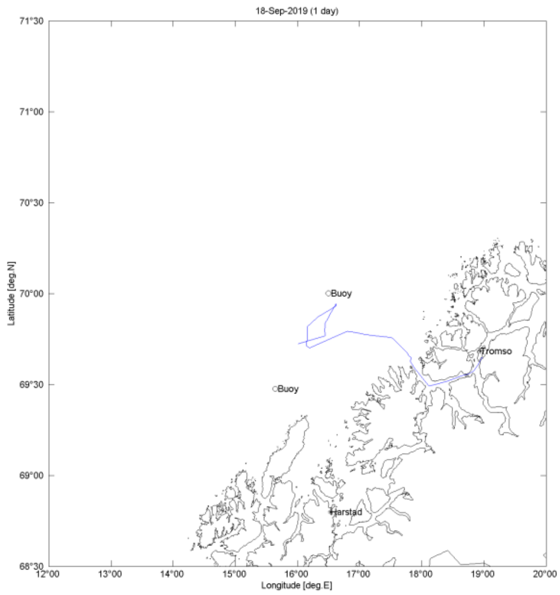
September 16th - Tagged sperm whales, conducted CEE11 with OSVE



September 17th – Finished CEE11, recovered tag and northern buoy, survey for blackfish.



September 18th - Survey for blackfish without success. Transit to Tromsø.



September 19th - De-brief, de-mobilization and celebration in Tromsø

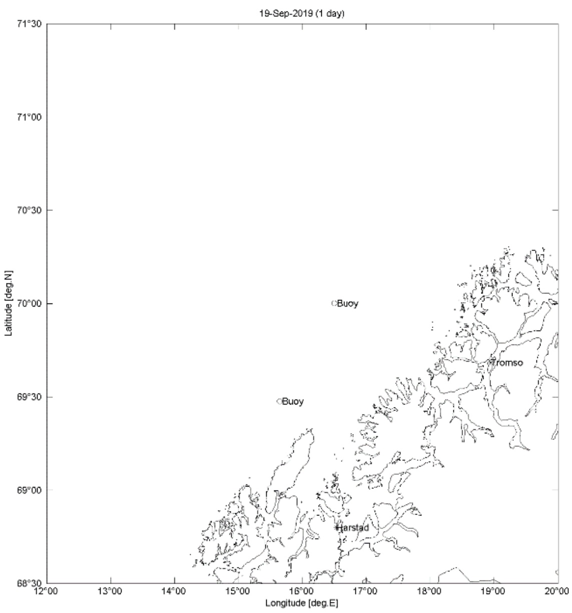


Photo: Frans-Peter Lam

C 3S-2019-OPS Cruise plan

3S-2019-OPS
Cruise Plan

Final Version
11/07/2019

The 3S-2019-OPS research trial is conducted by the 3S-consortium as part of the 3S3-project.

CONTENT

LIST OF ABBREVIATIONS

CAS	Continuous Active Sonar
PAS	Pulsed Active Sonar
OSVE	KNM Otto Sverdrup, Nansen class frigate of RNoN
HUS	R/V H.U. Sverdrup II, research vessel of FFI
DTAG	DTAG as originally developed by WHOI. Currently provided by Univ of Michigan
MDTAG	Mixed DTAG (DTAG core unit + ARGOS satelitte tag and GPS logger).
SMRU	Sea Mammal Research Unit, part of St.Andrews University, UK
FFI	Forsvarets forskningsinstiutt / Norwegian Defence Research Establishment
TNO	NL Organization for Applied Scientific Research
DGA	The Direction générale de l'armement, part of the French Ministry of Defence
DMO	NL Defence Materiel Organization, part of NL Ministry of Defence
RNLN	Royal Netherlands Navy
RNoN	Royal Norwegian Navy
CEREMA	Centre d'études et d'expertise sur les risques, l'environnement, la mobilité et l'aménagement, France
LMR	Living Marine Resources program of USN
USN	US Navy
NAVFAC	Naval Facilities, branch of USN hosting LMR-program
IMR	Institute for Marine Research, Bergen, Norway
LKARTS/ARTS	Private consultant company in Norway
DSTL	Defence Science and Technology Lab, part of the UK Ministry of Defence
NSM	Naval Strike Missile
ATC	Andøya Test Center
MOBHUS	small boat, Man-Overboard-Boat of HUS
ADF	Automatic Direction Finder
VHF / DDF	Digital Direction Finder using VHF
NARA	Norwegian Animal Research Authority (Mattilsynet)
MMO	Marine Mammal Observer
XBT	eXpandable BathyThermograph, probe to measure temperature profile of water column
CTD	Conductivity-Temperature-Depth, sensor to measure density/sound speed profile
CO	Comanding Officer
XO	Executive Officer
CAPTAS	Combined Active-Passive Towed Array System, operational sonar system of frigate OSVE
ATAS	Active Towed Array System (for OSVE: CAPTAS Mk2)
SOC	SOCRATES II sonar source
Delphinus	TNO towed array system for acoustic detection and tracking of marine mammals
CEE	Controlled Exposure Experiment
BRS	Bahavioural Response Study
HFM	Hyperbolic Frequency Modulation (sonar signal/sweep)
HPAS	High level PAS
MPAS	Medium/reduced level PAS
XHPAS	Extra high level PAS
PW	(long-finned) Pilot Whales
KW	Killer Whales
SL	Source Level (of sonar source)

PROJECT OBJECTIVES

Test how the distance to the source affects behavioural responses

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

CRUISE TASKS AND PRIORITY

Primary tasks:

1. Tag sperm whales with Mixed-DTAG and expose them to PAS at different levels and ranges using the Captas source on OSVE
2. Tag pilot whales or killer whales with Mixed-DTAG and expose them to PAS and CAS using the Socrates source on HUS.

Secondary tasks:

3. Tag sperm whales with Mixed-DTAG and expose them to PAS (HPAS) at distant ranges (close and distant) using the Socrates source on HUS, but mimicking the OSVE transmission scheme.
4. Collect data using moored passive acoustic sensors in the study area.
5. Collect baseline data of target species.
6. Collect information about the environment in the study area (CTD and XBT).
7. Collect acoustic data using towed arrays.
8. Collect sightings of marine mammals in the study area.

Priority:

When the frigate is available the priority is to work on sperm whales (task 1).

When the frigate is not available the priority is to work with pilot or killer whales (task 2).

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, it is a higher priority to replicate the CAS-vs-PAS experiment on pilot whales than to tag killer whales (task 2).

3S-CONSORTIUM

The main partners of the 3S3-project conducting the 3S-2019-OPS trial are:

- The Netherlands Organization for Applied Scientific Research (TNO), The Netherlands
- Sea Mammal Research Unit (SMRU), Scotland
- The Norwegian Defence Research Establishment (FFI), Norway
- CEREMA Dter Est, Acoustics Group, Laboratoire de Strasbourg, France
- The Royal Norwegian Navy

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

- University of Iceland,
- LKARTS-Norway
- Institute of Marine Research (IMR), Norway
- The Netherlands Defence Materiel Organisation, The Netherlands
- Marine Science & Communication, The Netherlands

The 3S3 research project is sponsored by;

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

OPERATION AREA

The operation area is defined based on expected whale availability and on where the frigate (OSVE) is most likely to be available. The primary target for the trial is to work with sperm whales and pilot whales. We will therefore primarily operate in deep water off the shelf break between Harstad and Tromsø.

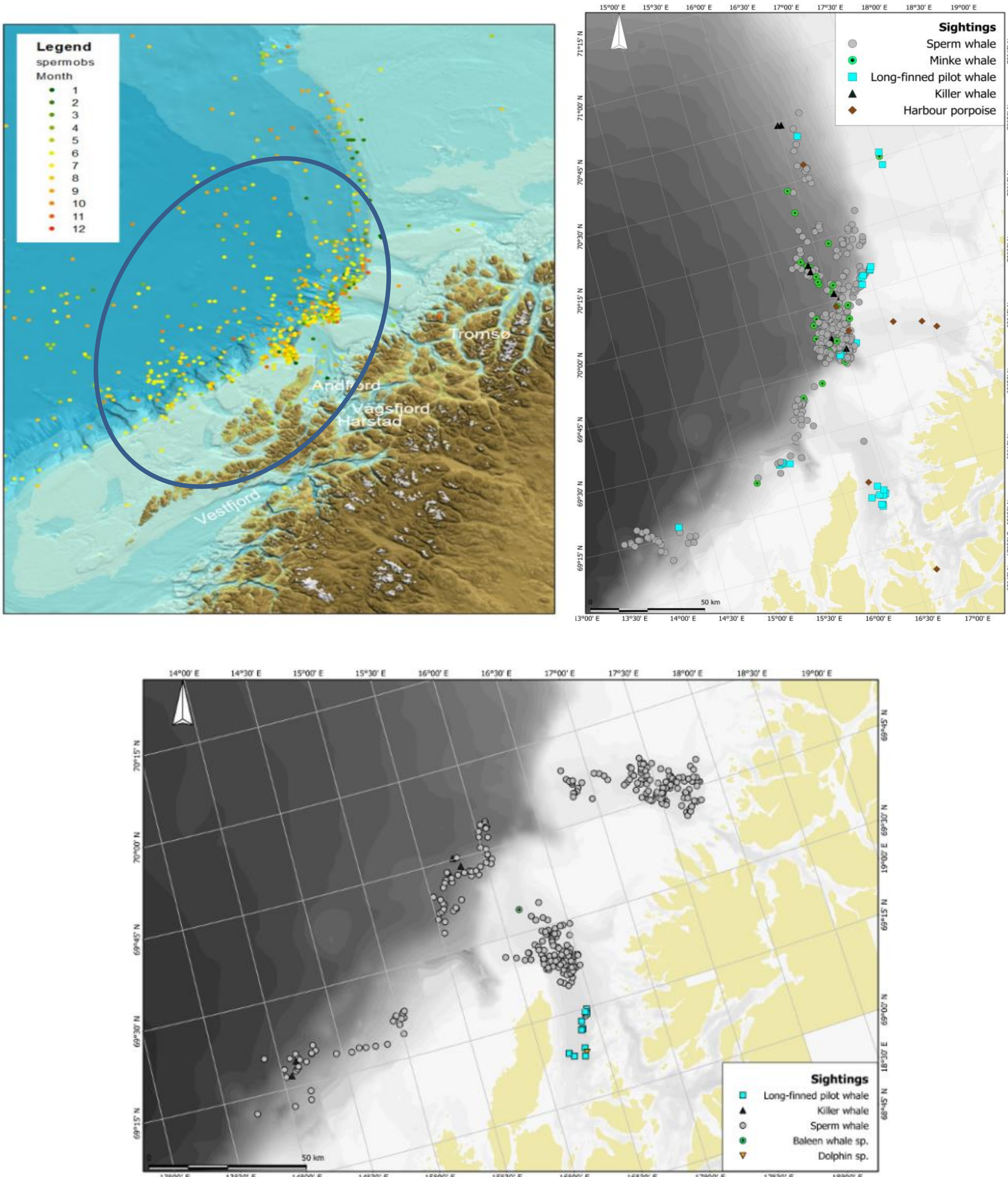
Sperm whales and pilot whales are generally found throughout the deep water basin of the Norwegian Sea but tend to concentrate along the steeper part of the shelf break and in canyons. However, we might also want to search for whales in areas with lower concentrations. In case of windy conditions we can also look for target species in Andfjord or Vestfjord. The frigate will operate roughly in the same area during most of the trial period. Due to other naval activities in the area, part of the operation area will be closed in shorter periods.

<u>*Figure 1.*</u>

Top left: The operation area for 3S-2019-OPS with positions of sperm whale sightings recorded in the IMR database. (colours represent different months)

Top right: Sightings of sperm whales (grey dots) pilot whales (magenta) and killer whales (black triangles) during the 3S-2017 trial.

Bottom: Sightings of sperm whales (grey dots) pilot whales (magenta) and killer whales (black triangles) during the 3S-2016 trial.



SAILING SCHEDULE

Table 1. *Sailing schedule for HUS and OSVE with overlapping windows of opportunities to do exposures in white, Saturdays in green, Sundays in red. HUS will do a 1 night port call to Tromsø for a crew change either 6-7 Sept. or 7-8. Sept*

Day	HUS - H.U. Sverdrup II	OSVE - KNM Otto Sverdrup
23.aug	Brief of operation in Harstad 19:00, joint no-host dinner in town	Spitsbergen
24.aug	Mobilization: Embarkment 08:00 Stangnes, Harstad, loading and technical installation. Sailing dram	Spitsbergen
25.aug	Finalize technical installation, safety training, safety brief, brief of ships crew, departure 14:00, engineer test of source and VHF tracking in Vågsfjorden. Transit back to Harstad if needed	Spitsbergen
26.aug	08:00 Transit to operation area. Regular ships watch. Fully operational	Spitsbergen, transit to Ramsund
27.aug	REGULAR OPERATION	Transit to Ramsund
28.aug	REGULAR OPERATION	Possible 3S window of opportunity
29.aug	REGULAR OPERATION	Possible 3S window of opportunity
30.aug	REGULAR OPERATION	Transit to Ramsund
31.aug	REGULAR OPERATION	In port
01.sep	REGULAR OPERATION	In port
02.sep	REGULAR OPERATION	Crew change in Ramsund, 3S liaison team embark OSVE in Ramsund 09:00, transit to ATC
03.sep	REGULAR OPERATION	NSM test, possible 3S window
04.sep	REGULAR OPERATION	NSM test, possible 3S window
05.sep	REGULAR OPERATION	NSM test, possible 3S window
06.sep	REGULAR OPERATION, 1 night port call to Tromsø	NSM test, possible 3S window
07.sep	REGULAR OPERATION, 1 night port call to Tromsø, crew change	NSM test, possible 3S window
08.sep	REGULAR OPERATION	NSM test, possible 3S window
09.sep	REGULAR OPERATION	Transit to ATC, NSM test, possible 3S window
10.sep	REGULAR OPERATION	NSM test, possible 3S window
11.sep	REGULAR OPERATION	NSM test, possible 3S window
12.sep	REGULAR OPERATION	NSM test, possible 3S window
13.sep	REGULAR OPERATION	NSM test, possible 3S window, transit to port
14.sep	REGULAR OPERATION	In port
15.sep	REGULAR OPERATION	In port
16.sep	REGULAR OPERATION	Transit, patrol, possible 3S window
17.sep	REGULAR OPERATION	Patrol, possible 3S window
18.sep	REGULAR OPERATION	Patrol, possible 3S window, transit to Bergen
19.sep	Transit to Tromsø, de-brief, de-mobilization, de-party!	Transit to Bergen, 3S liaison disembark and rendezvous with HUS in Tromsø for de-brief
20.sep	Off-loading, disembarkment by 14:00 (TBC)	Transit to Bergen

MAIN COMPONENTS OF THE TRIAL

R/V H.U. Sverdrup II (HUS)

Length: 55 m
Max speed 15 knots
Crew: 7
Scientific crew: 15

Sonar system: TNO, SOCRATES 2 low frequency active towed array sonar (1-2 kHz)

- Speed deployment: 6 knots
- Deployment time: 30 min
- Max deploy sea state: SS 4
- Speed recovery: 6 knots
- Max recovery sea state: SS 4
- Recovery time: 30 min

HUS 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 HUS 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 HUS. HUS will also lodge the research team and be the command centre for the operation.

KNM Otto Sverdrup (OSVE)

Length: 134 m
Max speed >20 knots
Crew: 140
Scientific crew: 2

Sonar system: Thales CAPTAS MK2 low frequency active towed array sonar (1-2 kHz).

- Speed deployment: 6-12 knop
- Deployment time: 30 min
- Max deploy sea state: SS 5
- Speed recovery: 6-8 knots
- Max recovery sea state: SS 4
- Recovery time: 30 min

OSVE will be using their CAPTAS source as the exposure source. A small research team will serve as liaisons for the 3S-project. Handheld VHF tracking equipment to recover tags will be on-board. OSVE will also collect temperature profiles during sonar transmission and time and position of transmissions.

Sonar source – SOCRATES

The multi-purpose towed acoustic source, called SOCRATES II (Sonar CalibRAtion and TESting), will be used and operated from the HUS. 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.

