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Effect of naval sonar exposure on killer whales and humpback whales

– 3S-2024 cruise report

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Summary

3S (Sea mammals and Sonar Safety) is a multidisciplinary and international collaboration studying how naval sonar affects cetaceans. One of the objectives of phase 4 of the 3S project (3S4) is to investigate 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. Another is to investigate empirically if responses from short-duration experiments predict responses from longer-duration exposures conducted over an operationally relevant duration. The 3S-2024 trial took place off the coast of northern Norway in October–November 2024 using FFI's research vessel H.U. Sverdrup II. The trial collected data to address these research questions. The purpose of this report is to summarize and document the data collected.

The experimental design was based on long-duration CAS and PAS exposures to killer whales and humpback whales using real-time GPS location data of multiple tagged subjects. The sonar source vessel was moved to achieve repeated dose escalations over 8 hours, and responses to the first approach will be compared to subsequent approaches in the analysis. Multiple whales were tagged with suction cup attached mixed-DTAG^{++}, which records high resolution movement and acoustic data and transfers the GPS position of the tagged whales directly to the source vessel. Behaviour was recorded for a minimum of 4 hours before exposure, during the 8-hour exposure and for a minimum of 4 hours after exposure. Wildlife Computers SPLASH10-F-333B Limpet tags, which transfer lower resolution data via the Argos satellites, were also deployed to record natural diurnal patterns of killer whales. In addition to data on animal behaviour recorded by the tags, we also collected data on the prey field in the area using echosounder and collected fish samples. Sound speed profiles were collected to understand how the sonar signals propagate in the area.

During the 3S-2024 trial, 20 mixed-DTAG^{++} and 3 satellite Splash tags were deployed to killer whales, and 8 mixed-DTAG^{++} were deployed to humpback whales. Of the 28 mixed-DTAG^{++} deployments, 14 were baseline-only records with durations varying from 5 minutes to 29 hours. Six long-duration controlled exposure experiments (3 CAS and 3 PAS) on 14 tagged killer whales (5 focal and 2 non-focal exposed to CAS and 5 focal and 2 non-focal exposed to PAS) were conducted. Despite some effort, we were not able to conduct an exposure experiment with humpback whales this year. The Splash tags collected data over periods from 4 to more than 20 days. The data collected so far show a very clear diurnal pattern, with whales generally feeding around purse seine fishing vessels at night and resting during the day. During the 3S-2024 trial all exposures were conducted during nighttime using the SOCRATES sonar source in the 1–2 kHz band at 214 dB energy source level (re 1μPa$^2 \cdot$s$\cdot$m^2). During the 3S-2023 trial, 2 CAS and 2 PAS exposures were conducted during daytime using the same source, but at 197 dB source level and in the 4–6 kHz band. We have collected a balanced dataset to address the CAS-vs-PAS question and the effect of longer duration exposures. However, we have a lot of variation in the dataset, and we need more data to generate conclusive results. We therefore recommend that a third trial is conducted in 2025 with the aim to complement the existing dataset. A video showing the activities during the 3S-2024 trial can be seen following this link.

Sammendrag

3S (Sea mammals and Sonar Safety) er et multidisiplinært og internasjonalt samarbeid for å studere effekten av militære sonarer på hval. Et av målene med fase 4 av 3S-prosjektet (3S4) er å undersøke om eksponering for kontinuerlige aktive sonarsignaler (CAS) fører til andre eller mer alvorlige reaksjoner enn eksponering til konvensjonelle pulsede aktive sonarsignaler (PAS). Et annet mål er å undersøke empirisk om reaksjoner til kortvarige eksponeringer kan brukes til å predikere reaksjoner til eksponeringer som har en mer realistisk operativ varighet. 3S-2024-toktet fant sted utenfor kysten av Nord-Norge oktober–november 2024 og skulle innhente data som kan gi svar på disse spørsmålene. I denne rapporten oppsummerer og dokumenterer vi datainnsamlingen.

Det eksperimentelle designet baserte seg på langvarige CAS- og PAS-eksponeringer på spekkhoggere og knølhval ved hjelp av GPS-sporing i sanntid av flere merkede hvaler samtidig. Sonarfartøyet manøvrerte på en måte som gjorde at vi oppnådde gjentatte doseeskaleringer over 8 timer, og hvalens reaksjon til den første eksponeringen vil bli sammenlignet med den andre eksponeringen i fremtidige analyser. Flere hvaler ble merket med mixed-DTAG^{++}, som registrerer høyoppløselig bevegelsesdata og akustiske data og sender dyrenes GPS-posisjon direkte til sonarfartøyet. Atferden ble registrert over en periode på minst 4 timer før sonareksponering, under den 8 timer lange eksponeringen og i en periode på minst 4 timer etter eksponeringen. I tillegg ble det brukt Wildlife Computers SPLASH10-F-333B Limpet-merker som sender data med lavere oppløsning via satellitten Argos for å studere dyrenes naturlige døgnrytme. I tillegg til atferdsdata ble det også samlet inn ekkoloddregistreringer av sildestimer og fiskeprøver av hvalenes byttedyr. Lydhastighetsprofiler ble samlet inn for å kartlegge lydforplantingsforholdene i området.

Under 3S-2024-toktet ble 20 spekkhoggere merket med mixed-DTAG^{++} og 3 med SPLASH-merker. Åtte knølhvaler ble merket med mixed-DTAG^{++}. Av de 28 mixed-DTAG^{++} som ble satt ut, samlet 14 kun inn grunndata om normalatferd, med varighet fra 5 minutter til 29 timer. Seks sonareksponeringer med 8 timers varighet (3 CAS og 3 PAS) ble gjennomført på til sammen 14 spekkhoggere. Til tross for gjentatte forsøk, ble ingen sonareksponering av knølhval gjennomført. Splash-merkene samlet inn data fra spekkhoggere over en periode fra 4 til over 20 dager.

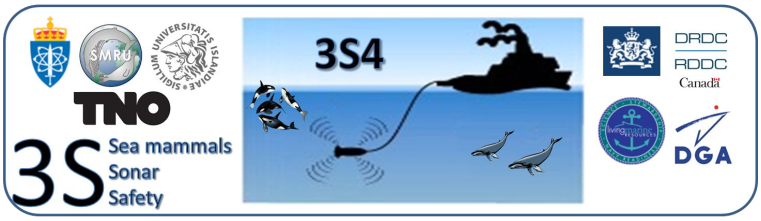
Ut fra data som er samlet inn så langt, ser vi en klar døgnrytme hvor dyrene spiser rundt sildesnurpere om natten og hviler om dagen. Under 3S-2024-toktet ble samtlige sonareksponeringer gjennomført om natten ved bruk av SOCRATES-sonarkilden i 1–2 kHz-båndet og med energikildenivå på 214 dB (re 1μPa^2·s·m^2). Under 3S-2023-toktet ble det gjennomført to CAS og to PAS-eksponeringer om dagen ved bruk av samme kilde, men i 4–6 kHz-båndet og med lavere kildenivå (197 dB). Vi har altså samlet sett et omfattende datasett som vil kunne brukes til å besvare spørsmålene om reaksjoner på CAS-vs-PAS og langvarige eksponeringer. Vi ser derimot store variasjoner i dataene og trenger mer data for å trekke sikre konklusjoner. Vi anbefaler derfor et tredje tokt i 2025 for å komplementere datasettet.

Du kan se en video som viser aktivitetene under 3S-2024-toktet, ved å følge denne linken.

Contents

Preface

3S (Sea mammals and Sonar Safety) is a multidisciplinary and international collaboration studying how naval sonar affects cetaceans. The objective is to gain information necessary to effectively manage the risk to cetaceans without unnecessarily restricting naval sonar activities. Phase 4 of the project (3S4) started in 2023 with FFI, TNO, DRDC, Sea Mammal Research Unit and University of Iceland as the main science partners. The project is funded by the US Navy Living Marine Resources research program (LMR), Defence Research and Development Canada (DRDC), The Dutch Materiel and IT Command (COMMIT) and the French Government Defence procurement and technology agency (DGA).



This report summarizes the achievements of the 3S-2024 sea trial. The purpose of the report is to document the data collected. The target readers are our sponsors and the science team involved in data analysis. This report does not contain higher level analyses or interpretations of the data. Analysis of the data collected is still on-going and will be published in peer-review literature in the coming years.

The 3S-2024 trial took place in the Norwegian Arctic in October-November 2024. The science team on board RV HU Sverdrup II was highly international with 9 countries represented (Norway, USA, the Netherlands, Germany, Italy, UK, Canada, France and Japan). (Photo: Cecile van der Stappen).

Horten, March 15. 2025
Petter Kvadsheim
CO 3S-2024

1 Introduction

Modern long-range anti-submarine warfare sonars transmit powerful sound pulses which can have a negative impact on marine mammals. Behavioural response studies (BRS) conducted by research groups on US ranges (the AUTEC, SOCAL and Atlantic BRS projects) (Tyack et al. 2011, Southall et al. 2012, Southall et al. 2019) and in Norway (the previous three phases of the Sea Mammals and Sonar Safety 3S-projects) (Miller et al. 2011, Kvadsheim et al. 2015, Kvadsheim et al. 2021) over the past 10 years have shown large variation in responsiveness between different species, as well as substantial variation within a species depending on the behavioural context of the animals and other factors (Harris et al. 2018). Behavioural responses such as avoidance of the sonar source, cessation of feeding, changes in dive behaviour and changes in vocal and social behaviour have been observed, and response thresholds quantified. Results from BRS have helped navies to comply with international guidelines for stewardship of the environment, as well as permit procedures and regulations within US, Canada and Europe.

BRS research so far have mostly been conducted using pulsed active sonars (PAS), typically transmitting at a 5-10% duty cycle. Recent technological developments imply that naval sonars 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 operationalize this technology. This raises imminent questions about the environmental impact of such sonar systems. Robust results from sperm whales indicated that the severity of reduced foraging response is better predicted by ping-by-ping cumulative signal energy than by received sound pressure level (Isojunno et al. 2020), but knowledge from other species is needed. Of particular relevance are species that vocalize in the frequency band of the sonar (e.g. killer whales and humpback whales), since CAS has higher potential than PAS for masking biologically important sounds (e.g. conspecific calls).

The biological relevance or severity of behavioural responses depends upon the duration of responses. Behavioural responses that last through the entire duration of a sonar exposure period, or longer, are considered more severe than equivalent responses that cease while the sonar is still transmitting (Miller et al. 2012). A key challenge exists to extrapolate results from the short duration (30-40min) experimental exposures used to date in BRS studies (e.g. Miller et al. 2014, Kvadsheim et al. 2015, 2021) to the typically longer duration operational activities of navies using sonar which might last 6-12 hrs (Tyack et al. 2011, Moretti et al. 2014, Stanistreet et al. 2022). If animals habituate over time (i.e. decrease their response to the sonar exposure over time), the severity of behavioural responses based on BRS would be overestimated. Conversely, if animals sensitize (i.e. increase their response to the sonar exposure over time), the severity would be underestimated.

1.1 Objectives of the 3S4 project

The objectives of the fourth phase of the 3S project (3S4) are to:

1. Investigate 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 in killer whales, humpback whales and bottlenose whales; and

2. Investigate empirically if responses from short duration experiments predict responses from longer duration exposures conducted over an operationally relevant duration.

These objectives will be achieved by doing long-duration CAS exposures to species for which the responses to short-duration PAS have already been investigated (Miller et al. 2012, 2014, 2015, Sivle et al. 2015, 2016, Wensveen et al. 2017, 2019). The first part of each exposure session will include a dose-escalation sequence designed to match previously conducted short-duration exposures. Using GPS location data of multiple tagged subjects received via ARGOS or directly from whale to ship, we aim to move the source vessel to achieve repeated dose escalations above the level at which 50% of subjects are expected to respond over 8 hrs, and compare responses to single dose escalation exposures over 40 min.

The study is a 4-year project starting January 2023, ending December 2026 with two 4 week field trials in the Norwegian sea. The 3S-2023 trial conducted in October-November 2023 was a success (Kvadsheim et al. 2024), and here we report the outcome of the 3S-2024 trial.

1.2 Navy needs

The project will address two critical navy needs: better understanding of the effect of sonar duty cycle (CAS vs PAS) and the effect of exposure duration.

Environmental impact assessment of new naval sonar technology (CAS) needs to be conducted based on knowledge gained from the impact of conventional sonar technology (PAS). In order to make this extrapolation, navies need to better understand whether or not the higher duty cycle of CAS leads to different types or severity of behavioural responses than PAS. This has so far only been studied in the field in sperm whales (Isojunno et al. 2020). Given the observed variation of responses to PAS across species, more information is needed on species potentially more sensitive to CAS. This is a critical deliverable from the 3S4 project.

Behavioural response studies of tagged free-ranging animals provide critical insight into behavioural responses of cetaceans to naval sonar. Studies on free-ranging animals are in a more realistic context than studies of captive animals. Furthermore, compared to observational studies of actual naval operations, these experiments are more controlled and the measured data easier to interpret (Harris et al. 2018). However, when BRSs are used, one must make assumptions to extrapolate to real naval scenarios. One assumption that was recently tested is the potential effect of the distance between the sonar source and the animal in driving or moderating behavioural responses (e.g. Wensveen et al. 2019; 2025). Another extrapolation that is important to assess is whether short duration BRS experiments can be used to predict severity of responses from more operationally relevant exposure durations. If animals habituate or sensitize during longer duration exposures this extrapolation is not trivial. By using cutting edge tagging technology (Mixed DTAG^{++} and satellite tags), and infrared mitigation technology (e.g. infrared thermal binoculars) we can expose several nearby animals at the same time to a realistic sonar dose over a realistic time duration, that includes nighttime exposures in the dark. This will allow us to collect and analyze data using state-of-the-art statistical approaches to better understand how BRS results can be extrapolated to assess the impact of real operational naval scenarios.

1.3 Tasks and priority of the 3S-2024 trial

1.3.1 Primary tasks

1. Tag killer whales with mixed-DTAG^{++} and expose them to dose escalating 1.3-2.0 kHz CAS or PAS twice over an extended period (8 hrs) during daytime or nighttime.
2. Tag killer whales with SPLASH tags in the core operation area (higher priority early in the trial).

1.3.2 Secondary tasks

3. Tag humpback whales with mixed-DTAG^{++} and expose them to dose escalating 1.3-2.0 kHz CAS or PAS twice over an extended period (8hrs) during daytime or nighttime.
4. Tag killer whales or humpback whales with mixed-DTAG^{++} and expose them to dose escalating 4-6 kHz CAS or PAS twice over an extended period (8hrs) during daytime or nighttime.
5. Tag killer whales and humpback whales with mixed-DTAG^{++} and expose them to short duration CAS or PAS (mostly back up if long duration exposure is not feasible).
6. Collect 24 h duration baseline data records of target species.
7. Collect echosounder data and fish samples to monitor the prey field.
8. Collect drone footage of tagged subjects for body condition characterization.
9. Collect information about the environment in the study area (CTD, XBT).
10. Collect sightings of marine mammals in the study area.
11. Perform sound source (SOC) long duration engineering test and harmonic characterization.
12. Collect photo documentation for photo id, tag documentation and public outreach purposes.
13. Record acoustic cues of fishing vessels and relate that to the different steps of the fishing activity.

1.3.3 Priority

- Primary tasks are higher priority than Secondary tasks. Secondary task should not interfere with our ability to accomplish primary tasks.
- Killer whales are higher priority than humpback whales.
- Primary focal whales are a higher priority than secondary focal whales.
- CAS exposures are higher priority than PAS exposures, but optimize contrast.
- LFAS exposures (1.3-2.0 kHz) are higher priority than MFAS exposures (4-6 kHz).
- Mixed-DTAG^{++} deployments are higher priority than SPLASH tag deployments.

2 Method

The 3S-2024 trial took place between October 10th and November 7th off the coast of Northern Norway. The main platform of the trial was the FFI RV HU Sverdrup II (HUS) with a regular crew of 7 persons. 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.

Detailed descriptions of the equipment used and data collection procedures can be found in the 3S-2024 cruise plan (Appendix C). Below follows a short description of the basic design of the experiments and the data collected during the 3S-2024 trial.

2.1 Experimental design

The basic design of the sonar controlled exposure experiments conducted during the 3S-2024 trial involved tagging of 1-2 focal subjects of the target species with the mixed-DTAG^{++}. The tag records high resolution behavioural data, and transfer the GPS-position of the tagged whales directly to the source vessel (Figure 2.1).

In addition to the focal whales, non-focal whales could also be tagged and exposed in the same area. Non-focal whales were tagged with either mixed-DTAG^{++} (Figure 2.2) or Wildlife Computers SPLASH10-F-333B Limpet tags. During the exposures we either used CAS signals or PAS signals during 8 hr long exposures. During this period focal animals were approached twice so that sonar received levels increases above their expected 50% response threshold (Figure 2.1). Before the exposure, baseline behaviour was recorded for a minimum 4 hrs and after the exposure there was a post exposure period of a minimum of 4 hrs. The mixed-DTAG^{++} was set to release after 18-24 hrs.

During the analysis we will determine response onset and severity during CAS exposures and compare to PAS exposures. We will also compare responses to the first approach to responses to the second approach within the same experiment to explore possible sensitization or habituation to sonar over time.

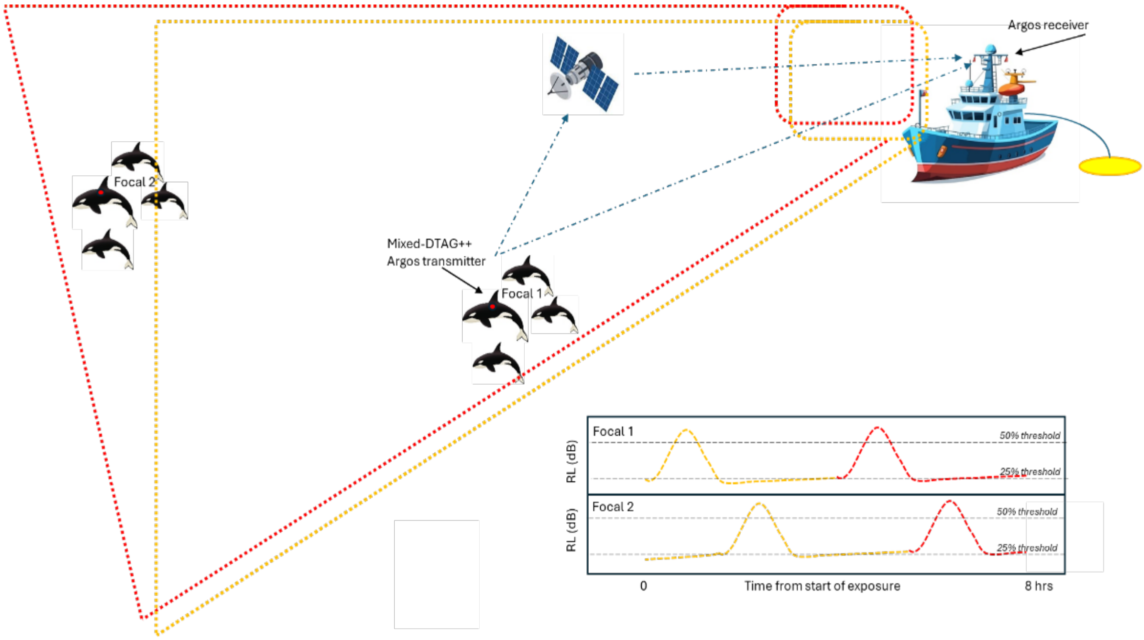


Figure 2.1 The objectives of the trial were achieved by doing long-duration CAS and PAS exposures using real-time GPS tracking of multiple subjects tagged with Mixed-DTAG^{++}. The tag sends near real time GPS position directly to the source vessel. As a back-up, GPS data are also transferred via Argos, but with significant delay. Each exposure includes 8 hr of continuous sonar exposure with two approaches to each focal whale. The focal whales experience increasing received levels during the approaches, but lower levels between the approaches. In the analysis, responses to the first approach will be compared against responses to the second approach.

During sonar exposure experiments the SOCRATES source was towed by HU Sverdrup II. During CAS 19s duration pulses (1.3-2.0 kHz hyperbolic up-sweeps) were transmitted every 20s (95% duty cycle), and during PAS exposures 1s duration pulses (1.3-2.0 kHz hyperbolic up-sweeps) were transmitted every 20s (5% duty cycle). During CAS maximum source level (SL) was 201 dB re 1 $\mu Pa^2 \cdot m^2$, and during PAS maximum SL was of 214 dB, with single-pulse energy source level (ESL_{20s}) of 214 dB re 1 $\mu Pa^2 \cdot s \cdot m^2$ for both CAS and PAS. Transmission started with a 60 dB ramp up from ESL_{20s} 154 dB to maximum level 214 dB (re 1$\mu Pa^2 \cdot s \cdot m^2$) in linear steps within 5 min. A CAS ramp up was used prior to CAS exposures and a PAS ramp up was used during PAS exposures.

Figure 2.2 During 3S-2024 the mixed-DTAG^{++} was deployed using the ARTS system (Kleivane et al. 2022) (left) or a 5,4 m handheld carbon fiber pole (right). The tags were attached to the skin of the whale by suction cups. The mixed-DTAG^{++} contains a DTAG3 core unit logging audio and movement of the ***tagged whale, and operates the tag-release system via tygon tubes attached*** *to each suction cup. It also contains the Little Leonardo video-data sensor that records wide-angle video as well as depth and 3-axis accelerometer data. The LOTEK GPS-ARGOS unit records GPS signals, which are logged and then transmitted to the ARGOS satellite system. A LOTEK V7G 149A VHF transmitter is used to assist tagged whale tracking and for tag recovery. Sufficient flotation is included to enable good positive buoyancy of the device. (Photos Ellen Hayward).*

2.2 CEE-tool

In order to conduct the controlled exposure experiments (CEE) as intended in the experimental design, we have developed a CEE tool which graphically displays:

- Bathymetry (depth-contours) and coastlines.
- Own ship track
- AIS tracks of other vessels in the area
- Interactive Range-Bearing tool on the map
- Manual input of positions (markers)
- Tracks of any tagged whales composed of the following sources
    - Position information from the ARGOS satellites (both ARGOS cross bearing and GPS quality positions with error ellipse).
    - Position information via the Line-Of-Sight Goniometer.
    - Position information via manual user input (for example Visual detections)

The tool consists of two screens, one screen shows a geographic overview of the above mentioned features and includes the user interface tools to edit some of these data (Figure 2.3). The second screen is a CPA-calculator which helps in setting up the approaches to achieve the intended exposure levels (Figure 2.3).