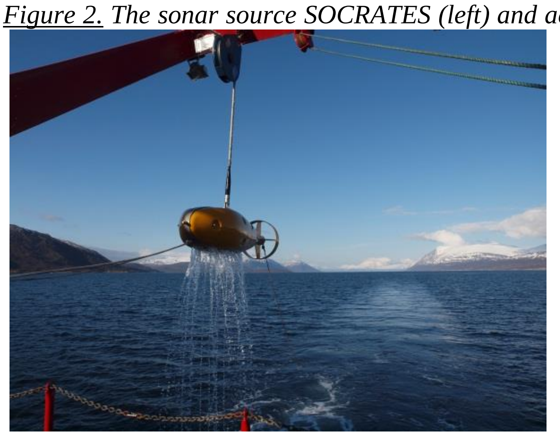



Figure 2. The sonar source SOCRATES (left) and acoustic array Delphinus (right) safely recovered on the HUS during a previous trial (3S-12).

Acoustic array – Delphinus

During the trial, the TNO developed Delphinus array system will be used. It will be deployed from the HUS 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 with HUS we will aim 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.

Mixed-DTAG

Subject animals will be tagged with Mixed-DTAGs (MDTAG). The tag is attached by 4 suction cups, and can be programmed to release after a specified deployment duration or at a set time. The MDTAG contains a core DTAG unit built at the University of Michigan with stereo hydrophones, 3-dimensional acceleration, 3-dimensional magnetometer information as well as time and depth. 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. In addition the MDTAG also contains a Fastloc GPS logger, a SPOT satellite transmitter and a VHF beacon. These additional sensors help record a more detailed track of the whale (GPS) and help us to find the tag when it has released from the whale. We have 8 MDTAGs available, in addition to a regular v3 DTAG-unit.

Figure 3. The Mixed-DTAG contains a DTAG core unit with acoustic and motion sensors, a VHF transmitter, a SPOT satellite transmitter and a Fastloc GPS logger. It has to be retrieved after release from the animal to download stored data.

The tags are attached to the animals with four suction cups. At the specified release time, 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.

Tagging boats

Two tag boats can be deployed from HUS. MOBHUS I is a water jet propulsion Man Over Board (MOB) boat deployed using a dedicated davit. MOBHUS II is a four stroke outboard engine fibre glass work boat deployed using the ships derrick crane. MOBHUS II can be deployed and operated at sea conditions up to sea state 2, while MOBHUS I is a heavier more robust system which can be deployed and operated up to sea state 4. MOBHUS I is the preferred tagging platform, and MOBHUS II is only used if we decide to work with two tagging teams in parallel. 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.

Figure 4. MOBHUS I will be the main platform for tagging. 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 both platforms will be equipped with this. The ARTS-tagging system can be used from both platforms

as a secondary back up system for sperm whales, and will be the primary tagging system for killer whales. The preferred method to tag long-finned pilot whales is the hand-held pole.

RESPONSIBILITIES

FFI

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

Equipment: Research vessels with crew, MOBHUS 2 with gas, MOBHUS 1 with diesel, CTD's, 2 VHF DDF, 2 sets of high quality ADF-cables, VHF-communication equipment, Ruggedized computer, Maria PC, NAVIPAC, Cantilever brackets for TB1 and TB2, Antenna mast

Permits: NARA permit, FOH cleared water permit (NATO subdanger warning)

SMRU

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

Equipment: 1 ARTS with pressure bottle, 1 DTAG3, 8 MDTAG, DTAG accessories, 2

	cantilever pole, 2 ARTS carriers for MDTAG, 5 LKDarts, 1 VHF DDF, 5 VHF receivers (219 MHz), 1 set of VHF yagi antennas, 1 set of high quality ADF-cables, 6 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, 2 mini big eyes, 3 binoculars, 2 drones with batteries and SD drives, DUCKT tape, Goniometer, 2 sets of headphones, 1 Loggerhead unit.
Permits:	SMRU ethics approval

LK-ARTS

Personnel:	Certified tag boat driver/tagger/marine mammal observer, ARTS tagger
Equipment:	1 ARTS with connector, (including spear kit and extra manometer), 1 set of VHF yagi-antenna (219Mhz), 2 handheld VHF-tracking antennas (219Mhz), 1 VHF Receiver (219 MHz), 1 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, 2 headsets, short antenna cables

TNO/RNLN

Personnel:	Software and hardware technicians for Socrates and Delphinus, 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, wireless network and data server, binoculars, 2 moored buoys with 2 Loggerhead sensor units each (1 supplied by SMRU, 3 by TNO).
Permit:	LMR Ocean Observing System Notification Warning

DGA

Personnel:	Marine mammal observer/acoustic operator

US navy

Personnel:	2 Marine mammal observers/photo id. Liaison on the frigate.

RNoN

Personnel:	Crew of the frigate, 3S liaison on the frigate.
Equipment:	1 pcs of ASW frigate with Captas sonar source.

BASELINE TRIAL

A few weeks before the main OPS trial (July) a smaller team will operate in the study area to do final test of the MDTAG, and to test and establish a protocol for tracking tagged pilot whales using drones.

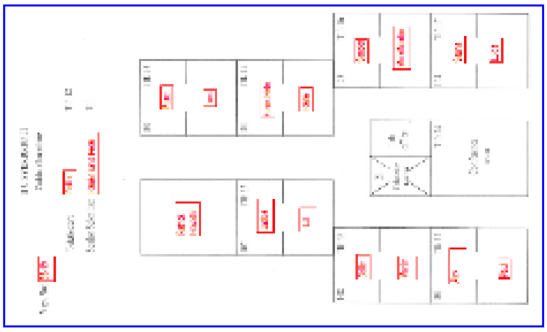
CREW PLAN

The total number of scientific crew on HUS is 15, including engineers, biologists, oceanographers and naval staff. In addition the 3S team included 2 people serving as liaisons on the frigate. There is one planned port call to replace two team members halfway. This will happen in Tromsø some time between 6-8. September.

Table 2. Crew list with primary and secondary roles. There is a planned crew change around mid sail. This will take place in Tromsø some time between 6-8.Sept. We will spend 1 night in port. Dekeling and van Spellen will be replaced by Gerard and van Riet. After the crew change Lam takes over as XO

HUS	**Aug 23 - Sept 6-8**			
Name	**Main role**	**Secondary roles**	**Affiliation**	**Nationality**
Petter Kvadsheim	CO	MMO	FFI	NOR
René Dekeling	XO	SOC/MMO/liason OSVE	RNLN	NL
Frans-Peter Lam	SOC	MMO	TNO	NL
Patrick Milller	PI/tagger/Drone pilot	MMO/Tag technician	SMRU	US
Mark van Spellen	SOC	MMO	TNO	NL
Sander von Ijsselmuide	SOC	MMO/Data management	TNO	NL
Lars Kleivane	Tag boat driver/MMO	Tagger	LKARTS	NOR
Rune Roland Hansen	Tag boat driver/MMO	Data management	FFI	NOR
Paul Wensveen	Tagger/MMO	Data management, tag tech.	Univ.Iceland	NL
Saana Isojunno	Tag technician	MMO/Photo id	SMRU	FIN
Lucia Martin Lopez	Tag technician	MMO	SMRU	SPA
Alexander Burslem	Drone pilot/MMO	Photo id, tag technician	SMRU	UK
Marije Siemensma	lead MMO	Data management	MSC	NL
Elizabeth Henderson	MMO	Data management	SPAWAR	USA
Jacqueline Bort	Lead MMO	Photo id	NAVFAC	USA
Total 15				
HUS	**Sept 6-8 - Sept 20**			
Name	**Main role**	**Secondary roles**	**Affiliation**	**Nationality**
Martijn van Riet	Replaces von Spellen on SOC	MMO	TNO	NL
Frans-Peter Lam	Replaces Dekeling as XO	SOC/MMO	TNO	NL
Odile Gerard	Replaces Lam on SOC	MMO	DGA	FR
Total 15				
OSVE	**Sept 2 - Sept 20**			
Tom Erik Lindhjem	Liason	MMO	RNoN	NOR
Jene Nissen (1 week)	Liason	MMO	USN	USA
Total 2				

Figure 5. *Cabin plan*



DAILY WORK PLAN

The 3S-2019-OPS 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 navigators on HUS, as well as the navigators, sonar operators and 3S-liaisons on the frigate.

The operation goes through different phases which require very different staffing from the different teams. The main phases are (Fig. 6): search phase, tagging phase, pre-exposure phase, exposure phase and post exposure phase.

Figure 6. Main phases of the operation. The tracking phase includes pre-exposure, exposure and post-exposure. The frigate is only needed in the exposure phase.

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.

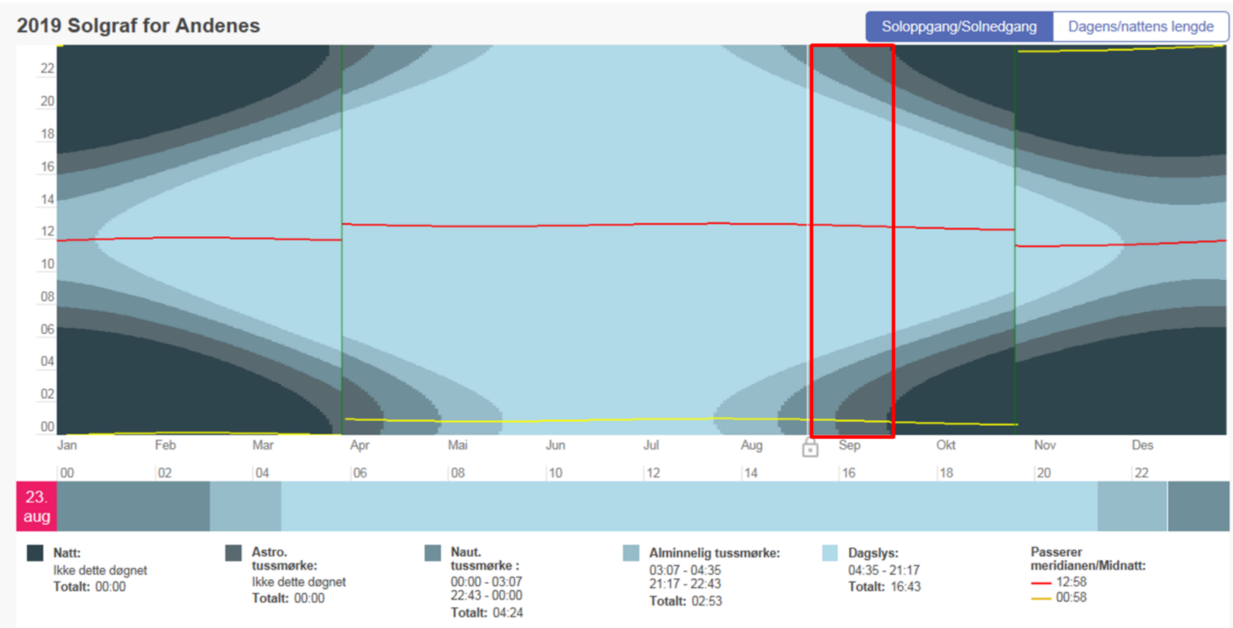
Planning meeting

Every day at 08:00 the CO (Kvadsheim) submit a situation report to the frigate and other relevant parties. At 09:00 there will be a short meeting by phone between the CO and the POC and liaison on the frigate to discuss frigate availability and plans for the next 24 and 48 hrs. Every day at 13:00 the chief scientists from the main 3S partners (Kvadsheim, Lam, Miller) and the XO (Dekeling) will convene on the bridge 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 14:00. Adjustments to the daily plan will be made by the CO and XO between the daily meetings as needed. 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 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). At the beginning of the trial we expect there to be enough daylight to operate 24 hrs around the clock. Near the end of the trial, there might be a few hours between 22-02 where visibility makes it difficult to work effectively.

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 (Siemensma and Bort) will organize the watch and make a watch plan for the MMO's which also includes the secondary MMO's. The lead MMOs are also responsible for data collection at the MMO station and to check logger data and back it up.



<u>Figure 7.</u> Light condition in the operation area and trial period (red box). Time given as local time

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 first 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 HUS is to track the tagged whale, and therefore the tag team has to work independent and cannot expect much support from the HUS during the second tagging attempt.

Name	Watch 08 - 14	14 - 20	20 - 02	02 - 08
Kvadsheim	■		■	
Dekeling / Lam		■		■
Lam / Gerard	■		■	
Milller	■		■	
van Spellen / van Riet		■		■
van Ijsselmuide	■		■	
Kleivane		■		■
Roland Hansen	■		■	
Wensveen		■		■
Isojunno	■		■	
Martin Lopez		■		■
Burslem		■		■
Siemensma	■		■	
Henderson	■		■	
Bort		■		■
	8	7	8	7

Table 3.
Basic watch plan used in the survey, tagging and tracking phases. The entire crew will follow a regular 6 hrs on (in red) and 6 hrs off (in white) 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): Hansen – Miller - Isojunno during the 14-20 and 02-08 watches and Kleivane – Wensveen – Bort during the 08-14 and 20-02 watches. Isojunno might be replaced by Henderson and Bort by Burslem on the tag boat if they have conflicting tasks on board.   HUS is equipped with two tag boats but we will normally only operate one. If we decide to use two tag boats in parallel to maximize tagging effort over a short period, we have to make ad hoc adjustments to the watch plan.

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. During experiments with pilot whales when HUS is the source boat, 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. During experiments with sperm whales when the frigate is the source boat, mitigation observations are done by the naval crew on the frigate assisted by the 3S liaison. In such cases the HUS MMO team will just continue to track the whale as before.

XO/CO will make ad-hoc adjustments to the watch plan prior to the exposures if needed to meet these requirements. At this time the tag team will have returned to HUS and will be available to support the MMOs. Tracking with killer and pilot whales may also be partially conducted from MOBHUS-I.

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.

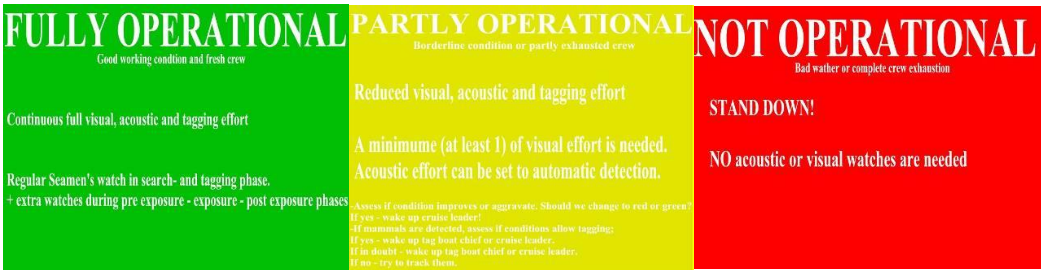


Figure 8. *Operational status green – we are fully operational with continuous full visual, acoustic and tagging effort. Operational status yellow – we are partly operational with reduced effort on visual, acoustic and tagging effort. Operational status red – we are not operational, everyone can and 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 (CO) 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 and communicated with the frigate.

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 20 nmi of the previous exposure within 24 hours when 214 dB max source levels is used, and 30 nmi when max source levels of >214 dB is used . 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 in killer whales and pilot whales, and to address the importance of the distance to the source in predicting responses in sperm whales. During CEEs with killer wales and pilot whales the SOCRATES source on HUS will be the sonar source, and during CEEs with sperm whales the CAPTAS source on OSVE will be the source. Thus, the priority is to tag sperm whales when the frigate is available and pilot/killer whales when the frigate is not available. The experimental protocols are designed to test these specific science questions, but also allow us to pool the data collected with data already collected during the 3S-2016 (Lam et al. 2018a) and 3S-2017 (Lam et al. 2018b) trials. The sonar signal transmitted by the CAPTAS on the frigate and the signals transmitted by the SOCRATES source in previous trials (3S-206 and 3S-2017) do not match exactly. Therefore, as a secondary objective, we might do a few control runs to sperm whales where the Socrates source transmit the "frigate signal".

Figure 9. *Experimental phases. The second tagging period should be two 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 min 1 hr 20 min of post exposure between each. The first exposure is always no-sonar control (NS), the following exposures use different signals (S1, S2, S3) depending on the species and source used. These are specified in Table5. The order of S1-S3 is rotated to maximize contrast (Table 7 and 9).*

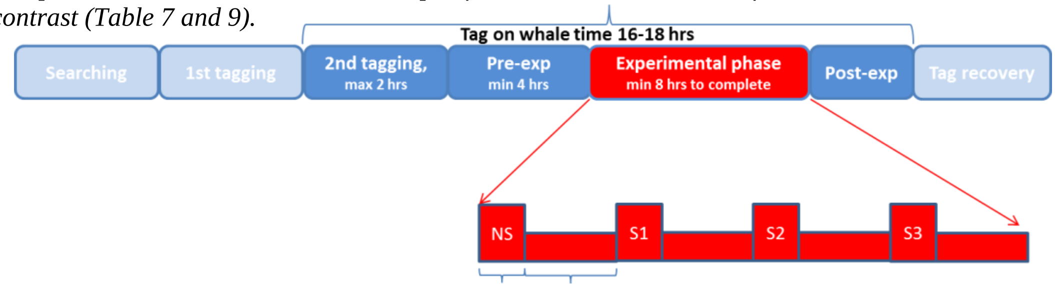


Table 4. *Comparison of the pulsed active sonar signals transmitted by the SOCRATES source on HUS and the CAPTAS source on OSVE. Further details of the frigates transmission scheme are given in Tables 5 and 8.*

	SOC on HUS	CAPTAS on OSVE	
	HPAS	HPAS	XHPAS
Max Source level	214 dB	214 dB	>220 dB
Pulse duration	1000ms	1000ms	1000ms
Pulse repetition time	20s	20s (12 ky)	20s (12 ky)
Frequency/pulseform	1000-2000 Hz HFM	1280-1920 Hz HFM	1280-1920 Hz HFM
Tow speed	8 knots	8 knots	8 knots
Source depth	100-120 m (min 100m)	100-120 (min 50m)	100-120 (min 50m)
Ramp up	-60 dB, +1 dB/pulse over 20 min	-55 dB, +3dB steps from -15 to -6 dB over 20min	-55 dB, +3dB steps from -15 to 0 dB over 20min
*Shut down range 180dB threshold	100 m	100 m	200 m

With sperm whales we aim to tag two separate animals before starting the experimental cycle. With pilot whales/killer whales we will try to tag up to 4 animals in the same group. The tagging period is limited to two hrs after the first tag is deployed. A focal whale will be tracked by HUS throughout the experiment. With pilot/killer whales the tracking will be supported with drones operated from MOBHUS. 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 16-17 hours for the first tag deployed and 14-15 hours for the following tags. Given 1-2 hrs for the tag to detach from the whale after the programmed release time, we expect 16-18 hour tag deployments. Specific release times will be refined based upon in-the-field performance of the system.

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, MOBHUS 1 will be launched from HUS 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 when needed.

DTAG technicians will ensure that a minimum of two tags are armed and ready for deployment prior to tagging. Release time will be set to 16-17 hours for the tag intended to be deployed first, and 14-15 hours on the tag intended to be deployed second.

When targeting sperm whales the default method to deploy tags is the cantilever pole. When targeting pilot whales, the default method is the hand held pole. With killer whales, the default method will be the ARTS system.

2nd tagging of sperm whales

Once a tag is attached the MMO-team on HUS will start tracking it. The tag boat will start searching for new animals based on the report from the MMO-team on HUS. 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 3 nmi of HUS, 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 1 nmi, 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 two 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.

In situations where the frigate is available within the next 24 hrs, but will become unavailable for extended periods after, we might decide to maximize tagging effort and use two tag boats in parallel. In such scenario we will try to deploy up to four tags total (1 focal and 3 non-focal).

2nd tagging of pilot or killer whales

Pilot whales and killer whales are social animals which will normally stay together with the group. Non-focal datasets are therefore likely to be of higher value than with sperm whales, where the non-focal typically end up far from the focal animal. With this species we will therefore attempt to deploy tags to one focal animal plus up to three non-focal animals which appear to be associated with the focal. 2nd tagging will still be limited to two hrs. The pre-exposure baseline period only starts when the tag boat leaves the group. With killer whales and pilot whales there is a strong preference to work in diverse areas to reduce risk of repeated exposures to the same animals.

Tracking of the tagged whale

Tracking sperm whales

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 HUS and recorded in Logger. From now on the MMO team has to also start using the VHF tracking (DDF) system to track 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 the 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 of the tagged whale under water.

HUS 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, HUS 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 in 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.

In addition to the VHF-tracking, the Mixed-DTAGs contain 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 on the internet for updates. Position updates will then be plotted on the tablet so that the MMOs can see it. We are also using a Goniometer who can track the ARGOS signal directly. This can also be used as back up for recovering the tag in case the VHF fails.

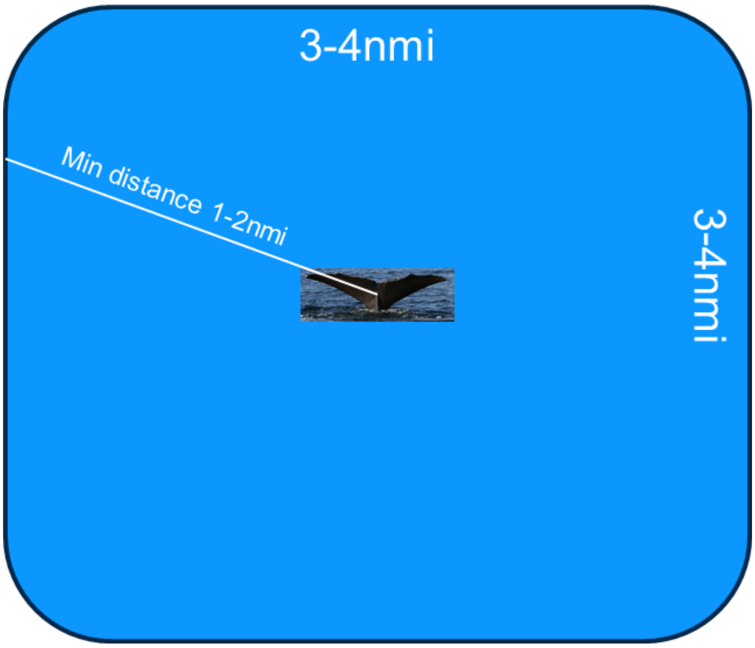


Figure 10. Idealized navigation pattern (outer box) of HUS during tracking

Tracking pilot whales and killer whales

When a tag is deployed to a pilot/killer whales the Delphinus array will be recovered, so that HUS can maneuver freely and stay still in the water. HUS will try to maintain a distance of about 1000m to the tagged whale. The MMOs will track the first tagged whales, while the tag team attempt 2nd tagging. When the tagging effort has ceased and the tag boat leaves the group, we move into the pre-exposure baseline period. The MMOs on HUS will continue to track the focal whale visually at a target distance of 1000 m. This will not allow collection of data on social interactions and group observations. This is key gap for masking related questions, which is very important aspect of the CAS exposures to pilot/killer whales. The main tracking will therefore be done from MOBHUS I using drones filming the focal group. There will be two drone teams, taking turns according to the regular watch schedule. A drone team consist of 3-4 people, a boat driver, a drone pilot and 1-2 MMOs. The drone teams will be (boat driver-pilot-MMOs): Hansen – Miller – 1-2 MMOs during the 14-20 and 02-08 watches and Kleivane – Burslem – 1-2 MMOs during the 08-14 and 20-02 watches. The drone team will bring batteries and memory cards to allow more or less continuous monitoring of the focal group. The details of the protocol of the tracking with drones will be established during the baseline trial in July.

Pre-exposure baseline period

Sperm whales

Pre-exposure baseline phase starts when the tag boat leaves the tagged animal and the MMO team has taken over tracking from HUS. 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 as it will be the non-focal whale for which the no-sonar approach of the focal whale can still be considered baseline. It’s possible to switch focal during the baseline periods, e.g. if the tag placement and thereby VHF tracking is better for the non-focal. In such 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.

Pilot/killer whales

As soon as the tag team returns, the drone team will be deployed to start the group observations. The baseline period starts when the drone team is on the water. They will track the focal group supported by the MMOs on HUS until end of the post exposure period.

Exposure phase

Sperm whales will be exposed by the frigate (OSVE) using the CAPTAS system and pilot/killer whales will be exposed by HUS using the SOCRATES system.

Sperm whale exposures with CAPTAS on OSVE
The full experimental phase will consist of a sequence of four CEE approaches (see table 7) 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 HUS, but has a Mixed-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.

Table 5. During the CEE approaches, one of five different sonar signals will be transmitted, depending on species and source vessel; No-sonar, Continuous active sonar (CAS), Moderate source level pulsed active sonar (MPAS), high source level pulsed active sonar (HPAS) or extra high source level pulsed active sonar (XHPAS)

SIGNAL	**No Sonar**	**CAS**	**MPAS**	**HPAS**	**XHPAS**
SOURCE VESSEL	HUS/OSVE	HUS	HUS	HUS/OSVE	OSVE
Start and end source level dB re 1µPa·m	No-signal	141-201	141-201	154-214 HUS 165-214 OSVE	165-220
Ramp-up duration [min]	20	20	20	20	20
SL increase during ramp-up	No-signal	Linear, 1dB/pulse	Linear, 1dB/pulse	Linear, 1dB/pulse Not for OSVE.	-55 dB, +3dB steps from -15 to 0 dB.
Full power period (min)	20	20	20	20	20
SEL_{19s} dB re 1µPa·s	No-signal	154-214	141-201	154-214 (HUS) 165-214 (OSVE)	165-220
Signal duration (s)	No-signal	19	1	1	1
Pulse repetition time (s)	No-signal	20	20	20	20
Duty cycle	No-signal	95%	5%	5%	5%
Frequency	No-signal	1-2 kHz	1-2 kHz	1-2 kHz	1.28-1.92 kHz
Signal shape	No-signal	HFM Upsweep	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.			

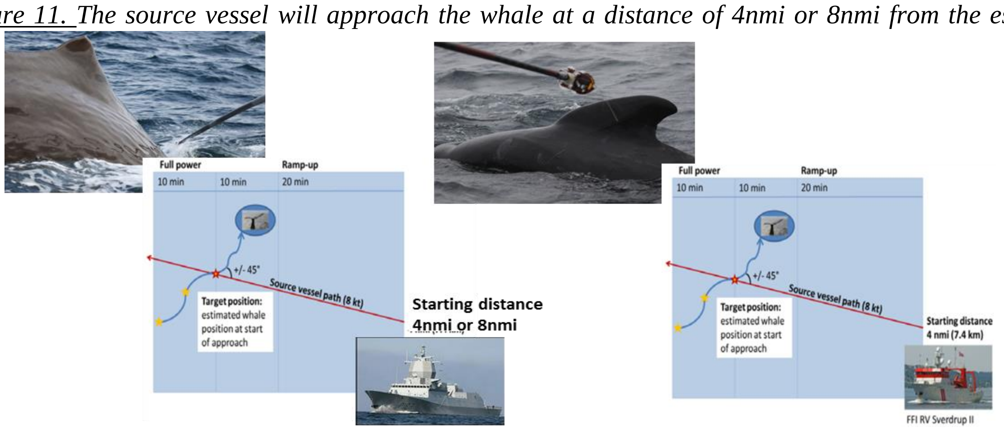


Figure 11. The source vessel will approach the whale at a distance of 4nmi or 8nmi from the estimated tagged whale's position at the start of exposure, at +/- 45 degrees to the side of the whale's direction of travel. Approach course will be fixed towards the estimated whale position at the start of the approach. The speed of the vessel should aim to maintain 8 kt over ground. The source should be towed at 100-120m depth. The final decision on when to start the approach will be made by CO/XO on watch on HUS.

Table 6. Overview of the exposure runs for pilot/killer whales (PW/KW) and sperm whales (SW). The sonar source used will be either the CAPTAS (CAP) on KNM Otto Sverdrup (OSVE), or the SOCRATES source (SOC) on RV HU Sverdrup II (HUS). The source vessel will either do a Close approach starting at a distance of 4nmi from the whale, or a Distant approach starting at a distance of 8nmi. The duration of the exposures is always 40min, speed and course should always be kept constant.

Run/session	Source/Ship	Species	Start range	Max SL	Ramp up start level	Duration	Speed
No-sonar-Close	CAP/OSVE	SW	4 nmi	0 dB		40 min	8 knots
HPAS-Close	CAP/OSVE	SW	4 nmi	214 dB	-55 dB	40 min	8 knots
XHPAS-Close	CAP/OSVE	SW	4 nmi	220 dB	-55 dB	40 min	8 knots
XHPAS-Distant	CAP/OSVE	SW	8 nmi	220 dB	-55 dB	40 min	8 knots
No-sonar-Close	SOC/HUS	PW/KW	4 nmi	0 dB		40 min	8 knots
MPAS-Close	SOC/HUS	PW/KW	4 nmi	201 dB	-60 dB	40 min	8 knots
HPAS-Close	SOC/HUS	PW/KW	4 nmi	214 dB	-60 dB	40 min	8 knots
CAS-Close	SOC/HUS	PW/KW	4 nmi	201 dB	-60 dB	40 min	8 knots

Table 7. Order of exposure runs for **sperm whales** using the CAPTAS on OSVE as the source. No-sonar means no transmissions but the source ship will do a close approach as if it was transmitting. XHPAS and HPAS transmissions mean 1000ms sonar transmission of 1280-1920 Hz HFM with 20spulse repetition time. Time vs source level is specified in Table 8. Maximum source level of HPAS is 214 dB re 1μPa·m and max source level of the XHPAS is 220 dB re 1μPa·m. The starting distance of the Close approaches will be 4 nmi, and the starting distance of the Distant approaches will be 8 nmi. Tow speed 8 knots, and source depth 100-120 m. At least two of the sonar runs have to be completed, otherwise the experiment has to be repeated.

Experiment	1st treatment	2nd treatment	3rd treatment	4th treatment
1	No Sonar Close	XHPAS-Distant	XHPAS-Close	HPAS-Close
2	No Sonar Close	XHPAS-Close	XHPAS-Distant	HPAS-Close
3	No Sonar Close	XHPAS-Distant	HPAS-Close	XHPAS-Close
4	No Sonar Close	XHPAS-Close	HPAS-Close	XHPAS-Distant
5	No Sonar Close	HPAS-Close	XHPAS-Distant	XHPAS-Close
6	No Sonar Close	HPAS-Close	XHPAS-Close	XHPAS-Distant

Table 8. *Sonar transmission scheme for the XHPAS and HPAS transmissions of the CAPTAS on OSVE. The transmitted signal will always be 1000ms sonar transmissions of 1280-1920 Hz HFM with 20s pulse repetition time. The approach speed should be 8 knots, constant course, tow depth 100-120m. Time vs source level is specified in the table as attenuation from full powered source level. Time T0 is the time of the first ping. Only the time of changes of the source level is given. Maximum source level of HPAS is 214 dB re 1µPa·m and max source level of the XHPAS is 220 dB re 1µPa·m.*

TIME (T0+min)	**XHPAS**		**TIME (min)**	**HPAS**
T0	-55 dB		T0	-55 dB
T0+10	-15 dB		T0+12	-15 dB
T0+16	-12 dB		T0+18	-12 dB
T0+17	-09 dB		T0+19	-09 dB
T0+18	-06 dB		T0+20	-06 dB
T0+19	-3 dB			
T0+20	Max SL			
T0+40	End of transmission		T0+40	End of transmission

After an exposure there is a post-exposure period of 1 hrs 20 min, during which the frigate will reposition for the next run. 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 run will include 20min of dose-escalation and 20 min of full SL transmission.

Pilot/killer whales exposures with SOCRATES on HUS

The pilot/killer whale exposures (see table 9) will be done in much the same way as the sperm whales exposures, except that all runs are Close runs. Another important difference is that tracking of the pilot/killer whales will be done from the MOBHUS and HUS will be the source vessel. The pilot/killer whales will also be exposed to continuous sonar.

The order of the four exposure sessions (see table 9) is determined to maximize the contrast between the different treatments with a minimum amount of data. No-sonar control approach is always conducted first to test the effect of ship on whale behaviour, before any sensitization by sonar can take place.