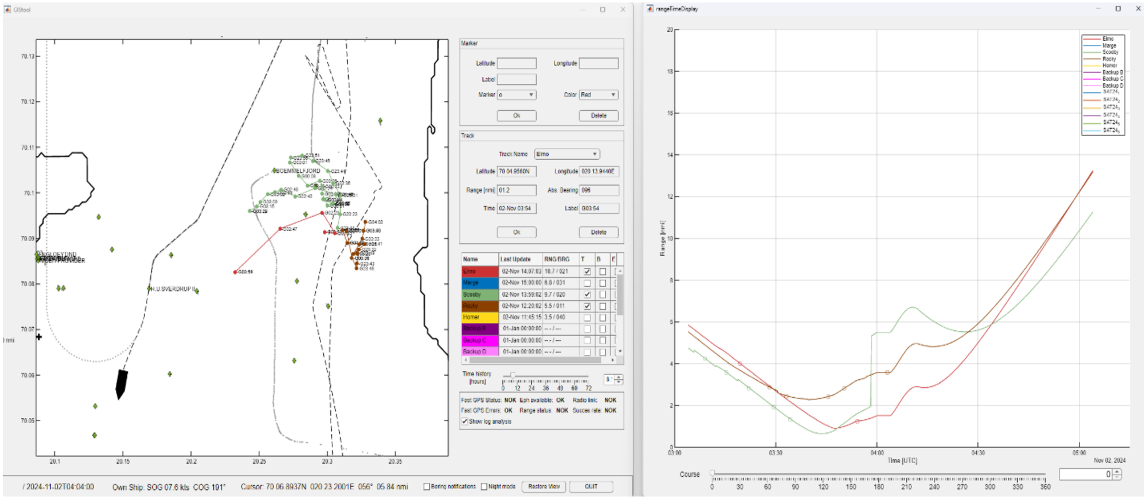


Figure 2.3 Screenshot of the CEE-tool during the CEE VI. Left panel: Tracks of three tagged whales (in orange, brown and green), track of HUS (in black) and tracks of other ships (in gray) (AIS). Right panel: The Range-Time display depicts the range to a focal whale track over the previous hour and a predicted range for the next hour based on the source vessel sailing with speed of 8 kts and a user defined course (240°).

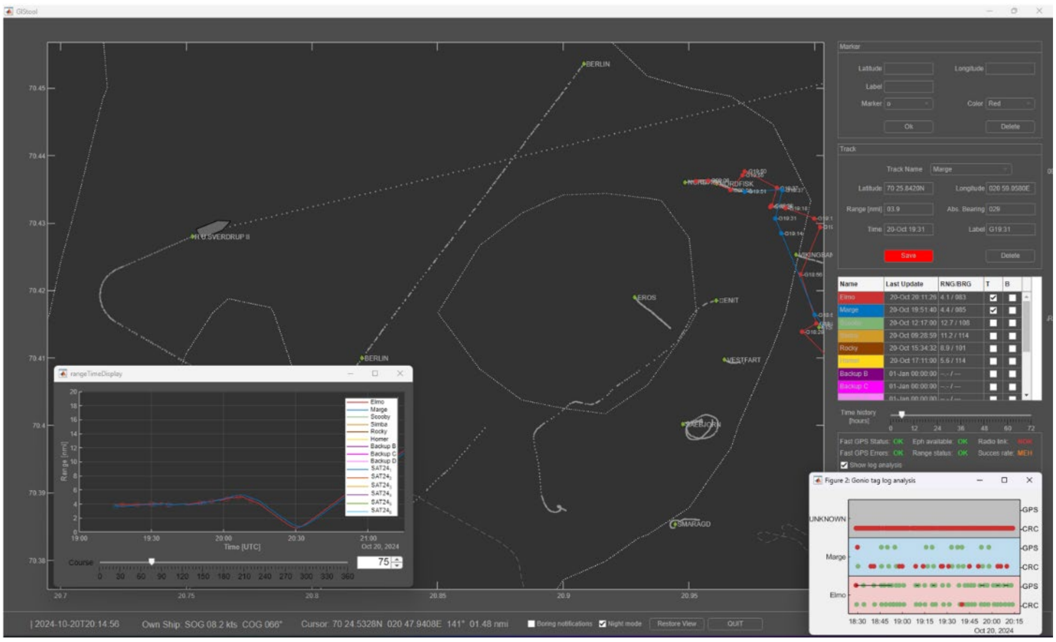


Figure 2.4 Screenshot from the CEE tool in night mode during CEE III of the 3S-2024 trial. Two tagged whale tracks are shown in red and blue. Track of H.U. Sverdrup II is shown as a solid grey line and tracks of other ships are shown as dotted grey lines based on AIS data. The status monitor (right bottom window) shows a green dot for a complete or red for an incomplete GPS signal and good or bad data check (CRC) respectively.

The CEE tool is fully operational, but during 3S-2024 several updates were made to the CEE-tool. One of these updates was the option to use the tool in night mode on the bridge (Figure 2.4). Since most of the exposures were performed during nighttime, and the experiments were set up on the bridge, this was an essential feature. Another addition to the CEE-tool is the status monitor, which gives a status indication of the data streams and the signal range of the GPS receiver. The status monitor was very useful during the trial as it gave an indication for distance of the tag and quality of the GPS connection from each tagged whale (Figure 2.4).

2.3 Data collection

The controlled exposure experiments were the primary task of the 3S-2024 trial. The primary data collected was thus the behavioural data collected by the mixed-DTAG^{++} and SPLASH10-F-333B Splash Limpet tags. The mixed-DTAG^{++} records high resolution movement and dive data, GPS positions at the surface and the camera records images of other animals and prey around the focal whales. The acoustic sensor of the tag records vocal behaviour of the focal animal (and other animals nearby), the received level of sonar we expose them to and other sources of noise (ship noise, echosounders, fishery sonars). The Splash tag transfer lower resolution dive data and GPS positions of the whales via Argos or directly to the Goniometer antenna onboard when we are close to the whales.

In addition to data on animal behavioural recorded by the tag, we also collected data on the prey field around the focal whales and in the general area. This was done using echosounder on the source vessel and by collecting fish samples. AIS data of fishing vessels were also collected to analyze potential interactions of the whales with the fishing fleet. Finally, data on the acoustic environment (sound speed profiles) were collected using XBTs and a CTD to understand how the sonar signals propagated in the area.

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 23/110085), 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, risk to third parties and risks to humans involved in the operation (Appendix C). This document also specifies suitable mitigation measures, endpoints and responsibilities.

Permits and ethics approvals required monitoring of a 500m mitigation action zone by marine mammal observers on the source vessel during sonar transmissions. If any mammals appear within 100 m from the source, the source was immediately shut down. During transmission in the dark the observers were equipped with Pulsar Merger thermal binoculars. The performance of the thermal binoculars was tested in the field before the trial (Kleivane 2023).

3 Results

3.1 Overview of activities and achievements

During the 3S-2024 trial, 20 mixed-DTAG++ and 3 satellite Splash tags were deployed to killer whales, and 8 mixed-DTAG++ were deployed to humpback whales. Of the 28 mixed-DTAG++ deployments, 14 recorded only baseline behaviour, with durations varying from 5 minutes to 29 hours. Six long-duration controlled exposure experiments (3 CAS and 3 PAS) on multiple (N=14) tagged killer whales (5 focal and 2 non-focal exposed to CAS and 5 focal and 2 non-focal exposed to PAS) were conducted. The Splash tags collected data over periods from 4 to >20 days. Despite some effort to try to achieve it, no exposure experiment was conducted to humpback whales.

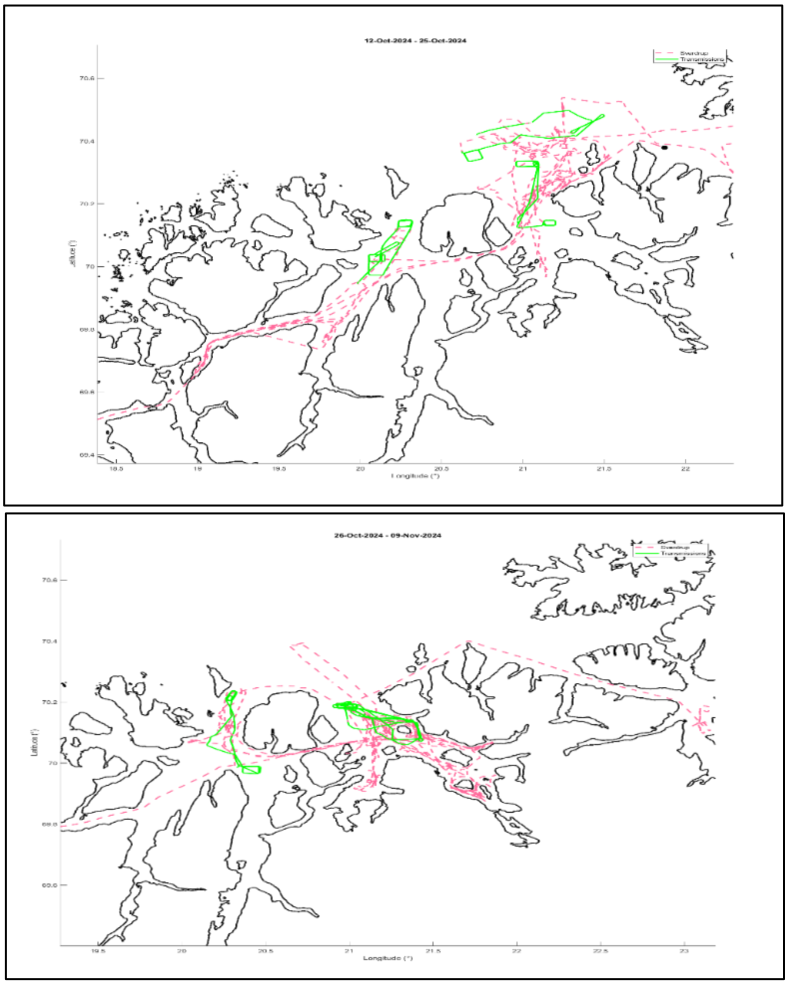


Figure 3.1 Overview of the sailed tracks of RV HU Sverdrup II during the first two weeks (upper panel) and second two weeks (lower panel) of the 3S-2024 trial. A green track indicates that the Socrates sonar source was transmitting, thus the location of the CEEs can be seen.

In the first few days of the trial we focused on installation, testing and training activities (Figure 3.1, Table 3.1). When we arrived in the operation area, the herring fishery had just started and we immediately found whales around the fishing vessels, started tagging and conducted the first

CEE on the first day of being fully operational. Use of the ARTS system allowed us to tag also during daylight hours, when there was no fishery activity, and to search for whales in areas where there was no fishing happening. However, most of the tag deployments were made in the dark period and around fishing vessels also this year (Figure 3.2), similar to the 3S-2023 trial (Kvadsheim et al 2024). The first two weeks were very busy with data collection, and halfway through the trial we had already done 3 CEEs. We then had to make a port call to Tromsø for a scheduled crew change.

Table 3.1 3S-2024 Overview of weather and overall activity during the trial. Wind force is given on the Beaufort scale. The color code for operational status is; fully operational (green), partly operational/reduced effort (yellow) and not operational (red). KW is killer whales and HW is humpback whales.