*Table 9. Order of exposure runs for **pilot and killer whales** using the SOCRATES source on HUS. No-sonar means no transmissions but the source ship will do a close approach as if it was transmitting. MPAS and HPAS transmissions mean 1000ms sonar transmission of 1000-2000 Hz HFM with 20s pulse repetition time. CAS means 19s transmission of 1000-2000 Hz HFM with 20s pulse repetition time. Time vs source level is specified in Table 10. Maximum source level of HPAS is 214 dB re 1µPa·m, MPAS is 201 dB and CAS is 201 dB re 1µPa·m. The starting distance of the Close approaches will be 4 nmi. Tow speed 8 knots, and source depth 100-120 m. At least two of the sonar runs have to be completed, otherwise the experiment has to be repeated*

Experiment	**1st treatment**	**2nd treatment**	**3rd treatment**	**4th treatment**
1	No Sonar Close	CAS-Close	MPAS-Close	HPAS-Close
2	No Sonar Close	MPAS-Close	CAS-Close	HPAS-Close
3	No Sonar Close	CAS-Close	HPAS-Close	MPAS-Close
4	No Sonar Close	HPAS-Close	CAS-Close	MPAS-Close
5	No Sonar Close	MPAS-Close	HPAS-Close	CAS-Close
6	No Sonar Close	HPAS-Close	MPAS-Close	CAS-Close

Table 10. Sonar transmission scheme for the CAS, MPAS and HPAS transmissions of SOCRATES on HUS. The transmitted signal will always be either 1s (PAS) or 19s sonar transmissions of 1000-2000 Hz HFM with 20s pulse repetition time. The approach speed should be 8 knots, constant course, tow depth 100-120m. Time vs source level is specified in the table as attenuation from full powered source level. Time T0 is the time of the first ping. Only the time of changes of the source level is given. Maximum source level of HPAS is 214 dB re 1µPa·m, max source level of the MPAS and CAS are 201 dB re 1µPa·m.

TIME (T0+min)	**CAS**		**TIME (min)**	**HPAS**		**TIME (min)**	**MPAS**
T0	-60 dB		T0	-60 dB		T0	-60 dB
From T0 to T0+20	+1 dB/ping		From T0 to T0+20	+1 dB/ping		From T0 to T0+20	+1 dB/ping
T0+20	-6 dB		T0+20	-0 dB		T0+20	-6 dB
T0+40	End of transmission		T0+40	End of transmission		T0+40	End of transmission

Post exposure phase

After each 40min exposure session there is a post-exposure phase of minimum 1 h 20 min. We might lose the track of the whale when HUS sails away to position for an approach on pilot/killer whales. 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. With sperm whales there is less risk that we will lose the track of the focal whales, since HUS will keep tracking it continuously during the exposures. Until we relocate the animal, the rest of the experiment has to be postponed. Once we have relocated HUS will again manoeuvre to track the whale as we did in 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. It’s important that the frigate is instructed to keep a minimum distance from the whale of at least 2nmi, except during exposures. As soon as each tag releases MOBHUS I will be deployed with a team to pick up the tag and bring it back to HUS for data download. Some tags might be recovered by OSVE.

Mitigation during transmission

During transmissions, MMOs on the source vessel HUS/OSVE will assure that no whales are too close to the source that they might be exposed to received SPLs over 180 dB re 1µPa as required by the permit. The stand-off range between source and animals during full power transmission is 100 m when source levels up to 215 dB are used and 200m when source levels >215 dB are used. 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 (Appendix B).

Sound speed profiles (CTD and XBT)

A temperature profile (XBT) should be taken by the source vessel (HUS or OSVE) during all the runs, including no-sonar approaches. CTD profiles will be taken from the HUS after the end of the full experimental cycle. However, HUS cannot reduce speed beyond 3 knots when towing Socrates or Delphinus. After an exposure experiment, Socrates and Delphinus are usually recovered on HUS, which allows HUS 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 two acoustic recorders on each 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:

<u>*Location 1)*</u>

1. Latitude / longitude: 70º00.000N / 016º30.000E
2. Sampling rate: 144 kHz
3. Duty cycle: 100%
4. Number of sensors: 2 hydrophones
5. Sensor depth: ≈ 1500m
6. Recording platform: Loggerhead DSG-ST
7. Method of deployment and mooring: Bottom mounted with acoustic release.
8. Method of data delivery (archive on hard drive, satellite transmission, etc.):
   Recording on
   SD-card
9. Deployment and recovery dates: deployment date is August 26 (or soon after) and recovery before or on September 19th

Location 2)

1. Latitude / longitude: 69º28.500N / 015º39.300E
2. Sampling rate: 144 kHz
3. Duty cycle: 100%
4. Number of sensors: 2 hydrophones
5. Sensor depth: ≈ 1500m
6. Recording platform: Loggerhead DSG-ST
7. Method of deployment and mooring: Bottom mounted with acoustic release.
8. Method of data delivery (archive on hard drive, satellite transmission, etc.): Recording on SD-card
9. Deployment and recovery dates: deployment date is August 26 (or soon after) and recovery before or on September 19th

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. 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 max 3 hours per mooring.

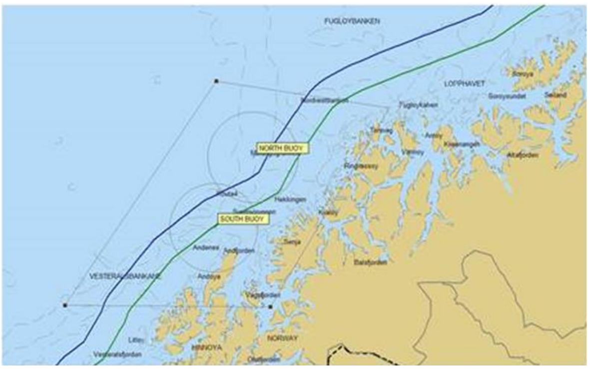


Figure 12. Intended mooring locations for acoustic recorders with 20nmi range rings. Indicated is also the general operation area. The planned positions of the moored buoys are: 70º00.000N / 016º30.000E

69º28.500N / 015º39.300E

3S LIAISON ON THE FRIGATE

There will be two 3S liaisons on the frigate (Nissen and Lindhjem). Their tasks are to answer questions from the frigate crew about the operation or forward the questions to CO on HUS (Kvadsheim). They will also assure good communication between OSVE and HUS. This includes participation on the daily brief on OSVE and the morning meeting by phone between HUS and OSVE. During exposures at least one of the liaisons will be available on the bridge to assure good communication between the navigators on OSVE and the experimental coordinator on HUS. They will also be responsible for permit compliance and assist as marine mammal observers during sonar exposure experiments.

The liaison will embark in Ramsund on Sept 2nd. There is a possibility that we can conduct an experiment before this (see table 1), when the frigate transit through our operation area on the 28-29th August. If this happens Dekeling will be transferred from HUS to OSVE to serve as liaison for the duration of that experiment.

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.

Safety issues

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

Frigate

The CO of the frigate makes final decisions on frigate availability and priorities. The sonar transmissions done by the frigate as part of the exposure experiment, is permitted by the Norwegian Animal Research Authority. The permit holder (Kvadsheim) makes final decision to start and end experiments.

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 – Frigate tactical data (sanitized) (XBTs, Transmission log with GPS, time, SL, pulse, source depth).

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 (HUS – TB1 – TB2 - OSVE. 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:

"HU Sverdrup"	Sverdrup (HUS) bridge (HQ) (answered by CO/XO, or captain/first officer if CO/XO not on the bridge)
"MOBHUS I"	Water jet propulsion MOB (MOBHUS)
"MOBHUS II"	4 stroke outboard engine work boat
"SOCRATES"	Sonar operator on HUS (Socrates and Delphinus)
"Obs deck "	Marine mammal visual observation deck on HUS
"Otto Sverdrup"	KNM Otto Sverdrup (OSVE) bridge (answered by navigation officer on watch).

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 "HU 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**

Communication between POC and liaisons on OSVE and HUS will be via IP phone.

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 Defence 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 18/126201) 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 180 dB re 1 μPa. During sonar exposure experiments using source levels >200 dB re 1 μPa m a 100m safety zone is established (SOCRATES source), and if source level is >215 dB re 1 μPa m (CAPTAS source) a 200m safety zone is established. If any animal enters the safety zone the sonar source will be shut down. The safety zone assures maximum exposure levels well below the established threshold of hearing impairment of the experimental subjects. In addition to Kvadsheim, Patrick Miller will be another field operator 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

Before departure the press office of all involved partners should be informed about the trial, and about our plan to on how to handle media. During the trial, media contact should be referred to the cruise leader (Kvadsheim) on HUS. Since the frigate is also supporting FFI doing animal experimentation under a civilian permit, it is preferred that the navy also forward any request from media to FFI. The FFI press office will coordinate with the naval press 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 fishing vessels and whale watching companies operating off Andenes. They have been informed about our operation, but if necessary we might do some public outreach meeting during the trial.

SPECIFIC INSTRUCTIONS TO THE FRIGATE (OSVE)

Daily contact between HUS and OSVE to exchange plans and clarify expected frigate availability the next 24 and 48 hrs. The 3S liaisons and the POC on the frigate will participate on a phone conference with the CO on HUS every morning at 09:00.

If the frigate is made available and HUS has tagged 1-2 whales, HUS will call in the need for support with estimated position and time of COMEX approximately 4-6 before. HUS will update OSVE on starting position and time, if predictions change.

Communication between HUS and OSVE in the experimental phase will be bridge to bridge on an announced VHF working channel (see communication plan).

OSVE deploys their ATAS. The frigate should sail in regular silent mode with AIS on during the experiments (ASW mode is not needed). OSVE stays in holding position until COMEX.

HUS gives final instructions on time, position, course and transmission scheme with ATAS. Transmission scheme codes and order are given in Table 4, 5, 6, 7 and 8.

At COMEX, OSVE report the first ping. Maintain constant speed (8 knots) and course until the transmission program is finished (40 min). Collect XBT roughly 20min into the exposure.

During transmissions, marine mammal observers will be in place on the bridge of the frigate. A 200m safety zone will be established. If any mammals enter closer than this from the active source, the source will be turned off, until the animal is safely outside of the safety range.

At the end of the transmission program, HUS will give the frigate navigation instructions and estimated position and time of the next run.

A full experiment consist of 4 runs and will take about 8 hrs to complete. If the frigate is not available to complete all four runs, the no-sonar run will be cancelled first, than the forth treatment (Table 7).

GENERAL ADVICE TO MEMBERS OF THE SCIENTIFIC CREW

The scientific trial you will be involved in 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 August-September 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 we will have almost 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 HUS is known to be very 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 the 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!

TRIAL READINESS REVIEW

All equipment and materials required for the planned research effort have been obtained or are scheduled for delivery in time for the trial start. The research team has been trained as necessary for the activities and procedures to be carried out during the trial. The 3S board approved this cruise plan on 1st July 2019 as ready for execution in the time-frame specified.

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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:

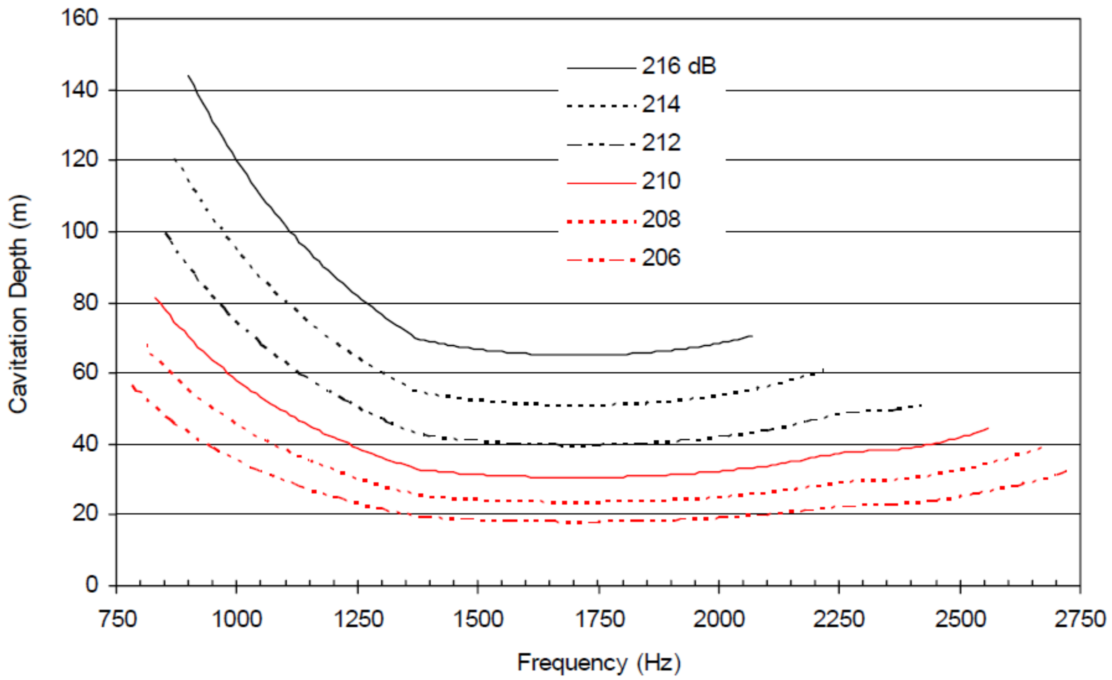
- Starboard turn for 3-12 kts with 20 deg/min.
- Port turn for 3-12 kts with 25 deg/min.
- While turning (and shortly before and after that (2min)) **speed should remain constant**

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

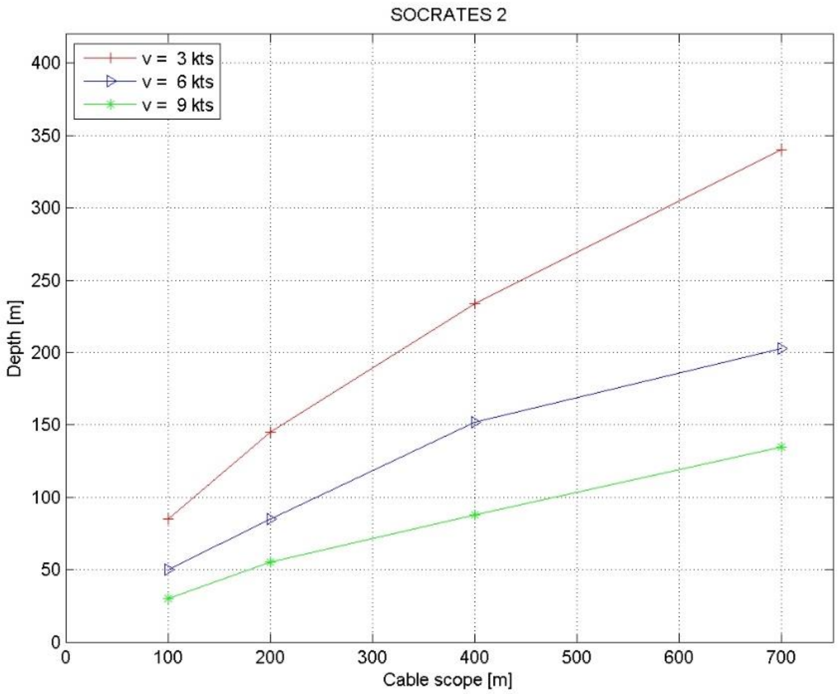
H.U. Sverdrup II can tow both the SOCRATES source and the Delphinus array simultaneously. The deploying sequence will be first the towed array and then the SOCRATES towed source. Consequently the retrieval sequence will be first SOCRATES and then the array.

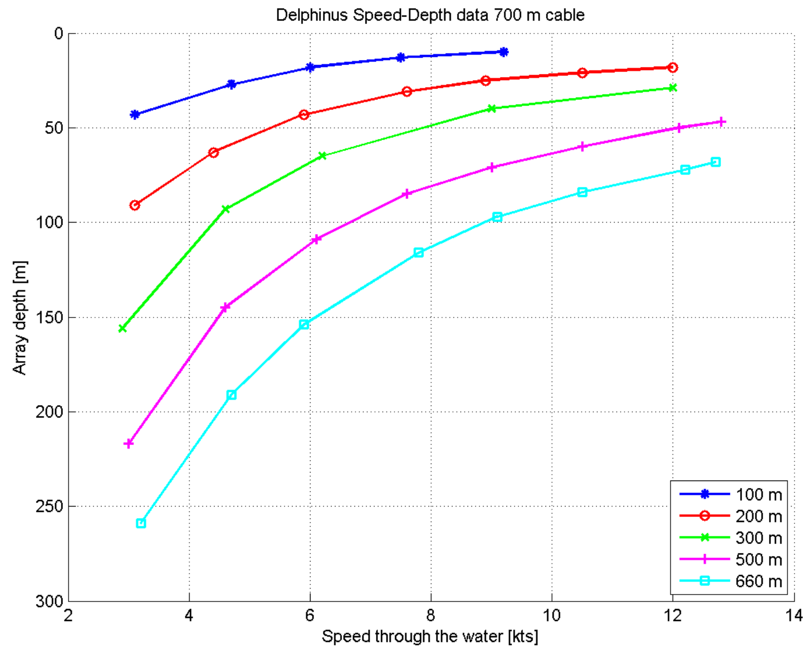
Data Sheet

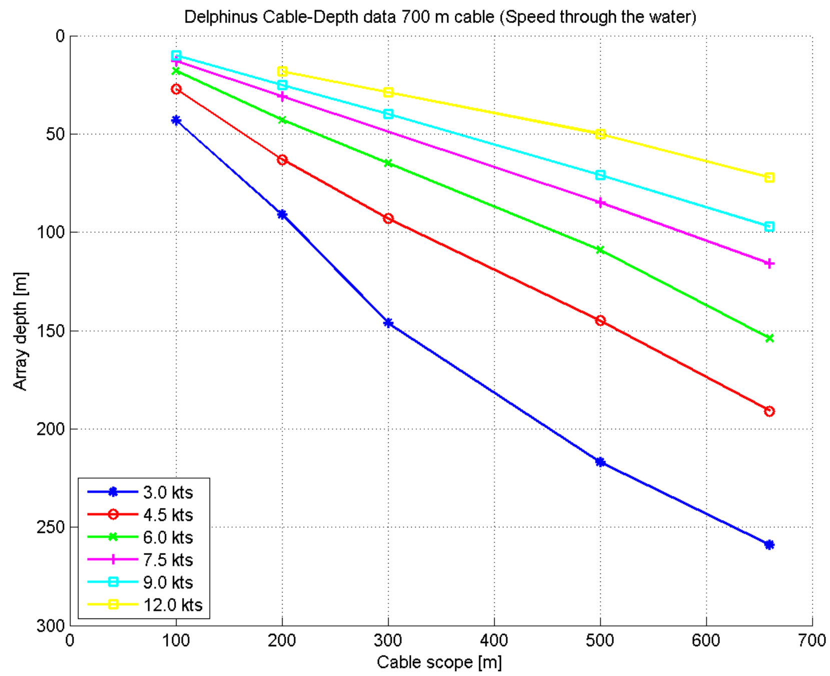
The operational limitations and additional information for H.U. Sverdrup II while towing are presented below:

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




Delphinus Speed-Depth data 700 m cable
Array depth [m]
Speed through the water [kts]
0
50
100
150
200
250
300
2
4
6
8
10
12
14
100 m
200 m
300 m
500 m
660 m


Delphinus Cable-Depth data 700 m cable (Speed through the water)
Array depth [m]
Cable scope [m]
0
50
100
150
200
250
300
0
100
200
300
400
500
600
700
3.0 kts
4.5 kts
6.0 kts
7.5 kts
9.0 kts
12.0 kts

APPENDIX B

Risk assessment and management plan for the 3S-2019-OPS research trial with RV HU Sverdrup II and KNM Otto Sverdrup

Introduction

This document describes the risk identified for the 3S-2019 research trial. The trial will primarily take place along the shelf break between Andenes and Tromsø in Norwegian territorial waters and EEZ between August 24th and September 20th 2019.

The objective of the trial is to test how the distance to the sonar source affects behavioural responses and if exposure to continuous-active-sonar (CAS) leads to different types or severity of behavioural responses than exposure to traditional pulsed active sonar (PAS) signals.

There are two primary tasks. To tag sperm whales with digital tags which records vocal-, movement- and dive behavior, and thereafter carry out no-sonar control-, and pulsed active sonar exposures using an operational sonar source. To tag pilot whales and/or killer whales with digital tags which records vocal-, movement- and dive behavior, and thereafter carry out no-sonar control-, pulsed and continuous active sonar exposures using an experimental sonar source.

The operation is described in detail in the 3S-2019-OPS cruise plan.

Risk inventory

The risk considered is risk to all 3S staff involved in the trial, both on the RV HU Sverdrup (HUS) and on board the frigate KNM Otto Sverdrup (OSVE), the risk to equipment on board HUS, risk to third parties as a result of the 3S-2019-OPS trial and risk to the environment. This includes the risk related to the use of the CAPTAS sonar system on OSVE since they are supporting the 3S-2019-OPS trial, but risk to naval staff and equipment is dealt with by the Norwegian Navy separately. 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]). A recent update of the exposure criteria implies that a frequency weighted SEL_{cum} PTS-criteria for mid-frequency cetaceans such as sperm whales, pilot whales and killer whales is maintained at

198 dB re 1 uPa2s (NMFS 2016[2]). TTS onset criteria for sonar is 20 dB lower than PTS, i.e. SEL_{cum} (TTS) = 178 dB re 1 uPa2s. However, recent studies indicate that in some particularly sensitive species hearing might be affected also at lower levels (e.g. Kastelein *et al.* 2014[3]), 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 (NARA permit no 18/126201) 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 180 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 NMFS (2016). Underwater Acoustic Thresholds for Onset of Permanent and Temporary Threshold Shifts. NOAA Technical Memorandum NMFS-OPR-55 July 2016. U.S. Department of Commerce - National Oceanic and Atmospheric Administration - National Marine Fisheries Service

3 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 on HUS, marine mammal observers 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.
- During active transmissions from the CAPTAS source on OSVE, marine mammal observers will assure that no whales are closer to the source than 200m. If any animals are approaching this safety zone an emergency shut-down of sonar transmission will be ordered.
- Exposure sessions will commence using a 20 min ramp-up (gradual increase of source level) starting 55-60 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, Rene Dekeling and Frans-Peter Lam 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. In addition to Kvadsheim, Patrick Miller, Rene Dekeling and Frans-Peter Lam (PI, CO and XO on HUS) will be field operators responsible for permit compliance in the field.

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[4] 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 maximum source level of 220 dB re 1μPa @ 1m and the maximum received sound pressure level of 154 dB re 1μPa and expected propagation conditions during the trial (18logR), the stand-off range from divers will be 5000 m for OSVE and 2000 m for HUS. This number includes a factor 2 safety margin

4. 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 CO on watch instantly, if any diver comes within the 5000 m stand-off range, transmission will be stopped.
- The 3S-19-OPS operation does not involve any diving activity by our own crew.

Responsibility

Management of risk to human divers is the shared responsibility of the navigation officers on watch on HUS and OSVE and the commanding officers on watch. For HUS this means cruise leader/CO Kvadsheim or co-cruise leader/XO Dekeling/Lam.

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[5]). The focal species of the trial is sperm whales, pilot whales and killer whales. Studies have shown that they might stop feeding and change their activity pattern shortly, but we have not observed sperm whales and pilot whales to leave the area during short term exposure to naval sonar (Sivle et al. 2015[5], Isojunno et al. 2016[6]). 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[5]. Typically such responses involve rapid avoidance of the source. Such avoidance responses might occur as much as 20 nmi from the exposure location. However, at the time of the trial the whaling season is expected to be mostly over. We will also 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[7]). 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[8] 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.

5. 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
6. 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.
7. 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
8. Instruction for use of active sonar in Norwegian waters. In: Nordlund and Kvadsheim - SONATE 2015 – a decision aid tool to mitigate the impact of sonar operations on marine life (https://www.ffi.no/no/Rapporter/14-02200.pdf)

Risk mitigation measures

- Prior to the operation we will contact the whale watching companies operating in the area and inform them about our planned activity.
- Prior to the operation we will investigate where the whale watching activity primarily happen, and during the operation we will monitor their activity and as much as possible stay away from their core area. This is also important to minimize risk that vessel traffic close to the focal whales compromises the controlled sonar exposure experiments.
- To minimize risk of accumulated effects active sonar transmissions will not be conducted within 20 nmi for HUS and 30nmi for OSVE 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 1000m 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 ultimate responsibility of FFI. On a daily basis the responsibility to manage this risk lay with the CO on HUS Petter Kvadsheim and the XO in his absence (Dekeling/Lam).

Risk of damaging expensive equipment on HUS (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 the CO/XO Kvadsheim/Dekeling 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-2019 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 (MOBHUS I and II) 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 4nmi 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 Kvadshiem) 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-2019-OPS cruise plan
NARA permit 18/126201
Instructions to survey personnel on board "HU Sverdrup II

APPENDIX C –

Justification of the operational transmission scheme

One of the main objectives of the 3S-2019-OPS trial is to collect data to test how the distance to the source affects behavioural responses. The experimental protocol is designed to test this by combining data already collected during previous trials in 2016 and 2017 using the SOCRATES source with data collected during this year's trial using the operational CAPTAS source on a Norwegian Navy ASW frigate (KNM Otto Sverdrup). The reason why we need an operational source is that the source level is significantly higher than with the SOCRATES source and by combining the two we will get better data coverage with exposures to similar levels at longer distances, and at higher levels at the same distance. However, the transmission scheme used by the CAPTAS on the frigate and the scheme used by the SOCRATES source will not match exactly (table A1). The main difference is the higher maximum source level, but the frequency band and ramp-up scheme will also not be exactly the same.

Table A1. Comparison of the pulsed active sonar signals transmitted by the SOCRATES source on HUS and the CAPTAS source on OSVE. Further details of the frigates transmission scheme are given in Table 5 and 8.

	SOC on HUS	CAPTAS on OSVE	
	HPAS	HPAS	XHPAS
Max Source level	214 dB	214 dB (-6 dB)	>220 dB (max)
Pulse duration	1000ms	1000ms	1000ms
Pulse repetition time	20s	20s (12 ky)	20s (12 ky)
Frequency/pulseform	1000-2000 Hz HFM	1280-1920 Hz HFM	1280-1920 Hz HFM
Tow speed	8 knots	8 knots	8 knots
Source depth	100-120 m (min 100m)	100-120 (min 50m)	100-120 (min 50m)
Ramp up attenuation from max SL	-60 dB, +1 dB/pulse over 20 min	-55 dB, +3dB steps from -15 to -6 dB over 20min	-55 dB, +3dB steps from -15 to 0 dB over 20min
Shut down range 180dB threshold	100 m	100 m	200 m

Due to the technical restrictions of the operational source, only a limited number of transmission modes are possible: -55, -15, -12, -9, -6 , -3 and 0 dB relative to the full power source level used. The XHPAS source level will be at SL = 220 dB re 1 $\mu Pa^2 m^2$ during these experiments. This limited the ability to exactly match the ramp-up scheme as used in the dose-escalation experiments with the Socrates source (starting at -60 dB relative to full power with incremental steps of 1 dB per transmission for 20 minutes). To enable an optimal match, the XPHAS exposure approach was specified as follows.

An important goal is to ensure similar exposure conditions between the distant XHPAS exposure with CAPTAS and the close HPAS exposure with Socrates. The start location in the exposure protocol for the distant XHPAS exposure was chosen as such to match the receiver SPL with that was produced by the close HPAS exposure starting at 7.4 km (4 NM). Due to differences in start location, SPL could not be matched for all periods, therefore a single time needed to be selected. For which we chose to match the received level at the time of the first full power transmission. Assuming a mode-stripping propagation loss (~15*log R spreading law), as suggested by the average SPL on tagged sperm whales and bottom-moored recorders in this environment, this led to a starting distance of 15 km (8.1 NM) for the XHPAS exposure (Fig A1).

Due to differences in approach distance, and related change in SPL and SEL with time, it was decided to match the *transmitted* sound levels of both HPAS and XHPAS transmissions as closely as possible: First, the last final five XHPAS ramp-up steps (3 dB each) were matched in time to every three HPAS transmissions (with 1 dB each transmission). The timing of the initial large jump from -55 to -15 dB in the XHPAS was then chosen by minimizing difference in SELcum (total transmitted SEL accumulated to each transmission) for each transmission between the start time and the first -12 dB step (Figure A3). This resulted in the following ramp-up scheme (Table A2) (detailed scheme provided in Table A3):

<u>Table A2.</u> Sonar transmission scheme for the XHPAS and HPAS transmissions of the CAPTAS on OSVE. The transmitted signal will always be 1000ms sonar transmissions of 1280-1920 Hz HFM with 20s pulse repetition time. The approach speed should be 8 knots, constant course, tow depth 100-120m. Time vs source level is specified in the table as attenuation from full powered source level. Time T0 is the time of the first ping. Only the time of changes of the source level is given. Maximum source level of HPAS is 214 dB (re 1µPa·m) and max source level of the XHPAS is 220 dB.

TIME (T0+min)	**XHPAS**		**TIME (min)**	**HPAS**
T0	-55 dB		T0	-55 dB
T0+10	-15 dB		T0+12	-15 dB
T0+16	-12 dB		T0+18	-12 dB
T0+17	-09 dB		T0+19	-09 dB
T0+18	-06 dB		T0+20	-06 dB
T0+19	-3 dB			
T0+20	Max SL			
T0+40	End of transmission		T0+40	End of transmission

The resulting XHPAS and HPAS ramp-up scheme, and a comparison with a hypothetical ramp-up scheme using the Socrates ramp-up at matching source level is given in Figure A1 for XHPAS. The expected exposure range (both in SELcum as well as SPL) is similar over the relevant range of SPL and SELcum for which HPAS exposures have previously indicated sperm whale responses.