Date	Area	Weather	Wind	Sea State	Activity	Ops. status by watches
Oct 10	In port Harstad	Clouded	S 2	0	Joint briefing, embarkment, mobilization	
Oct 11	In port Harstad	Clouded	SW 2	0	Testing, training, safety briefs	
Oct 12	Vågsfjorden – transit N	Clouded	SE 4-11	2	Endurance test of Socrates successful. Overnight transit	
Oct 13	Grøtsundet - Ulsfjorden	Partly clouded	SW 3	1-2	ARTS training, VHF and Goniometer range and bearing tests of tags.	
Oct 14	Tromsø – Grøtsundet	Clouded	S 4	2	In Tromsø to fix AIS on MOBHUS. Training with DanInject during transit out.	
Oct 15	Ulsfjorden - Fugløyfjorden	Clouded	S 3-5	3	Visual survey for target species in in-shore areas. Tagged a KW and conducted CEE I	
Oct 16	Fugløyfjorden - Kvænangen	Clouded	S /SW 2-5	1-4	Post exposure and recovering tag. Survey through Kvænangen. Tagged a KW, preparing for CEE II.	
Oct 17	Kvænangen	Clouded	S 3-5	2-3	Tag slipped on the animal CEE cancelled. Started tagging again. Two splash tags and three more Mixed-DTAGs deployed	
Oct 18	Kvænangen	Clouded	S/SW 5-10	2-5	Conducted nighttime CEE II with 2 focal KW and two non-focals. Post exposure and recover tags	
Oct 19	Sørøysundet-Lopphavet	Clouded	W/SW 1-7	0-3	Searching into deeper water in Sørøysundet. No fishing going on, and no killer whales, but lots of herring and baleen whales. Tagging around fish vessels at Loppphavet. No success	
Oct 20	Lopphavet	Sun	S/SW 4-5	3-4	Wild tagging in day time. Deployed 1 splash tag and two Mixed-DTAGs. Conducted CEE III	
Oct 21	Lopphavet	Sun	NE/SE 2-10	2-4	Post exposure and recover tags. Seek shelter from the storm. Tagging near fishing vessels without success.	
Oct 22	Kvænangen-Lopphavet	Rain	SW/SE 3-7	2-5	Wild tagging in the fjord, and later around fishing vessels without success.	
Oct 23	Ulsfjorden-Tromsø	Sun	SW 1-4	1-2	Harmonics and source level test of the Socrates source en route to Tromsø. Mid sail de-brief	
Oct 24	Tromsø – transit N	Clouded	S/SW 2-3	2	Crew change. Transit back to operation area	
Oct 25	Sørøysundet – northern in-shore areas	Clouded rain	NW/SW 3-8	1-2	Rough weather off-shore. Searching for whales in-shore based on position updates from Splash tags.	
Oct 26	Altafjorden–Sørøysundet – Kvænangen-Reisafjord	Clouded	W/NW 3-5	1-3	Searching for whales in in-shore areas. Tagged 2 KW around fishing fleet. Conducted CEE IV	
Oct 27	Kvænangen	Clouded	SE 5-7	2	Post exposure and tag recovery from CEE IV. A Mixed-DTAG deployed to a KW for baseline data collection. Recording of fish vessel sounds.	
Oct 28	Kvænangsfjord – Fugløyfjord	Rain showers	NW 2-12		Tagging a HW with Mixed-DTAG in very rough weather for baseline data collection.	
Oct 29	Fugløyfjord – Kvænangen	Snow showers	NW/SW 3-12	3	Recovering baseline tags. Three new tags deployed on KWs around fishing vessels for baseline	
Oct 30	Kvænangen – Reisafjord	Snow	N/NW 5-10	2-4	Tracking and recovering baseline tags. Tagging for CEE	
Oct 31	Reisafjorden – Kvænangen	Snow	N/NW 2-8	2-3	Witnessed a by-catch incident. 3 tags deployed to KW. Conducted CEE V	
Nov 1	Kvænangen – Fugløyfjorden	Partly clouded	N 3-4	2-3	Post exposure and recovering tags from CEE V. Tagging 3 KW , conducting CEE VI in different area.	
Nov 2	Fugløyfjorden – Kvænangsfjorden	Snow	NW 3-9	2-3	Post exposure and recovering tags from CEE VI. Baseline tagging of HW. Two tags deployed	
Nov 3	Kvænangsfjorden	Snow	NW/W 3-9	2-3	Tracking baseline tags on HWs. Recovering tags. Deploying 2 new tags to HWs for baseline. CEE not possible in the area due to bathymetry restrictions.	
Nov 4	Kvænangen	Snow	NE / NW 3-5	2-3	Recovering baseline tag. Deployed 3 new tags for CEE, but tags comes off or no tracking	
Nov 5	Kvænangsfjord - Tromsø	Rain	N/ NE 2-9	1-3	Recovering remaining tags. Hot wash de brief. Transit to Tromsø. Celebration!	
Nov 6	Tromsø	Rain	S 2	1	De-mobilization	
Nov 7	Tromsø				Off-loading, dissembarkment, end of trial	

Table 3.2 Overview of data recoding events during 3S-2024. Controlled Exposure Experiments (CEE) were conducted using Mixed-DTAG^{++} and the SOCRATES source on RV HU Sverdrup II transmitting low frequency (LFAS 1.3-2.0 kHz) signals as either CAS (Continuous Active Sonar runs with 95% duty cycle) or PAS (Pulsed Active Sonar runs with 5% duty cycle). Splash tags were deployed to record overall movements of KW in the area and their baseline diel cycle. F1 is the primary focal animal, F2 is the secondary focal, F0 are non-focal animals.

Tag type	Deployment ID	Species	Date/Area	Experiment / data collected
Mixed-DTAG^{++}	Oo24_289a	Killer whale	October 15th Fugløyfjord	Baseline + CEE I LFAS CAS
Mixed-DTAG^{++}	Oo24_290a	Killer whale	October 16th Kvænangen	Baseline + F0 for CEE II LFAS CAS
Mixed-DTAG^{++}	Oo24_291a	Killer whale	October 17th Kvænangen	Baseline + F0 for CEE II LFAS CAS
Mixed-DTAG^{++}	Oo24_291b	Killer whale	October 17th Kvænangen	Baseline + F2 for CEE II LFAS CAS
Mixed-DTAG^{++}	Oo24_291c	Killer whale	October 17th Kvænangen	Baseline + F1 for CEE II LFAS CAS
Splash tag	Oo24_291SAT#1	Killer whale	October 17th Kvænangen	Baseline diel cycle
Splash tag	Oo24_291SAT#2	Killer whale	October 17th Kvænangen	Baseline diel cycle
Splash tag	Oo24_294SAT#3	Killer whale	October 20th Lopphavet	Baseline diel cycle
Mixed-DTAG^{++}	Oo24_294a	Killer whale	October 20th Lopphavet	Baseline + F1 for CEE III LFAS PAS
Mixed-DTAG^{++}	Oo24_294b	Killer whale	October 20th Lopphavet	Baseline + F2 for CEE III LFAS PAS
Mixed-DTAG^{++}	Oo24_300a	Killer whale	October 26th Reisafjorden	Baseline + F1 for CEE IV LFAS CAS
Mixed-DTAG^{++}	Oo24_300b	Killer whale	October 26th Reisafjorden	Baseline + F2 for CEE IV LFAS CAS
Mixed-DTAG^{++}	Oo24_301a	Killer whale	October 27th Kvænangen	Baseline record, no CEE*1
Mixed-DTAG^{++}	Oo24_301b	Killer whale	October 27th Kvænangen	Baseline record, no CEE*1
Mixed-DTAG^{++}	Mn24_302a	Humpback whale	October 28th Kvænangen	Planned baseline record
Mixed-DTAG^{++}	Oo24_303a	Killer whale	October 29th Kvænangen	Baseline record*2
Mixed-DTAG^{++}	Oo24_303b	Killer whale	October 29th Kvænangen	Baseline record*2
Mixed-DTAG^{++}	Oo24_304a	Killer whale	October 30th Kvænangen	Baseline behaviour*3
Mixed-DTAG^{++}	Oo24_305a	Killer whale	October 31st Kvænangen	Baseline + F1 for CEE V LFAS PAS
Mixed-DTAG^{++}	Oo24_305b	Killer whale	October 31st Kvænangen	Baseline + F0 for CEE V LFAS PAS
Mixed-DTAG^{++}	Oo24_305c	Killer whale	October 31st Kvænangen	Baseline record, no CEE*3
Mixed-DTAG^{++}	Oo24_306a	Killer whale	November 1st Kvænangen	Baseline + F0 for CEE VI LFAS PAS
Mixed-DTAG^{++}	Oo24_306b	Killer whale	November 1st Kvænangen	Baseline + F1 for CEE VI LFAS PAS
Mixed-DTAG^{++}	Oo24_306c	Killer whale	November 1st Kvænangen	Baseline + F2 for CEE VI LFAS PAS
Mixed-DTAG^{++}	Mn24_307a	Humpback whale	November 2nd Kvænangsfjord	Planned baseline record
Mixed-DTAG^{++}	Mn24_307b	Humpback whale	November 2nd Kvænangsfjord	Planned baseline record
Mixed-DTAG^{++}	Mn24_308a	Humpback whale	November 3rd Kvænangsfjord	Baseline record, no CEE*4
Mixed-DTAG^{++}	Mn24_308b	Humpback whale	November 3rd Kvænangsfjord	Baseline record, no CEE*3
Mixed-DTAG^{++}	Mn24_309a	Humpback whale	November 4th Kvænangsfjord	Baseline record, no CEE*3
Mixed-DTAG^{++}	Mn24_309b	Humpback whale	November 4th Kvænangsfjord	Baseline record, no CEE*5
Mixed-DTAG^{++}	Mn24_309c	Humpback whale	November 4th Kvænangsfjord	Baseline record, no CEE*3

**1 No CEE possible due to the 48 hr rule in permit*
**2 Not enough time to conduct nighttime CEE*
**3 Tag comes off prematurely before CEE*
**4 CEE not possible in the area due to bathymetry restrictions*
**5 No GPS tracking therefore no CEE*

Even though the transit time to/from Tromsø is only ~8hrs, we ended up losing 2 days around the crew change because of very bad weather the last day before the port call. However, this gave us an opportunity to do a mid-sail de-brief with the science team and give ourselves a break to rest the team before the second half. The last two weeks of the trial were dominated by rough weather, but the herring and the fishing fleet moved deeper into the fjords earlier than previous years, which allowed us to continue to tag and collect data in protected waters. However, the CEEs require >200m water depth because of the towed source and space to maneuver to execute the experiments according to the protocol. We were therefore still somewhat limited in doing experiments in the second half. During the last days of the trial, we made intense effort to complete a CEE to humpback whales. A number of tags were deployed, but because of bathymetry restrictions, intermittent GPS-tracking or premature tag release, no CEE to humpbacks were conducted (Table 3.3).

Table 3.3 Hours of mixed-DTAG^{++} data collected during the 3S-2024 trial. Twenty tags were deployed to killer whales and eight tags to humpback whales. This gives a total of 448.7 hrs of tag data collected.

	Baseline only	Experimental	**Total**
	44.6	297.4	342.0
	106.7	0	106.7
Total	**151.3**	**297.4**	**448.7**

3.2 Sonar exposure experiments

A total of 6 CEEs were conducted, 3 CAS and three PAS to a total of 14 killer whales (Table 3.4). No exposure experiment was conducted to humpback whales. All CEEs were done at night (Figure 3.2) using the high powered LFAS (1.3-2.0 kHz) transducer of SOCRATES. The duration of all the exposures was 8 hrs, during which focal animals were approached twice. In the analysis of the data, we plan to compare responses between the two approaches to the same animal, and therefore it is important that the closest point of approach distances were similar. In most cases where good tracking was maintained during both approaches, the two exposures were comparable in terms of distance and maximum received level (Table 3.4).

Factors like fishing vessel traffic or bathymetry restrictions could complicate the approaches, and avoidance responses by the animals increased the minimum distance and decreased the maximum received level (Figure 3.3. and Figure 3.4). Estimation of the received levels of the exposures was sometimes complicated by whale vocalizations overlaying the sonar pings (Figure 3.5), particularly for CAS. The whale GPS tracks from the CEE tool and the dive records from the tag are given for all the CEEs in figures 3.6. - 3.11.

Table 3.4 Controlled exposure experiments (CEE) conducted during 3S-2024. F1 are primary focal animals, F2 are secondary focals, F0 are non-focal animals. PAS is Pulsed Active Sonar runs (5% duty cycle), CAS is Continuous Active Sonar runs (95% duty cycle). KW is killer whales, HW is humpback whales. Time, distance estimated in the field and received sound pressure level (RL) for the closest point of approach (CPA) is also given.

CEE #	Focal #	Species	Deployment Id	Tag id	Approach #	CPA time (UTC)	CPA estimated	RL dB Re1µPa
CEE I LFAS CAS NIGHT	1	KW	Oo24_289a	ELMO	1	15 Oct 21:53	750m	146 dB
	1	KW	Oo24_289a	ELMO	2	16 Oct ~02	Lost tracking, track reconstruction needed	
CEE II LFAS CAS NIGHT	0	KW	Oo24_290a	Marge		17-18 Oct		
	0	KW	Oo24_291a	Elmo		17-18 Oct		
	2	KW	Oo24_291b	Rocky	1	17 Oct 23:45	900m	150 dB
	1	KW	Oo24_291c	Homer	1	17 Oct 23:36	1100m	147 dB
	2	KW	Oo24_291b	Rocky	2	18 Oct 03:59	600m	150 dB
	1	KW	Oo24_291c	Homer	2	18 Oct 04:03	600m	148 dB
CEE III LFAS PAS NIGHT	1	KW	Oo24_294a	Elmo	1	20 Oct 20:41	2600m	153 dB
	2	KW	Oo24_294b	Marge	1	20 Oct 20:41	1100m	156 dB
	1	KW	Oo24_294a	Elmo	2	21 Oct 01:10	2200m	157 dB
	2	KW	Oo24_294b	Marge	2	21 Oct 01:05	1300m	154 dB
CEE IV LFAS CAS NIGHT	1	KW	Oo24_300a	Homer	1	26 Oct 23:45	1100m	152 dB
	2	KW	Oo24_300b	Marge	1	26 Oct 23:43	1000m	152 dB
	1	KW	Oo24_300a	Homer	2	27 Oct 03:55	750m	148 dB
	2	KW	Oo24_300b	Marge	2	27 Oct	Lost tracking	
CEE V LFAS PAS NIGHT	1	KW	Oo24_305a	Marge	1	31 Oct 18:38	2600m	147 dB
	1	KW	Oo24_305a	Marge	2	31 Oct 22:03	2000m	155 dB
	0	KW	Oo24_305b	Homer		31 Oct		
CEE VI LFAS PAS NIGHT	0	KW	Oo24_306a	Elmo		Nov 1-2	Close to F1&F2	
	1	KW	Oo24_306b	Rocky	1	Nov 1st 23:39	900m	140 dB
	2	KW	Oo24_306c	Scooby	1	Nov 1st 23:44	350m	156 dB
	1	KW	Oo24_306b	Rocky	2	Nov 2nd	Lost tracking	
	2	KW	Oo24_306c	Scooby	2	Nov 2nd 03:43	1100m	162 dB

Table 3.5 Effort table for deployment of the Socrates source during 3S-2024.

Date (start time)	Exp Name	Transmission	Start Time (UTC)	Stop Time (UTC)	Summary
15-10-2024	Harmonics LF	CW-Harmonics-Test	07:22	07:41	Harmonics testing including ram-pup. Trouble configuring OWID hydrophone, exp. aborted
15-10-2024 16-10-2024	CEE I	LFAS-CAS_FullPower	21:12	05:12	Exposure experiment including ram-pup
17-10-2024 18-10-2024	CEE II	LFAS-CAS_FullPower	22:55	06:55	Exposure experiment including ram-pup
20-10-2024 21-10-2024	CEE III	LFAS-PAS_FullPower	20:07	04:07	Exposure experiment including ram-pup
23-10-2024	Harmonics LF and HF	CW-Harmonics-Test 2.0	07:37	09:05	Harmonics testing including ram-pup.
26-10-2024 27-10-2024	CEE IV	LFAS-CAS_FullPower	23:00	7:00	Exposure experiment including ramp-up
31-10-2024 01-11-2024	CEE V	LFAS-PAS_FullPower	17:04	01:04	Exposure experiment including ramp-up
01-11-2024 02-11-2024	CEE VI	LFAS-PAS_FullPower	22:45	06:45	Exposure experiment including rampup

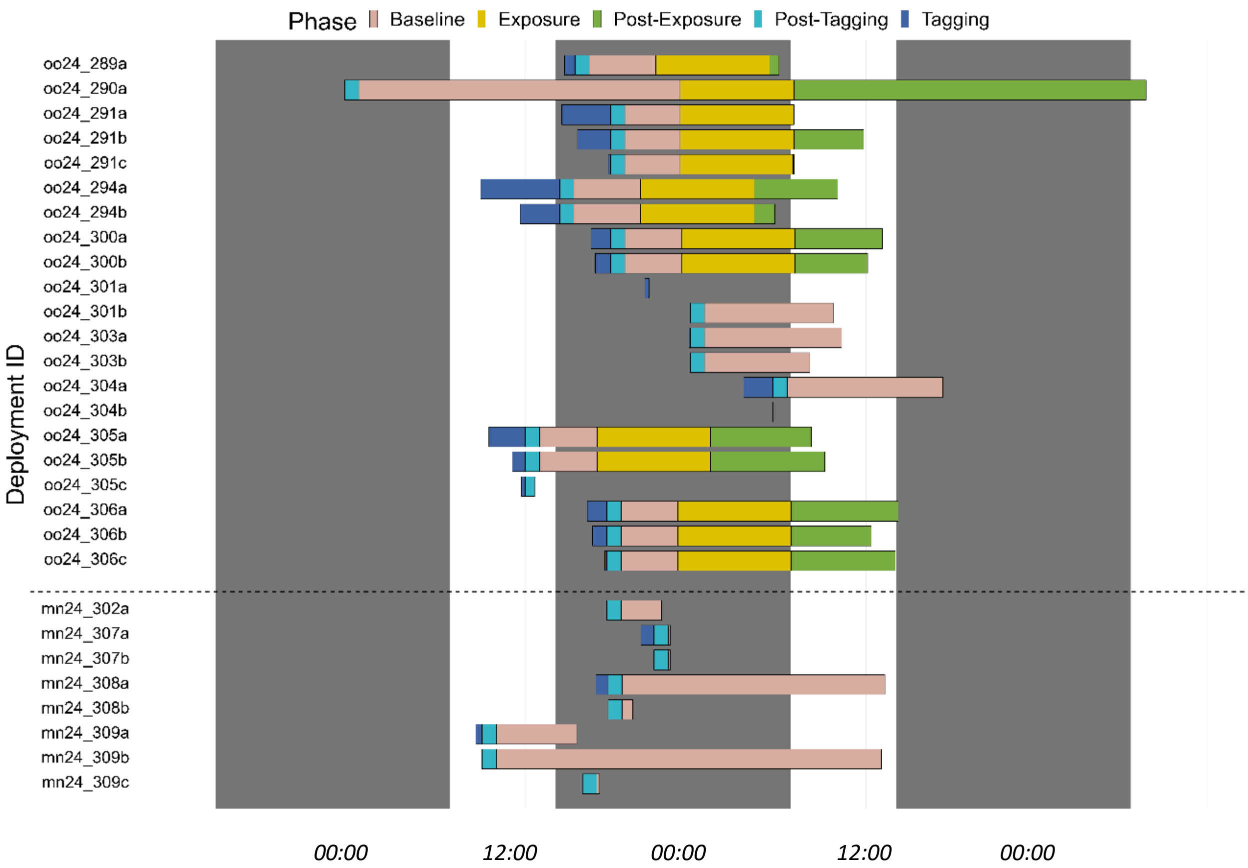


Figure 3.2 Timing of the Mixed-DTAG++ deployments and the different phases of the experiments during 3S-2024. Note that all the sonar exposures happened during nighttime (approximate dark hours are represented by the dark grey background and increased throughout the trial).

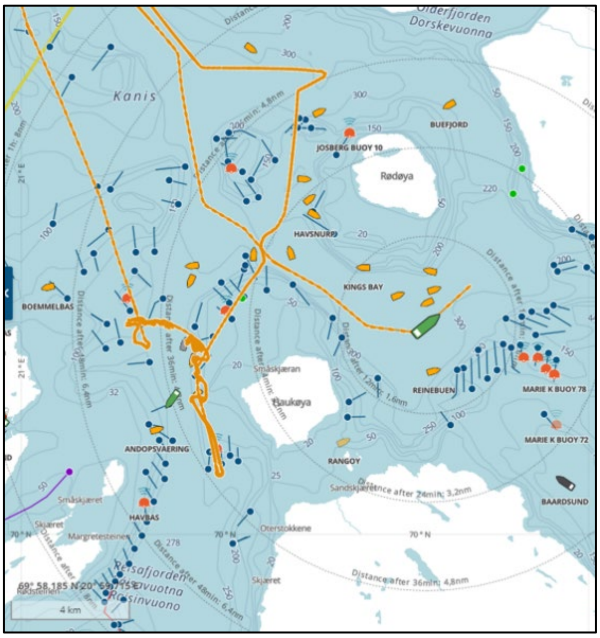


Figure 3.3 Screenshot from the [FishInfo - BarentsWatch] used to monitor fishing vessels (orange symbols) and fishing gear (blue symbols) in the area of the CEEs. HU Sverdrup is the green symbol with the orange track. The screenshot is from Kvænangen on October 27th during CEE IV. Executing the experiment as planned was sometimes complicated with restrictions on maneuverability due to bathymetry, vessel traffic and fishing gear.

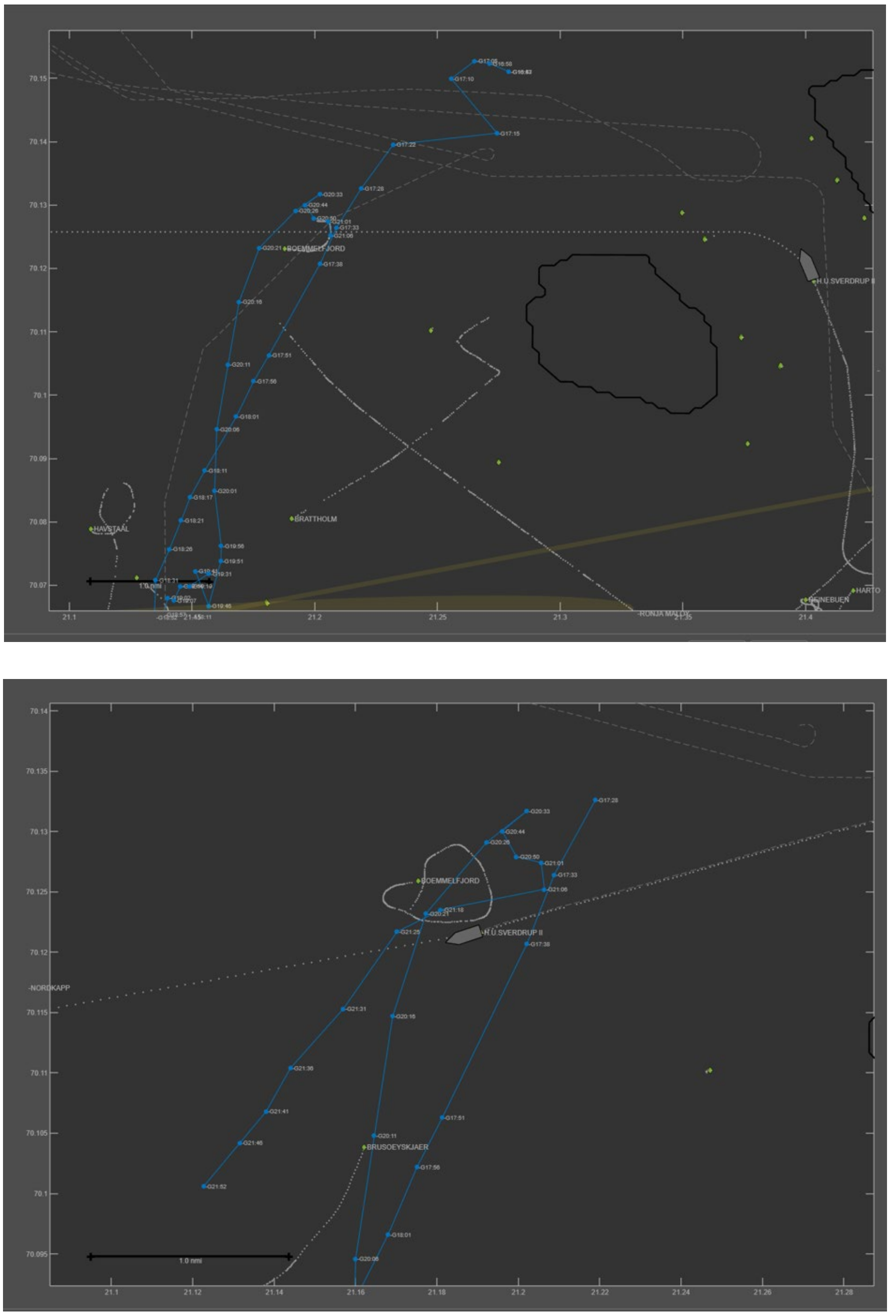


Figure 3.4 Screenshots from the CEE tool during the 2nd approach to focal 1 (Oo24_305a) of CEE V. The source vessel (HU Sverdrup) approaching from east, was forced to make a turn around an island during the initial phase of the approach (top panel). The focal animal is feeding around the fishing vessel MS Bømmelfjord, but later in the approach (lower panel) moves SW away from the fishing vessel and away from our approach trajectory. The CPA ended up being 2000m due to this apparent avoidance response.