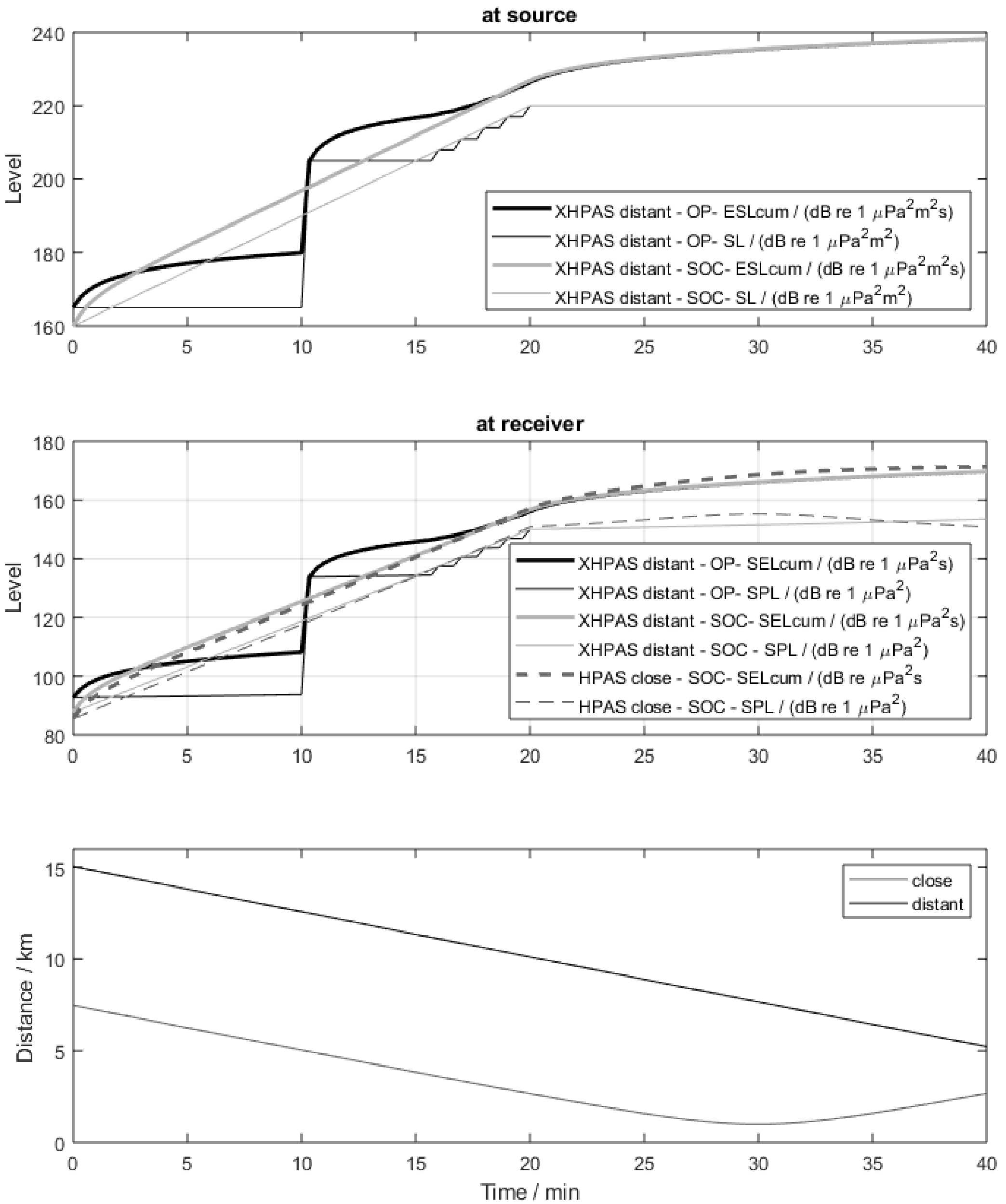
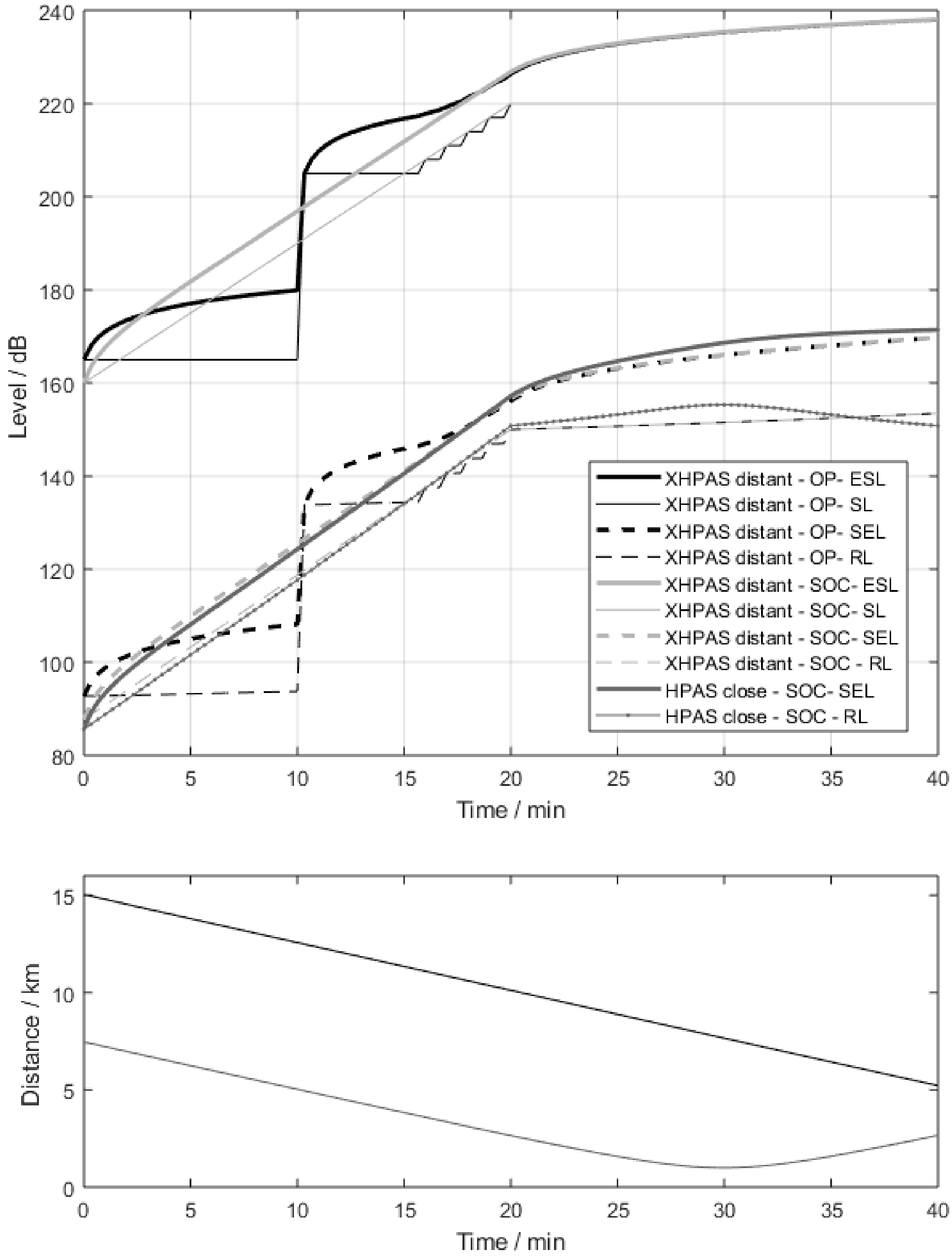


Figure A1: Top panel: Adopted XHPAS ramp-up scheme using the operational source compared with a hypothetical Socrates ramp-up scheme, transmitting at 220 dB re µPa2m2. The cumulative transmitted energy source level during the ramp-up was matched with that of a hypothetical Socrates exposure. Middle panel: comparison of predicted average SPL and SELcum on the sperm whales, showing that for a large range of SELcum and SPL similar exposure histories are expected using the adopted XHPAS ramp-up scheme.

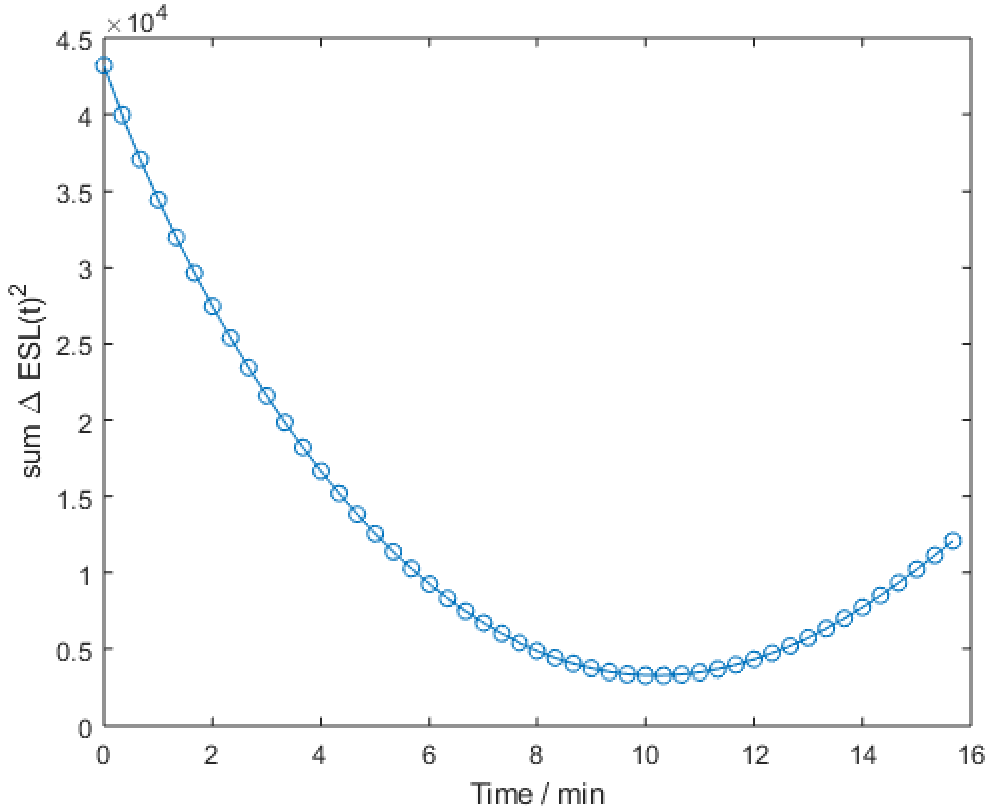
<u>Table A3</u>: Ping by ping XHPAS and HPAS ramp-up scheme. Following ramp-up both schemes will continue for another 20 min at the level of the last ping of ramp up.

Transmission number	Time / s	Time / min	**XHPAS**		**HPAS**	
			SL attenuation step / dB	SL / dB	SL attenuation step / dB	SL / dB
1	0	0.00	-55	165	-55	165
2	20	0.33	-55	165	-55	165
3	40	0.67	-55	165	-55	165
4	60	1.00	-55	165	-55	165
5	80	1.33	-55	165	-55	165
6	100	1.67	-55	165	-55	165
7	120	2.00	-55	165	-55	165
8	140	2.33	-55	165	-55	165
9	160	2.67	-55	165	-55	165
10	180	3.00	-55	165	-55	165
11	200	3.33	-55	165	-55	165
12	220	3.67	-55	165	-55	165
13	240	4.00	-55	165	-55	165
14	260	4.33	-55	165	-55	165
15	280	4.67	-55	165	-55	165
16	300	5.00	-55	165	-55	165
17	320	5.33	-55	165	-55	165
18	340	5.67	-55	165	-55	165
19	360	6.00	-55	165	-55	165
20	380	6.33	-55	165	-55	165
21	400	6.67	-55	165	-55	165
22	420	7.00	-55	165	-55	165
23	440	7.33	-55	165	-55	165
24	460	7.67	-55	165	-55	165
25	480	8.00	-55	165	-55	165
26	500	8.33	-55	165	-55	165
27	520	8.67	-55	165	-55	165
28	540	9.00	-55	165	-55	165
29	560	9.33	-55	165	-55	165
30	580	9.67	-55	165	-55	165
31	600	10.00	-55	165	-55	165
32	620	10.33	-15	205	-55	165
33	640	10.67	-15	205	-55	165
34	660	11.00	-15	205	-55	165
35	680	11.33	-15	205	-55	165
36	700	11.67	-15	205	-55	165
37	720	12.00	-15	205	-15	205
38	740	12.33	-15	205	-15	205
39	760	12.67	-15	205	-15	205

40	780	13.00	-15	205	-15	205
41	800	13.33	-15	205	-15	205
42	820	13.67	-15	205	-15	205
43	840	14.00	-15	205	-15	205
44	860	14.33	-15	205	-15	205
45	880	14.67	-15	205	-15	205
46	900	15.00	-15	205	-15	205
47	920	15.33	-15	205	-15	205
48	940	15.67	-15	205	-15	205
49	960	16.00	-12	208	-15	205
50	980	16.33	-12	208	-15	205
51	1000	16.67	-12	208	-15	205
52	1020	17.00	-9	211	-15	205
53	1040	17.33	-9	211	-15	205
54	1060	17.67	-9	211	-15	205
55	1080	18.00	-6	214	-12	208
56	1100	18.33	-6	214	-12	208
57	1120	18.67	-6	214	-12	208
58	1140	19.00	-3	217	-9	211
59	1160	19.33	-3	217	-9	211
60	1180	19.67	-3	217	-9	211
61	1200	20.00	0	220	-6	214
After the 20min ramp-up continue for another 20 min at the level of the last ping (ping 61)						



<u>Figure A2:</u> top: Comparison of the SL and SEL of the specified XHPAS ramp-up (with steps), and 3S ramp-up (1dB per transmission) at the same full power SL (220 dB re 1 µPa2m2). Bottom: Assumed sailed ship tracks for distant and close exposures.



<u>Figure A3:</u> Minimization of SELcum over all transmissions to choose time of switch from -55 dB to -15 dB point. Minimum indicates after 10 min switch to -15 dB. Also practical for operator.

D 3S-2019-Baseline trial

Final Cruise report: 30 Sept, 2019

The 2019 3S-OPS baseline trial is funded by UK DSTL, US Living Marine Resources (LMR).
Additional funding is provided by French DGA.

Cruise Report
3S-OPS 2019 Baseline Trial

Above : Mixed-Dtag deployed on a long-finned pilot whale in Vestfjord, Norway. Filmed from a video tag attached to another whale.

June 29 – July 16, 2016
Patrick Miller, , Cruise Leader

Cruise Report prepared by:
Patrick Miller, Kagari Aoki, Alec Burslem

The 2019 Norway trial was funded by UK DSTL, US LMR, and French DGA as part of the 3S research collaboration.

1

TRIAL OUTCOME

The 2019 baseline trial was executed with the primary aim of testing field procedure, equipment, and collecting baseline data to support the full 3S-OPS sonar trial conducted in Aug-Sept 2019. The sailboat platform was effective for surveying protected waters within Norwegian fjords, but had limited ability to work in the high offshore wind conditions experienced during the baseline trial. Target species (long-finned pilot whale) were encountered only on one day: 13 July off the Tranøy lighthouse in Vestfjord. During this encounter, we successfully deployed a mixed-Dtag, a standard Dtag2, and a heart-rate/video tag prepared by the U of Tokyo. All tags functioned as designed, confirming their suitability for the full 3S-OPS trial. A set of 7 UAV drone flights above the tagged whales confirmed our ability to locate and track a tagged whale, enabling use of UAV tracking to conduct experiments during the full 3S-OPS trial using the protocols detailed in the appendix to this report. Range testing in Vestfjord confirmed substantially longer detection ranges of newly-prepared double-powered VHF transmitters, compared to the standard Dtag3 and the VHF transmitters used in previous Mixed-Dtags. Though the dataset collected was rather limited due to only one encounter, the trial successfully achieved its primary objectives.

OPERATION AREA

The operation area was the inland waters near Tromsø down to Bodø, Norway.

OUTOMES VERSUS CRUISE TASKS

Below is a summary of the outcome of the cruise tasks. Primary tasks had a higher priority than the secondary tasks. We tried to accomplish as many of the secondary tasks as possible, but they were given a lower priority.

Primary tasks:

1. Deploy the redesigned mixed-Dtag on sperm, long-finned, or killer whales to confirm the tag's performance and collect baseline data. When possible, deploy a second tag in the same group.

<u>OUTCOME</u>: One deployment of the redesigned mixed-Dtag was accomplished with the long-finned pilot whale. Two other tags (standard Dtag3 and a heart-rate/video tag) was deployed on two other individuals in the same group. The mixed Dtag functioned as designed. Separate testing was done on the detection range of VHF transmitters with the new double-power transmitter being detectable at 12nm range, further than the range of detection for either the standard Dtag3 or the standard-power VHF transmitter previously used in mixed-Dtags. Based upon this outcome, more double-power transmitters were prepared for sperm whale tracking in the main 3S-OPS trial.

2. Follow tagged whales using an UAV drone. Record video to: a) track the location of tagged whales, b) observe the social context of a focal tagged whale and its group,

including recording surface behavior of tagged and non-tagged whales, c) make photogrammetry measurements of tagged and non-tagged whales. Priority is to refine this procedure with long-finned pilot and killer whales.

OUTCOME: A total of 7 UAV drone flights were conducted with the group of tagged long-finned pilot whales. One flight was aborted. The tagged whale was located in 5 of the 6 other flights. The real-time position of the drone in Lat/Long was visible in the operator screen, enabling accurate tracking of the tagged whale in real time. Characteristics of group behavior such as group size, spacing and synchrony were observed in the recordings, demonstrating that UAV drone video recordings have the capability to record the social behavior of this species, replacing human observers. A detailed protocol for use of the drone for recording long-finned pilot and killer whale social behaviour was produced, and is available in the appendix to this report.

Secondary tasks:

1. Deploy camera and heart-rate measuring tags (during second half of trial only).

OUTCOME: One tag was deployed with a duration of ~2hrs. Excellent video data imagery was recorded. The heart sensor did not record notable ECG signals, likely due to tag placement.

2. Collect sightings, photographs, and acoustic recordings of target species and other cetaceans encountered.

OUTCOME: Extensive photographs of the encountered group were successfully obtained.

3. Collect CTD profiles using a Valeport Mini-CTD to measure water density in the study area. Lower the system on a line close to areas where tags are deployed.

OUTCOME: Unfortunately this task could not be completed as the tags detached from the animals too late in the day to spend time conducting a CTD. Instead we needed to commence our return transit to Tromsø.

CHRONOLOGICAL OUTCOME

29-30 June	Arrived Tromsø, set up equipment
01-06 July	No whales in Andfjord, wind from North
	too rough to work offshore
07-09 July	Moved to Westfjord, conducted VHF range tests
	skipper change (+ Kagari joined science team)
10-12 July	Searched Westfjord / Ofotfjord

13 July	Pilot whales found off Tranøy lighthouse

3 tags deployed, all recovered

7 drone flights accomplished

14-15 July	Transit back to Tromsø, demobilization

16 July	Departed Tromsø

VHF range-test

On 07 July, a long-distance range test was conducted using the tags transmitting from the Iolaire at deck level. The receiver was Miller with a Yagi handheld antenna on the zodiac, roughly 1m above the water line, with the R1000 set at max gain.

Time (local)	**Iolaire**	**Zodiac**	**Range (nm)**	**Double power**	**Standard D3**	**Normal power**
13:37	68° 02.642 15° 01.285	68° 05.29 15° 11.60	4.70	3-4 bars	audible	1 bar
14:02	68° 02.595 15° 01.207	68° 07.76 15° 17.85	8.11	3-4 bars	Audible w/ phones	Audible w/o phones
14:34	68° 01.901 14° 59.455	68° 09.63 15° 23.01	11.75	Clearly audible w/o phones	inaudible	Barely audible with phones

Suction cup tag deployments

A total of 3 tag deployments were made, and all tags were recovered.

Table 1. Suction cup tag deployments on long-fined pilot whales during the 2019 3S OPS baseline trial. No other species were tagged.

Dataset / sighting #	**Tag on (Date Time UTC)**	**Tag on location**	**Dur. (h:min)**	**Method**	**Tag type**	**reaction**	**NOTES:**
gm19_194c	13 July, 2019 15:11:00	68° 12.66 15° 26.59	226 min	Pole	Mixed - Dtag	1 - rolled on side	Released as scheduled. GPS logger data: baseline_194_arcivalGPS.kmz
gm19_194a	13 July, 2019 15:15:29	68° 13.59 15° 22.45	~13 min	Pole	Standard Dtag3	1 - minor tail slap	Tag slipped off early
Gm19_194video_heart	13 July, 2019 17:41	68° 09.87 15° 13.78	123 min	Pole	Heart-rate / Video logger	2 -2 strong tail slaps	Tag detached without release mechanism

Figure 1, above. Picture of Mixed Dtag on a long-finned pilot whale

Table 2; below, Configuration of the mixed Dtag when deployed.

Release BY	13/07/2019 18 00 00
Release AFTER (01 00 00 default) days:hrs:mins	01 00 00
Salinity - 30	30
Burn - (hours minutes seconds)	02 30 00
Pulse rate and length - 1,1	1,1
Audio - 240 (120 for sperm whales)	240
Gain in Channels - 1,0	1,0
Sensors - A&M	a+m
VHF - 1	1

Table 3;below Configuration of the standard Dtag 3 when deployed.

Release BY	13/07/2019 18 00 00
Release AFTER (00:16:00 def spw 00:10:00 def mink) days:hrs:mins	01 00 00
Salinity - 30	30
Burn - 2:30:00 (hours minutes seconds)	02 30 00
Pulse rate and length - 1,1	1,1
Audio - 120 (240 for killer whales and pilot whales)	240
Channels - 1,0	1,0
Sensors - A&M	a+m
VHF - 1	1

Figure 2, above, heart-rate / video tag on a long-finned pilot whale. Placement was intentionally low in the water.

Table 4; Configuration of the heard-rate video tag.

DVLW2000M130-4W sn18003, no flash, Start time 17:04:30, 1h delay
ORI1300-PD3GT sn18010, acceleration 0.02 msec. others 1 sec
w400-ECG, sn38849 0.004 sec

UAV Flights

A total of 7 flights were conducted. 6 successful UAV flights were conducted between 17:32 and 19:50, when flights were ceased due to mist/light rain. One additional flight was aborted and landed shortly after take-off due to erratic flight behaviour by the UAV. No reaction to the drone was observed during any of the flights. The whale bearing the mixed tag was successfully located and followed on 5 of the 6 flights. The real-time position of the drone above the tagged whale was visible in the operator screen.

The tag was clearly visible from the UAV at heights of 10, 30 and 46m (see figs 3 and 4) and was sometimes visible even when the outline of the whale was not. Defecation and a variety of near-surface behaviours (spyhopping, tail sailing, mother supporting calf, apparent nursing; see fig.5) were also clearly visible.

Based upon the successful outcome of these observations, we concluded that video recording from the UAV drone would be effective in the main 3S sonar trial. Recommendations for a specific observation protocol will be produced in time for the main trial.

Figure 3; UAV video frame showing the mixed tag on the focal animal (circled in red), the tag boat, the associated calf and other animals from 13m..

Figure 4; UAV video frame showing the tag (circled in red) on the animal from 46m.

Figure 5; possible nursing behaviour. The calf turned on its side, passed beneath the associated female and remained in this position for a period of around one minute.

Post-trial recommendations:

Equipment and Logistics:
Externally label Dtag core units → this was actioned by A Shorter for the main trial

Make a video tag with a depth trigger to not waste recording time.

Add a hydrophone to the video tag to store audio data.

Work with the LIDAR system to reduce how it affects flight of the UAV.

Work to define height limits for the drone depending upon wind.

ADF box (eg DFHorten) would help drone flyers to locate tagged animals.

Sailboat w/RHIB system was ideal for in-fjord work but limited our ability to work offshore given the wind. Consider a large RHIB-only scenario to work offshore Andenes for tagging and drone work from the same platform.

WIFI hub was crucial to the project. Better to use a project phone or Hub.

The sighting network to locate whales was very helpful.

If possible, plan to work in areas with more whales of the target species.

Drone batteries need to be recharged on MOBHUS in the main trial.

Protocols:
May be difficult to see tag at >30m height. Requires further evaluation.

1s delay on ARGOS may not be helpful for on-animal SPOT locations of pilot whales.

Logger was very effective for recording information about operational status / effort.

Greater care of Drone batteries during transport would reduce signs of 'wear-and-tear'

Safety:
The established procedures were effective

Consider to source a light dry suit that can be worn under a mustang suit. Sanja sent a link for Ursuit MPS drysuits her company uses for small boat operations:

https://www.ursuit.com/en/mps

Appendix 1: UAV Protocol; 3S Cruise 2019
A.C Burslem
23rd July 2019

Background
This document lays out the UAV protocols and background information specific to the 2019 3S trial. Its purpose is to supplement the 3S cruise plan and the SMRU operations manual which contains the rules and procedures to be followed in all UAV operations conducted by SMRU personnel.

Legal Restrictions
Under Norwegian law, there is a 5km exclusion zone around all airports (see *Figure 0.1* below). Furthermore, it is not permitted to fly within 150m of people, buildings or traffic, or at an altitude greater than 120m.

Figure 0.1; Map of the operational area, showing 5km exclusion zones (red buffers) and controlled airspace (blue dashed boxes)

Personnel

Drone Team

The drone team will consist of a UAV pilot (P.J.O Miller / A.C Burslem) an assistant (TBC) and the tag boat driver (R.R. Hansen / L. Kleivane).
The pilot is responsible for flying the UAV, operating the camera and taking relevant imagery. The pilot bears ultimate responsibility for flight safety and therefore makes the final decision on whether or not to launch the drone.
The assistant is responsible for launching and retrieving the drone, recording data, and relaying the UAV position to other teams where necessary.
The driver is responsible for positioning the boat during take-off, flight and landing.

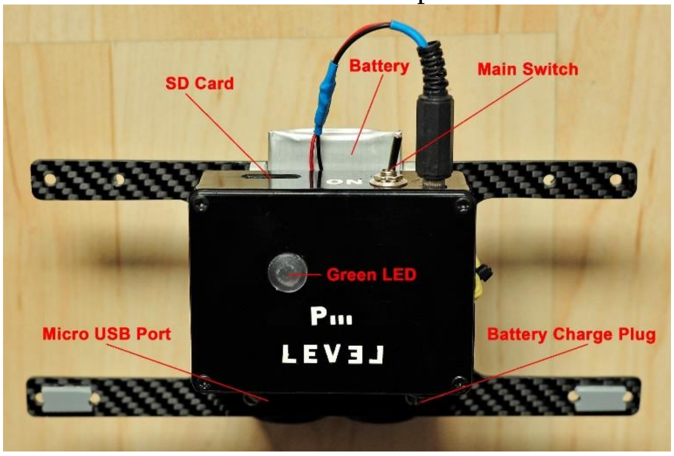
Equipment

DJI Phantom 4 Quadcopter

SMRU will provide two aircraft for the 3S trial, both are DJI phantom 4 quadcopters equipped with a stabilised 4K/12MP camera and real time GPS telemetry.
This UAV can only be flown in conditions which are relatively calm and completely dry. It can also experience initialisation problems in chop/swell. The UAV will therefore only be launched if the prevailing wind is under 4.2 m/s, the sea state is less than 3 and there is no rain.

Lidar unit

One of the Phantom 4 UAV's will be equipped with a Lidar unit, carried as additional payload. The Lidar unit samples height above the water at a frequency of 1 Hz, with allowing for accurate and objective photogrammetry measurements. Measurements are automatically taken all the time the unit is switched on. There is no charge indicator on the unit, but a green LED on the USB charger will light when the battery is fully charged and the main switch is in the on position.



Procedures

Launch

The UAV is hand launched from a stationary research vessel positioned upwind from the targeted animals such that the UAV is blown away from the vessel and the crew.
The UAV is launched by an assistant using the landing gear, with the pilot a few meters away in visual and auditory contact. The assistant releasing the UAV will be wearing a

full face clear visor and heavy welding gauntlets. This will minimise the potential for injury should problems occur during the launch. The pilot will fly the UAV away from the research vessel immediately once launched.

The launch procedure is as follows:

1. Battery levels of the UAV, the Controller and the tablet are checked.
2. Loss of signal procedure is set to 'hover'.
3. Maximum altitude is set to 120m.
4. SD card is formatted.
5. Lidar unit is activated, if using, confirmed by the presence of a blinking green light.
6. An image is taken of a handheld GPS using the UAV camera.
7. Video recording is activated, with the GPS still in shot.
8. Pilot engages ATTI mode and verbally confirms to the assistant that this has been done
9. Assistant raises the UAV above their head, holding it by the landing gear. The pilot checks orientation of the drone and requests adjustments if necessary.
10. Pilot starts the motors and verbally counts down "3,2,1, launching" before taking off. The assistant releases the landing gear. If they have any doubts that the UAV is behaving normally (e.g. aircraft seems to be pulling in any direction other than up), or if ATTI mode has not been verbally acknowledged by the pilot, then the assistant should not release, and should shake their head to signal an abort.
11. The pilot takes off, clears the launch vessel immediately, and switches to GPS positioning mode for the remainder of the flight.

Flight

All flights will be conducted according to a flight plan agreed in advance by the pilot and the relevant PI as per the SMRU operations manual. The drone team will then be briefed by the pilot before any flights are undertaken. In this trial variations in flight plan are likely to consist of whether and at what point in the flight to take images for photogrammetry, observation height and what battery margin to leave at the end of the flight depending on the prevailing wind and the distance between MOBHUS and the whale. Visual sightings of the focal whale, combined with ADF bearings using a DF-Horten box will help guide each flight plan.

The primary objective of all flights above pilot/killer whales will be to locate and follow the focal whale as continuously as possible. Behavioural observations will be undertaken at a constant altitude of 50m if the tag can reliably be seen at that elevation. If tags are not visible at 50m, a height of 30m should be flown. The UAV will also be used to get the precise GPS position of the focal whale, to be relayed to other members of the team where necessary to assist the coordination of controlled exposures. The assistant will photograph the screen showing the UAV position when it is directly above the whale and pass the location to the driver for relay to the HU Sverdrup team. Any reaction by the whales to the UAV will be scored and recorded in the datasheet, any

other behaviour of interest (e.g. nursing) will be recorded along with the elapsed time in the UAV video.
If possible and practical without interfering with the primary objective, the UAV may also periodically descend to ~10m in order to take photogrammetry images/video.

Landing
The UAV returns to MOBHUS and is recovered by hand. The research vessel remains immobile, again, upwind of the UAV, while it is brought into land and is caught using the landing gear by the assistant at the bow of the boat. Again, the assistant wears personal protective clothing and is a few meters away from the pilot in visual and auditory contact while the driver and remaining crew remain at the stern.

Shut down
The UAV will be shut down after landing, with the removal of the LiPo batteries, followed by powering down the controller. After each flight, the battery and both the UAV and Lidar SD cards must be changed. The SD cards must be placed in the 'used' bag and their numbers recorded in the UAV datasheet. Spent batteries will be placed in a constantly cycling charge queue on the tagging boat in order to maximise available flying time.

Flight length and battery rotation
The battery life of the UAV while flying is ~20 minutes, but will vary with wind strength and direction. Time take to turn around the battery and SD card, reinitialise the UAV and relaunch is assumed to be 10 minutes. The batteries take 80 minutes to recharge, assuming 3 chargers it would take 22 batteries to fly continuously for 15 hours. Unfortunately, It has only been possible to source 15 flight batteries in advance of the trial.
We therefore propose a slightly reduced flying itinerary comprising 5 100 minute observation periods each consisting of the 40-minute exposure period, 40 minutes pre exposure, and 20 minutes post exposure for each sonar treatment, plus one additional 100 minute mock exposure during the baseline period. This leaves 20 minute intervals of down time between post exposure observations of one treatment and pre exposure observations of the next. Downtime is planned at the closest point of approach between MOBHUS and HU Sverdrup, minimising disruption due to shift changes.
As well as requiring fewer batteries, this protocol standardises observation durations and makes time for breaks and shift changes part of the experimental procedure.

Data offload

1. Transcribe UAV field notes datasheet into an excel file and save along with a photo of the datasheet.
2. Refer to the datasheets for the launch times and SD card numbers.
3. Create a folder for the date (yyyymmdd), and a sub folder for each flight that day with the time the flight commenced (e.g. 1_1730)
4. For each sub folder:

    a. Offload the relevant UAV video files and rename with the start time (confirmed using the image of the handheld GPS) and a,b,c etc denoting the chunk number.
    b. Offload the DATALOG.csv file from the relevant Lidar SD card. Rename the file with the time in the first row of data
5. Double check that the times for the UAV footage and the Lidar data line up as expected, after accounting for their respective time differences: Lidar = UTC, UAV EXIF data = UTC+1, GPS device = UTC.
6. Back up all data to two redundant hard drives

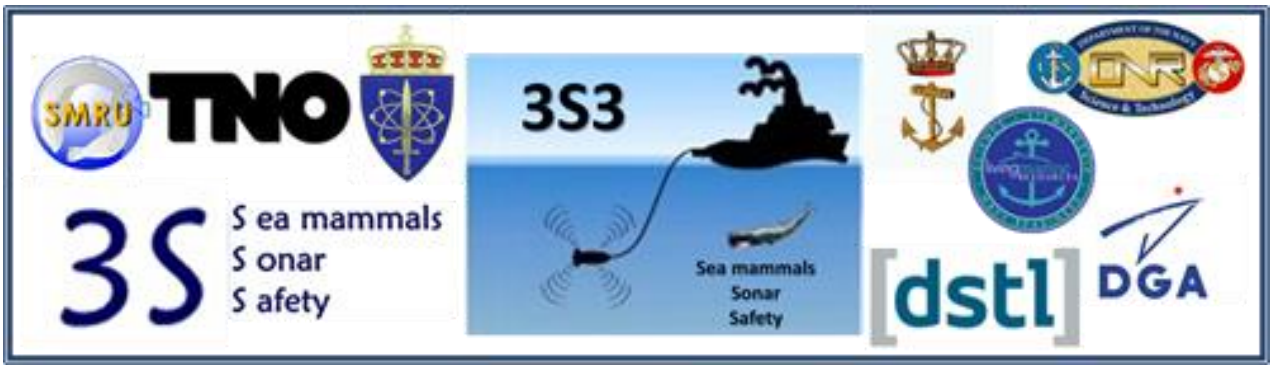
Note that the Lidar SD card cannot be formatted without a computer. If the Lidar is powered up with an SD card already containing data, a new header row will be added below the existing data, followed by the new data. If the Lidar data appears out of sync with the UAV and GPS data, scroll to the bottom of the csv to make sure there aren't multiple flights recorded on the same SD card.