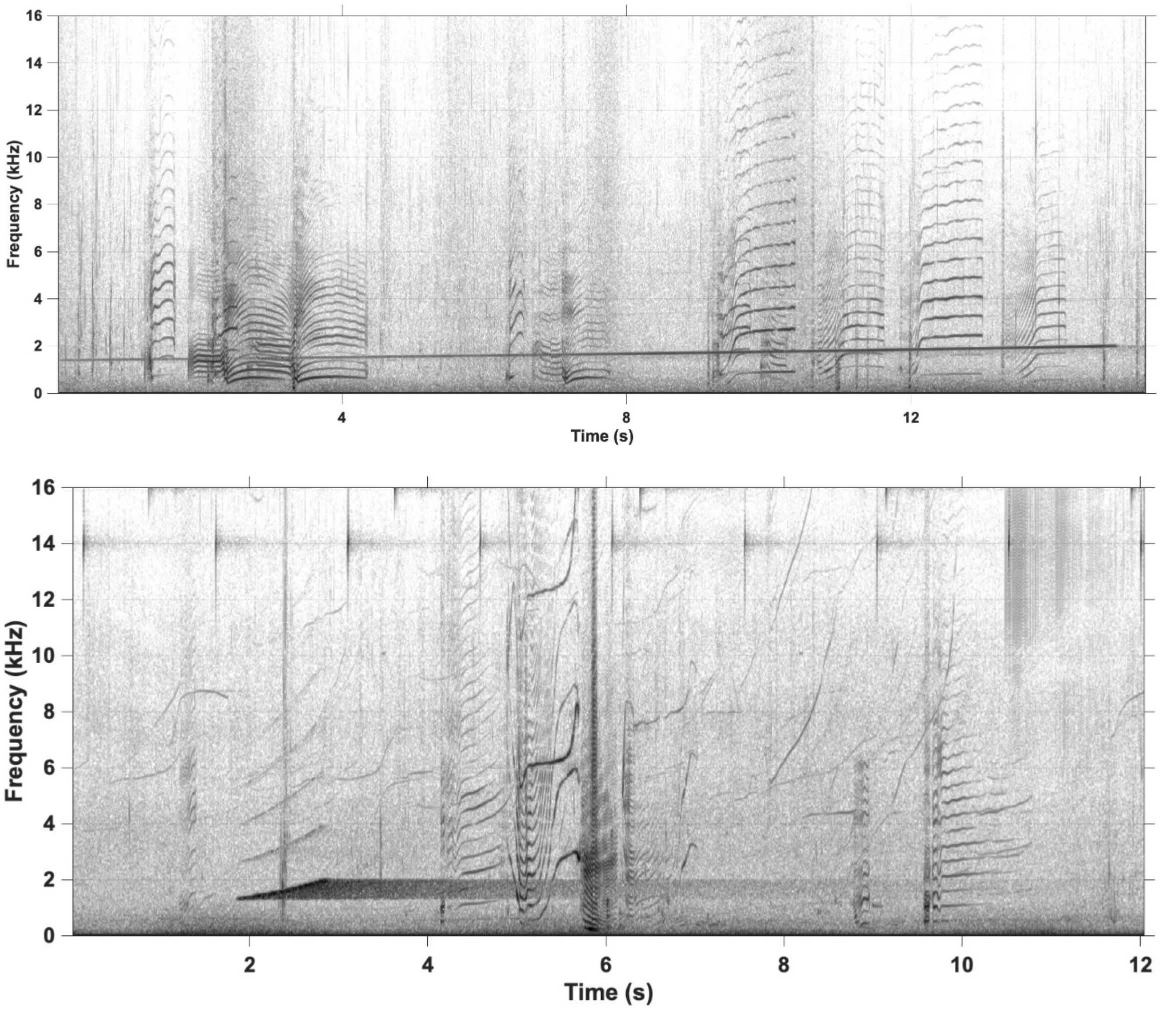


Figure 3.5 Top panel: Spectrogram of DTAG recording of CAS ping and killer whale vocalizations during CEE I (Oo24_289a). Bottom panel: Spectrogram of DTAG recording of PAS ping and killer whale vocalizations during CEE III (Oo24_294a).

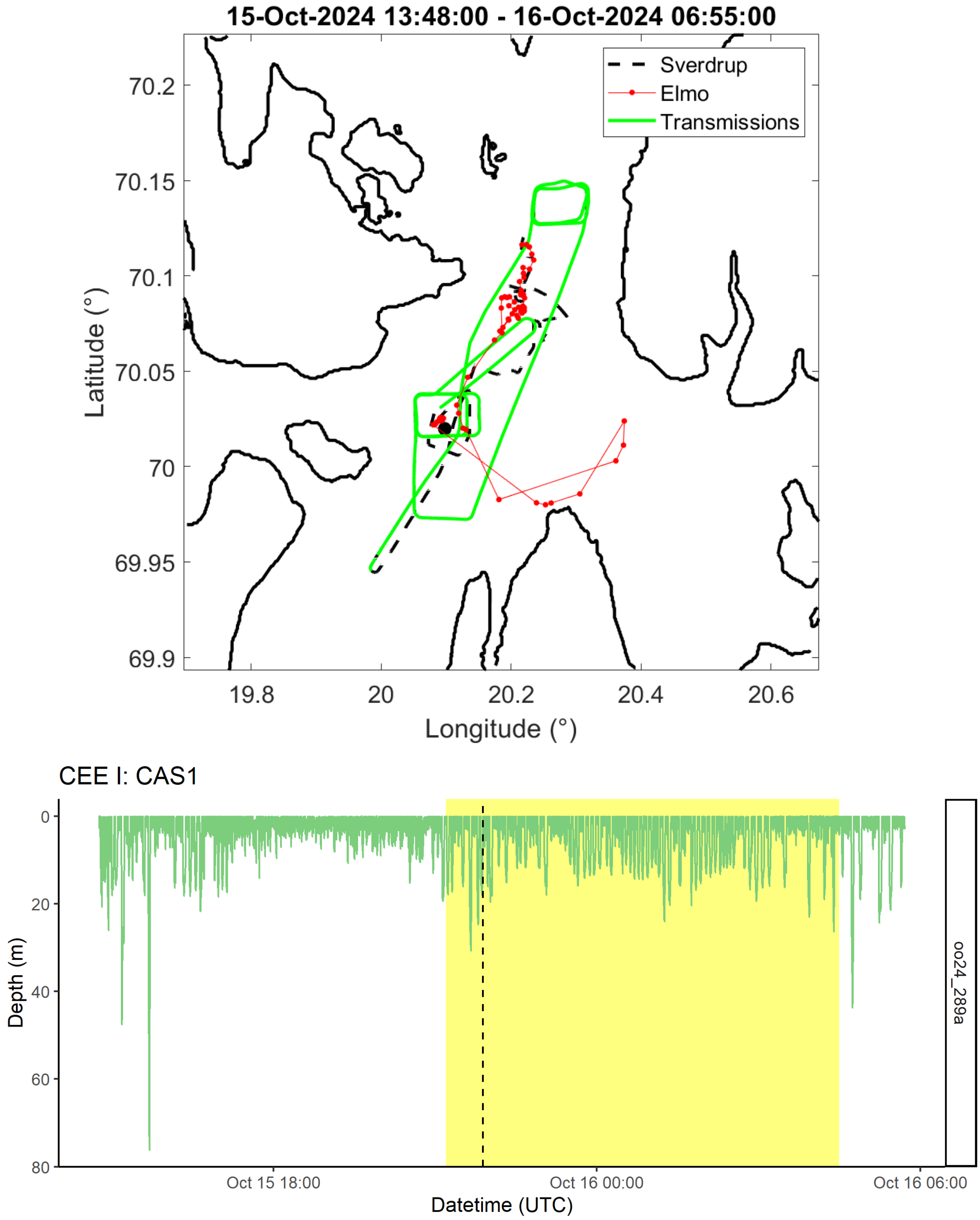


Figure 3.6 CEE I – LFAS CAS. Upper panel: Geographical tracks from the CEE-tool of the source vessel without transmissions (----) and when transmitting sonar signals (-—), focal 1 whale Oo24_289a (—). Lower panel: Time-depth plot of focal 1 whale Oo24_289a during CEE I. The region highlighted in yellow indicates the experimental period. The dashed lines indicate the time of closest approach by the ship towing the exposure source.

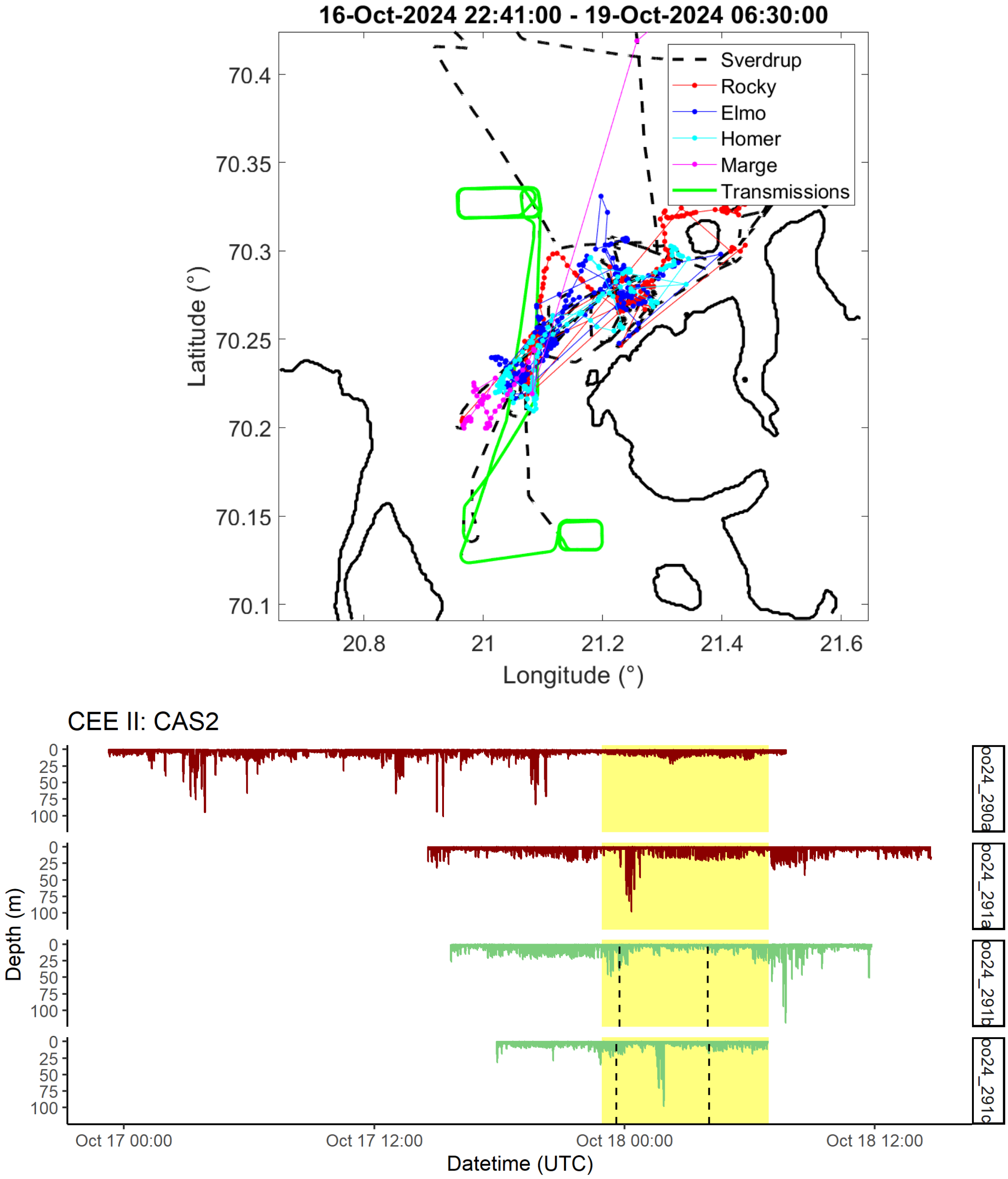


Figure 3.7 CEE II – LFAS CAS. Upper panel: Geographical tracks from the CEE-tool of the source vessel without transmissions (----) and when transmitting sonar signals (-—), focal 1 whale Oo24_291c (—), focal 2 whale Oo24_291b (—), non-focal whale Oo24_290a (—) and non-focal whale Oo24_291a (—). Lower panel: Time-depth plot of non-focal whales Oo24_290a, Oo24_291a and focal whales Oo24_291b and Oo24_291c during CEE II. The region highlighted in yellow indicates the experimental period. The dashed lines indicate the time of closest approach by the ship towing the exposure source.

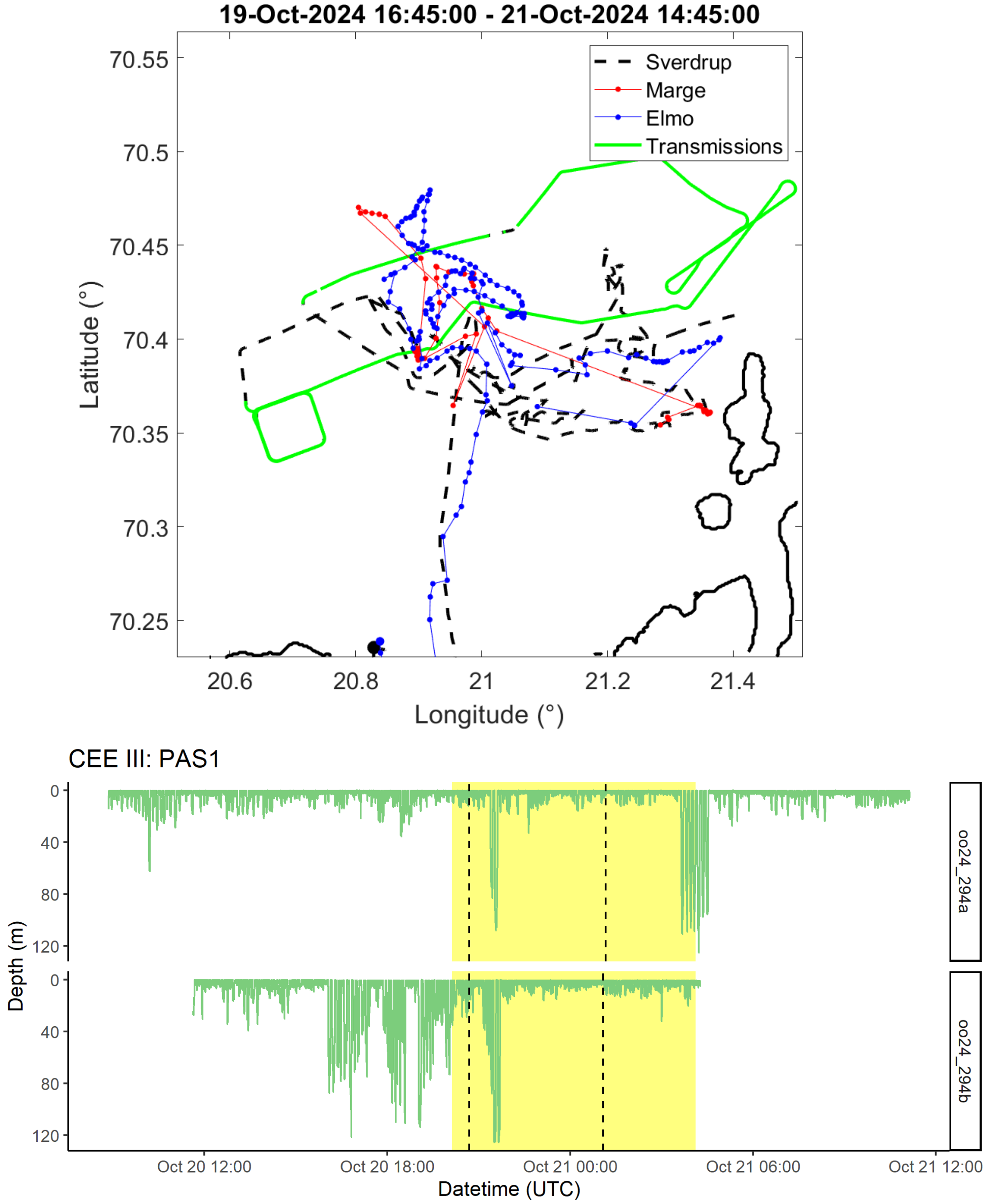


Figure 3.8 CEE III – LFAS PAS. Upper panel: Geographical tracks from the CEE-tool of the source vessel without transmissions (----) and when transmitting sonar signals (-—), focal 1 whale Oo24_294a (—) and focal 2 Oo24_294b (—). Lower panel: Time-depth plot of focal whales Oo24_294a and Oo24_294b during CEE III. The region highlighted in yellow indicates the experimental period. The dashed lines indicate the time of closest approach by the ship towing the exposure source.

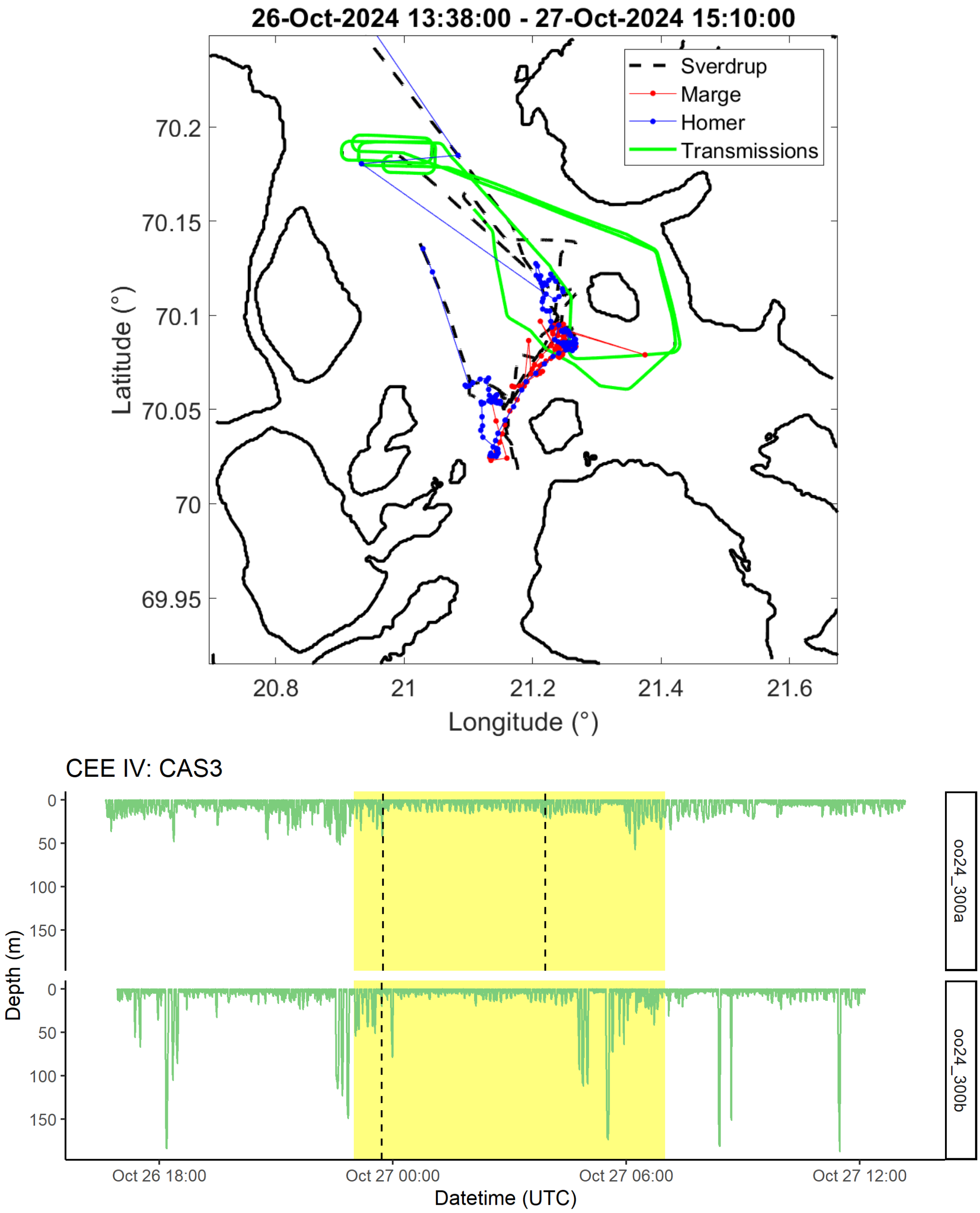


Figure 3.9 CEE IV – LFAS CAS. Upper panel: Geographical tracks from the CEE-tool of the source vessel without transmissions (----) and when transmitting sonar signals (-—), focal 1 whale Oo24_300a (—) and focal 2 Oo24_300b (—). Lower panel: Time-depth plot of focal whales Oo24_300a and Oo24_300b during CEE IV. The region highlighted in yellow indicates the experimental period. The dashed lines indicate the time of closest approach by the ship towing the exposure source.