Appendix 2 – Cruise plan

<u>Cruise Plan</u>

3S-OPS Project: 2019 Baseline Trial

July 1 – 15, 2019
Professor Patrick Miller, Cruise Leader;



The 2019 3S-OPS baseline trial is funded by UK DSTL, US Living Marine Resources (LMR). Additional funding is provided by French DGA.

PROJECT OBJECTIVE

The 3S (Sea Mammals, Sonar, Safety) 2019 baseline trial forms part of a larger 3S study entitled 3S3-OPS. The 3S3-OPS study has two objectives: 1.) to test if exposure to continuous active sonar (CAS) leads to different types or severity of behavioural responses than pulsed sonar, and 2.) to test how the distance to naval sonar sources affect behavioural responses. A full scale 3S-OPS BRS trial is scheduled for August-September and includes the use of a naval frigate as the sonar source.

CRUISE TASKS

The primary objective of this baseline trial is to test and validate methodology intended to be used during the 3S-OPS-2019 full scale BRS trial in August-September. Primary tasks have a higher priority than the secondary tasks. We will try to accomplish as many of the secondary tasks as possible, but they will be given a lower priority if they interfere with our ability to accomplish the primary tasks.

Primary tasks:
1. Deploy the redesigned mixed-Dtag on sperm, long-finned, or killer whales to confirm the tag's performance and collect baseline data. When possible, deploy a second tag in the same group.

2. Follow tagged whales using an UAV drone. Record video to: a) track the location of tagged whales, b) observe the social context of a focal tagged whale and its group, including recording surface behavior of tagged and non-tagged whales, c) make photogrammetry measurements of tagged and non-tagged whales. Priority is to refine this procedure with long-finned pilot and killer whales.

Secondary tasks:
1. Deploy camera and heart-rate measuring tags (during second half of trial only).

2. Collect sightings, photographs, and acoustic recordings of target species and other cetaceans encountered.

3. Collect CTD profiles using a Valeport Mini-CTD to measure water density in the study area. Lower the system on a line close to areas where tags are deployed. Initial plan is to conduct CTDs from Lars' boat.

MAIN LOGISTICAL COMPONENTS

'Vessel 1: Iolaire'

Length: 12m. Base of operations

Skipper: Martin Arntsen (1st half)

maarntsen@gmail.com

+47 917 35 601

Sanja Forstrøm (2nd half)

sanja.forsstrom@gmail.com

+47 456 75 344

Science crew: 3-4

Engine:Nanni Diesel 85 HP 2004

220V power available

Max/cruising speed:7.5/6.0 knots

Phone: +354 464 7272

Small 4HP dinghy available

'Vessel 2: tag boat'

Zodiac mark2 with 30HP 4-stroke outboard motor, will be towed by Iolaire. This second vessel will serve as a tagging boat, and can be used to search for whales in tandem with Iolaire.

'Mixed-Dtag'

Suction-cup attached whale tag, attached using poles or ARTS launcher. Contains: Dtag3 core unit (audio, depth, 3-axis accelerometer, 3-axis magnetometer, programmable release); Sirtrack GPS logger; Wildlife Computers SPOT transmitter; VHF transmitter. In addition to two mixed-Dtags, which is the priority tag for testing performance and recording baseline data, we have three additional suction tags (standard Dtag3, heart-rate tag, video camera tag) that will be used during the trail.

'DJI Phantom-4 UAV drone'

Video-recording drone with flight logs to record position and altitude. Custom procedures are used to safely launch and recover the drone at sea.

OPERATION AREA

The primary operation area will be the in-fjord waters near Tromso, ideally in Andfjorden or adjacent waters, but we will need to move to where long-finned or killer whale are located. With good weather conditions, we may work in offshore waters outside Andenes, outer regions of Westfjord and Vesterålen, and waters off Vengsoya and Sommerøya.

SAILING SCHEDULE

29 June: team arrives Tromsø. Stay on board Iolaire.
30 June: organize gear, set up boat and check all systems. Check network for long-finned
pilot or killer whale sightings.
01 July: Finalize boat and personal preparations. Depart afternoon if possible.
02 July: Start of full operations with whales.
08 July: Kagari Aoki arrives Tromso.
09 July: Skipper change, Kagari arrives to Iolaire. Continue to work with whales.
15 July: Iolaire arrives Tromso. Break down and store equipment.
16 July: Finalize shipment from IMR to Harstad. Science team departs Tromso.

STUDY ANIMALS
Individuals of the target species (long-finned, killer or sperm whales) will be chosen opportunistically from animals found in the study site.

SCIENCE CREW LIST / ROLES

NAME:	Primary Role	Secondary Role	Tertiary Role
Patrick Miller	Cruise leader	Tagger / Dtag3 technician	Tagger / Drone pilot
Joanna Kershaw	Drone pilot	Visual observer	CTD
Kagari Aoki (2nd half only)	Camera / heart-rate tags	Visual observer	CTD
Alec Burslem	Dtag3 technician	Drone pilot	CTD

DAILY WORK PLAN
We will plan to work for a maximum of 12 hours each day, with Iolaire resting at anchor or at a dock each night. A daily planning meeting will be held each evening to determine the specific plan for the next 24 hours. The research team and skipper will share tasks of cooking and cleaning the boat.

Searching phase
As much as possible, tags and drone systems should be prepared for immediate use. During this phase tags should be prepared so they are ready for use upon encountering animals – in ‘grab and go’ mode. If tags were deployed on whales the previous day, recovery of tags deployed the previous day need to be given a high priority to be sure of safe recovery of the loggers.

The team will start by searching for whales at the start of each day. Contacting local contacts should take place to ascertain where target species have recently been seen. As much as possible the Norwegian 3S team (Petter and Lars) will try to give shore support using their local network to localize presence of target whales. The zodiac can be used to search at higher speed.

Tagging phase
One a target species is encountered, we will observe and record the overall group characteristics in Logger software. If weather conditions allow, we will commence tagging operations. We expect most tagging to occur from the zodiac, but we may try to use the dingy to assess its functionality. During approach, the driver should drive parallel to animals, driving as slowly as possible and approaching from the side. The photographer will take images of the animals, and document whether or not there is a calf within the group. The photographer should attempt to photograph the tagging operation. Mothers and calves should be prioritized for tagging, but neonates cannot be tagged.

In addition to assessing the success or failure of each tagging attempt, it is critical to document the response of the animal to the operation, following the 1-4 point scale below:

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

The tagger should attempt to place the tag high on the back of the animal when possible, but a low attachment on the side is also acceptable for all tags except the Dtag. If the first tagging attempts is successful, a datasheet noting the information should be completed and attempts should then be made to deploy a second tag on a different individual. Ideally the second animal should be closely associated to the first animal. A maximum of 2 hours will be allowed to attempt to tag a second animal in the same group.

During the tagging phase, one person on Iolaire (likely the skipper) should monitor the VHF frequency of each tag before it is deployed. This is to confirm that the VHF transmitter is working before the tag goes onto a whale, and to listen in case any tag comes off the whale prematurely.

Data sheets for each deployment should be completed promptly to assure that no information is lost.

UAV Drone - Follow and Photogrammetry phase
Once tags are deployed, the tagboat team will return to Iolaire. If weather conditions allow, we will commence the use of UAV drones to fly above focal tagged whales to make video recording from overhead. This can potentially continue for as long as the tags remain attached, so drone flyers and handlers will need to rotate throughout the day. Each drone flights will last as long as possible given the battery duration, and spare batteries and SD cards will be available to swap them out each flight. Care is needed during launch and recovery phases to reduce vessel motion, so the ship may need to be driven down-wind in certain circumstances.

The primary objectives of the drone flights are 1.) to track and record video images of the social context of tagged whales (20m min altitude above whales); 2.) to take photogrammetry images (5m minimum altitude above whales); and 3.) to make video recording of surface behavior of tagged and non-tagged whales – with a focus to identify and record episodes of nursing between females and calves.

At the end of each drone flight, it is critical to document the response of the animal to the operation, following the 1-4 point scale below:

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

Tag-recovery phases / data download and backup

Detached tags will be recovered using the VHF signal or SPOT Goniometer to approach the tag, followed by visual sighting of the floating tag. A pole with a net will be set up for recovering floating tags. Suction cups should be inspected for any sloughed skin before tags are disassembled for data download and battery change.

Tags with ARGOS transmitters need not be followed by Iolaire after tagging, unless drones are used to observe group behavior. The VHF frequencies of the deployed tags should be routinely checked to listen in case they come off the whale. After 8 hours of deployment time, checks of ARGOS fixes can be made to help ascertain the position of the tagged whale. Once the tag detaches, it is expected that a larger number of higher-quality ARGOS fixes should be made, which should be used to guide the boat close enough to detect the floating tags using VHF.

All tag data must be checked that it has downloaded properly and has been backed upon on at least two different hard drives before it is deleted from the recording device.

MANAGEMENT AND CHAIN OF COMMAND

Operational issues

Operational decisions such as decisions on which tag types to deploy, sailing plan, crew dispositions etc. are ultimately made by the cruise leader, Dr. Patrick Miller, after seeking advice from the rest of the team and the skipper.

Safety issues

The skipper of Iolaire will make the final decisions on safety issues, and consumption of alcohol on board. Always remember: 'Safety First'!

TRIAL RISK ASSESSMENT

The Iolaire is fully equipped with all required safety equipment to conduct the operations within the study area. The University of St Andrews Health and Safety Office has created a safety risk assessment for the activities to be undertaken on board which must be understood and signed by all members of the science team and the skipper.

PERMITS

Appropriate permits for working with the target species in the study site have obtained from the NARA by Petter Kvadsheim at FFI. All drone flights will be carried out following Norwegian Law: drones may not be flown within 5km of an airport or airfield. Drones may not fly greater than 120 meters above the ground or sea-level.

ENVIRONMENTAL IMPACT AND RISK ASSESSMENT

Risk Inventory: The baseline trial will be conducted during the first half of July, 2019. This is a time when many marine mammals are expected to be present in the study area, and other human users of the area are also expected to be abundant. As no active sound sources will be used during the trial, we do not need to consider secondary effects of sound on animals and humans. The environmental impact of the trial will therefore primarily stem from usage of the research vessels within the study area, and the impact of our research activities on the study animals.

The impact of the research vessels on the environment will be mitigated by driving at optimal speeds to reduce fuel consumption, and use of standard procedures to strictly regulate the disposal of waste materials. The impact of our activities on marine mammals is expected to be minor, and consist only of short-term behavioural disturbance. The activities to be conducted in the study area have authorization from the Norwegian Animal Research Authority (NARA), and have been ethically approved by the University of St Andrews Animal Welfare and Ethics Committee. Details of mitigation procedures to limit our impact on the study animals are detailed in the next section.

ANIMAL RESEARCH MITIGATION PROCEDURES

We have specified the following mitigation procedures to limit the potential impact of our research on the study animals.

Close approach by for tagging:

Individuals or groups will not intentionally be tagged more than three times during the course of the fieldwork. Approaches by the vessel will be made at minimal possible speed. We should not manoeuvre to stay within 10m of any individual whale for more than 10 minutes. Specific groups should not be actively approached for more than 2 hours total.

Behavioural response monitoring:

During each tagging attempt, and each drone flight, the reaction to the procedure will be carefully observed and recorded using the 4-pt scale used by Hooker et al., 2001.

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

Approaches to groups for tagging will be ceased if any animal in the group exhibits a level 4 response to the approach.

Drone flights will be ceased if any animal in the group exhibits a level 4 response to the approach.

TRIAL READINESS REVIEW

All equipment and materials required for the research effort have been obtained or are scheduled for delivery in time for the project start. The research team has been trained as necessary for the activities and procedures to be carried out during the trial. The 3S board approved this cruise plan on 05 June 2019 as ready for execution in the time-frame specified.

TRAVEL AND ACCOMMODATION

Miller, Kershaw and Burslem will stay onboard Iolaire upon arrival in Tromso on 29 June.
Kagari Aoki will arrange for her own accommodation for 08 July.
The entire team will disembark from Iolaire on 16 July.

CONTACT INFORMATION

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EQUIPMENT PACKING FOR SHIPMENT AT THE END OF THE CRUISE

We expect that all gear will be brought to Tromso as extra luggage. Some gear is stored at IMR with Martin Biuw.

<u>SHIPPING ADDRESS TO TROMSO:</u>
c/o Martin Biuw
Institute of Marine Research
Hjalmar Johansens gate 14
9007 Tromsø
Tel: (+47) 77 75 03 16

At the end of the trial, items will be shipped to Harstad for FFI storage for the 3S sonar trial.
Tissue samples will be stored by Martin Biuw for CITES export to SMRU.

<u>HARSTAD SHIPPING ADDRESS:</u>
HU Sverdrup
C/O Norbase AS
Stangnesterminalen 6
NO-9409 Harstad
Norway

About FFI

The Norwegian Defence Research Establishment (FFI) was founded 11th of April 1946. It is organised as an administrative agency subordinate to the Ministry of Defence.

FFI's MISSION

FFI is the prime institution responsible for defence related research in Norway. Its principal mission is to carry out research and development to meet the requirements of the Armed Forces. FFI has the role of chief adviser to the political and military leadership. In particular, the institute shall focus on aspects of the development in science and technology that can influence our security policy or defence planning.

FFI's VISION

FFI turns knowledge and ideas into an efficient defence.

FFI's CHARACTERISTICS

Creative, daring, broad-minded and responsible.

Om FFI

Forsvarets forskningsinstitutt ble etablert 11. april 1946. Instituttet er organisert som et forvaltningsorgan med særskilte fullmakter underlagt Forsvarsdepartementet.

FFIs FORMÅL

Forsvarets forskningsinstitutt er Forsvarets sentrale forskningsinstitusjon og har som formål å drive forskning og utvikling for Forsvarets behov. Videre er FFI rådgiver overfor Forsvarets strategiske ledelse. Spesielt skal instituttet følge opp trekk ved vitenskapelig og militærteknisk utvikling som kan påvirke forutsetningene for sikkerhetspolitikken eller forsvarsplanleggingen.

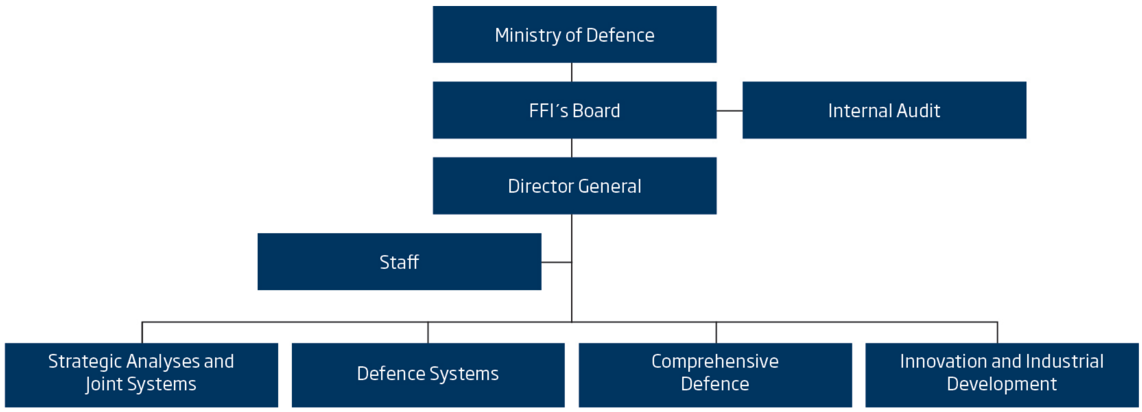
FFIs VISJON

FFI gjør kunnskap og ideer til et effektivt forsvar.

FFIs VERDIER

Skapende, drivende, vidsynt og ansvarlig.

FFI's organisation



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