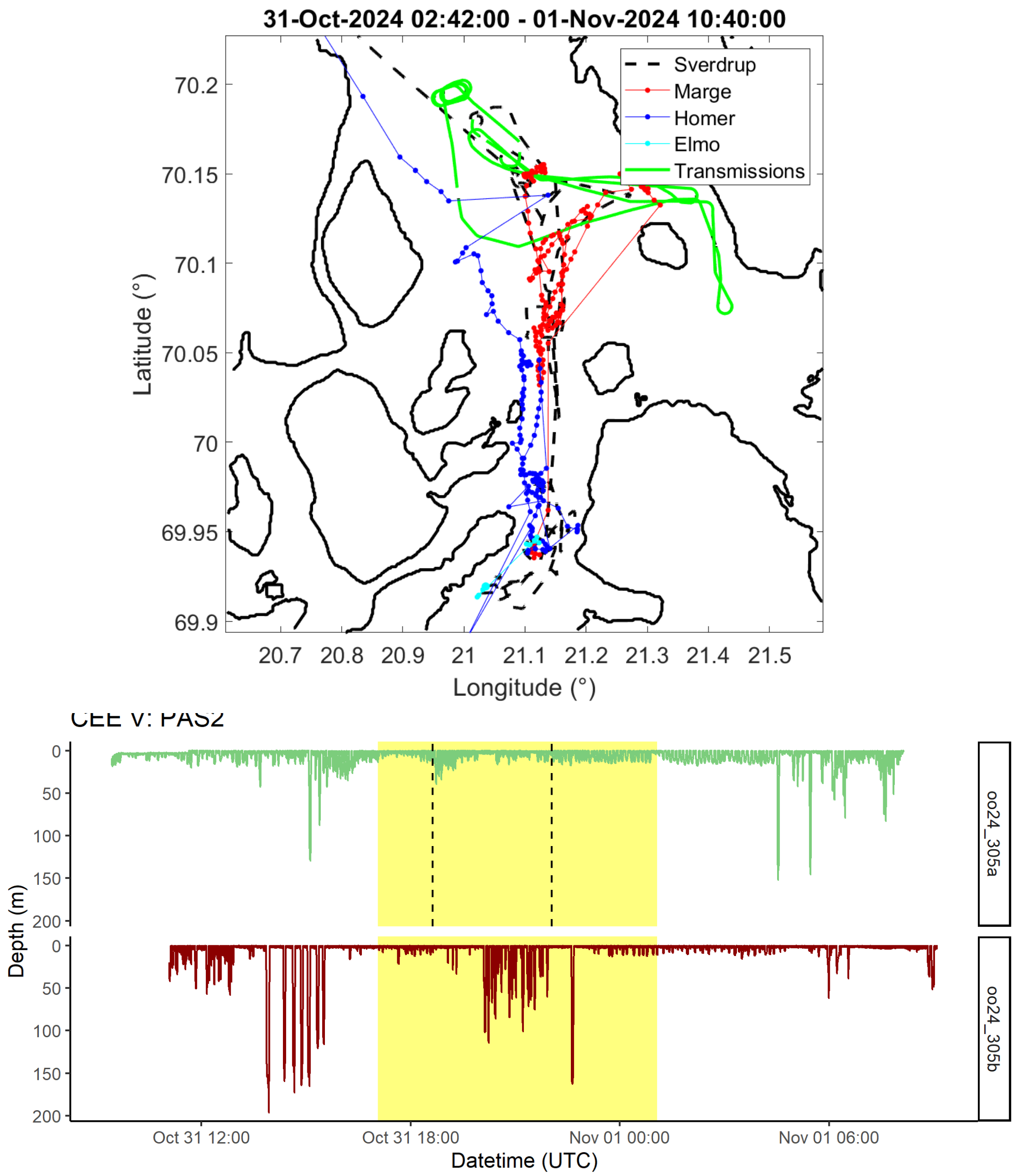


Figure 3.10 CEE V – LFAS PAS. Upper panel: Geographical tracks from the CEE-tool of the source vessel without transmissions (----) and when transmitting sonar signals (—), focal 1 whale Oo24_305a (—) and non-focal whale Oo24_305b (—) (Oo25_305c (—) is also shown, but the tag detached before the exposure started). Lower panel: Time-depth plot of focal whales Oo24_305a and non-focal Oo24_305b during CEE V. The region highlighted in yellow indicates the experimental period. Dashed lines indicate the time of closest approach by the ship towing the exposure source.

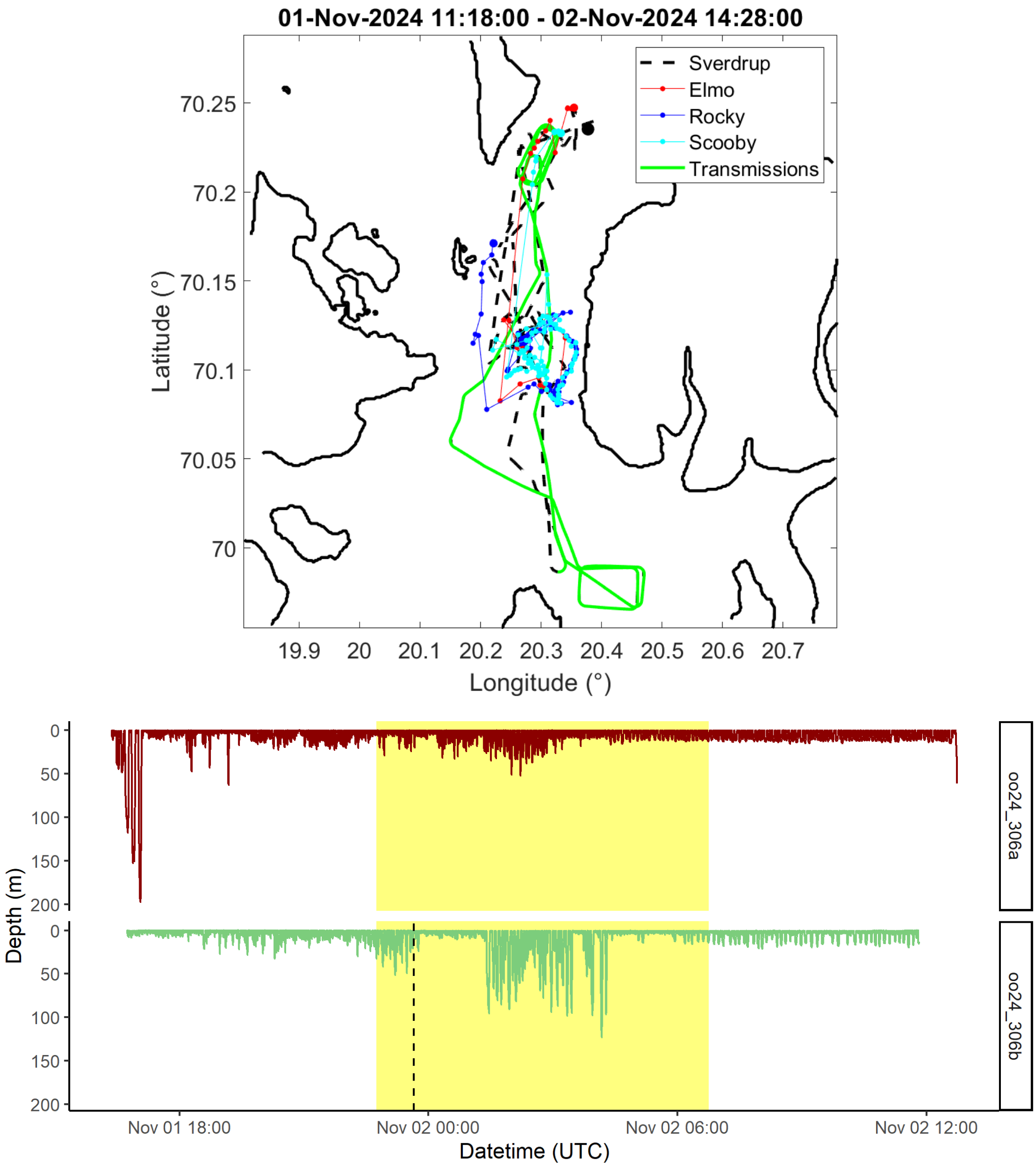


Figure 3.11 CEE VI – LFAS PAS. Upper panel: Geographical tracks from the CEE-tool of the source vessel without transmissions (----) and when transmitting sonar signals (—), focal 1 whale Oo24_306b (—) focal 2 Oo24_306c (—) and non-focal whale Oo24_306a (—). Lower panel: Time-depth plot of non-focal whale Oo24_306a and focal Oo24_306b during CEE VI. Oo24_306c was also exposed as focal 2, but is not plotted here because data from the Little Leonardo data sensor needs to be used to replace faulty depth data recorded by the DTAG3 core unit. The region highlighted in yellow indicates the experimental period. The dashed lines indicate the time of closest approach by the ship towing the exposure source.

3.3 Visual effort and data collection

A total of 84 visual sightings of five cetacean species were recorded during the trial. The most sighted species was killer whales (*Orcinus orca*) (34), followed by humpback whales (*Megaptera novaeangliae*) (26), fin whales (*Balaenoptera physalus*) (9), minke whales (*Balaenoptera acutorostrata*) (3), and sperm whales (*Physeter macrocephalus*) (1). There were 10 sightings of unidentified balaenopterids, and 1 unidentified whale sighting (Figure 3.12 and 3.13). It should be noted that sightings were mostly logged during search and transit phases. Most of the tagging occurred around fishing vessels and not all sightings around fishing vessels were recorded.

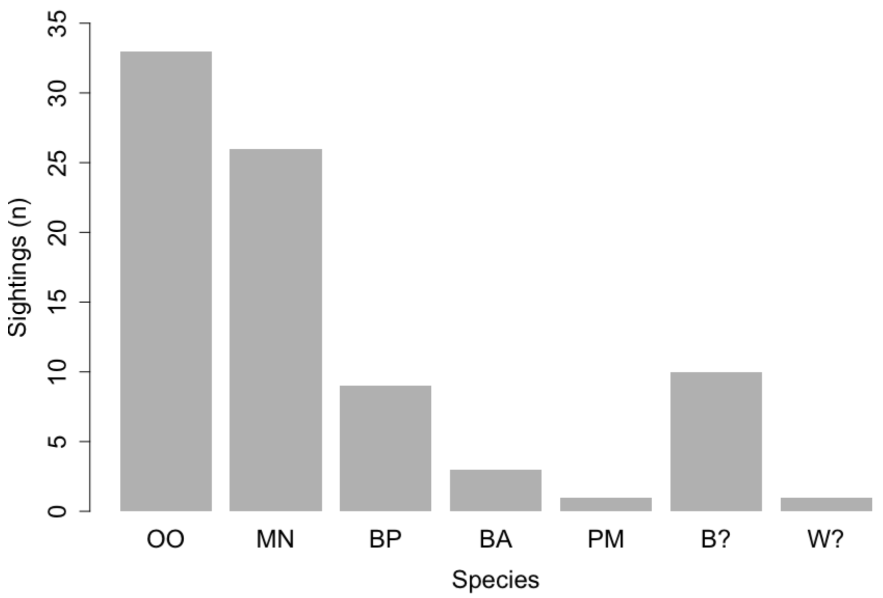


Figure 3.12 Total number of sightings per species recorded over the entire 3S-2024 trial period. OO=Orcinus orca (Killer whale); MN=Megaptera novaeangliae (Humpback whale); BP=Balaenoptera physalus (Fin whale); BA=Balaenoptera acutorostrata (Minke whale); PM=Physeter macrocephalus (Sperm whale); B?=unidentified balenopterid; W?=unidentified whale.

Generally, marine mammal observers (MMOs) rotated on the observation deck (OBS deck) of HU Sverdrup II (HUS) during day light hours. During darkness or in adverse weather conditions an MMO provided support from the bridge using handheld binoculars guided by either the lights of the fishing fleet or the moon. The thermal binoculars sometimes also proved to be of support in the tagging phase. MMOs searched for whales and provided visual support to the tag teams in the tagging phase. The height of the observation deck or bridge provided additional value to the tag teams. Visual tracking of animals from the observation deck or bridge provided the opportunity to keep track of the different whale groups and to guide the tag team. Tracking animals from the tag-boat is challenging because the tag-boat is very close to the water surface compared to the observation deck. Observers used both naked eye and handheld binoculars to search and keep track of whales. Big eye binoculars were available but were only used once, as we mostly operated within fjords. Searching using handheld binoculars in some cases resulted in finding groups of killer whales further away. The crew plan only had two dedicated MMOs, one for each shift. There were occurrences when the availability of MMOs was limited because of other priority tasks for secondary MMO's. This probably led to a lower number of recorded sightings. When one MMO was on OBS deck, tag-boat support was a higher priority than recording sightings.

Two 360-degrees angle boards were used to measure the angle to the whale sighting location relative to the heading of the vessel. The ship-whale range estimates were based on the reticle count of the hand-held binocular. When reticles could not be counted to the 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. These types of range estimates were relatively frequent because of the large amount of time spent working in the fjords. These field estimates were reported as estimates by eye, although these were often guided by binocular observations. Sightings were entered into the IFAW Logger software.

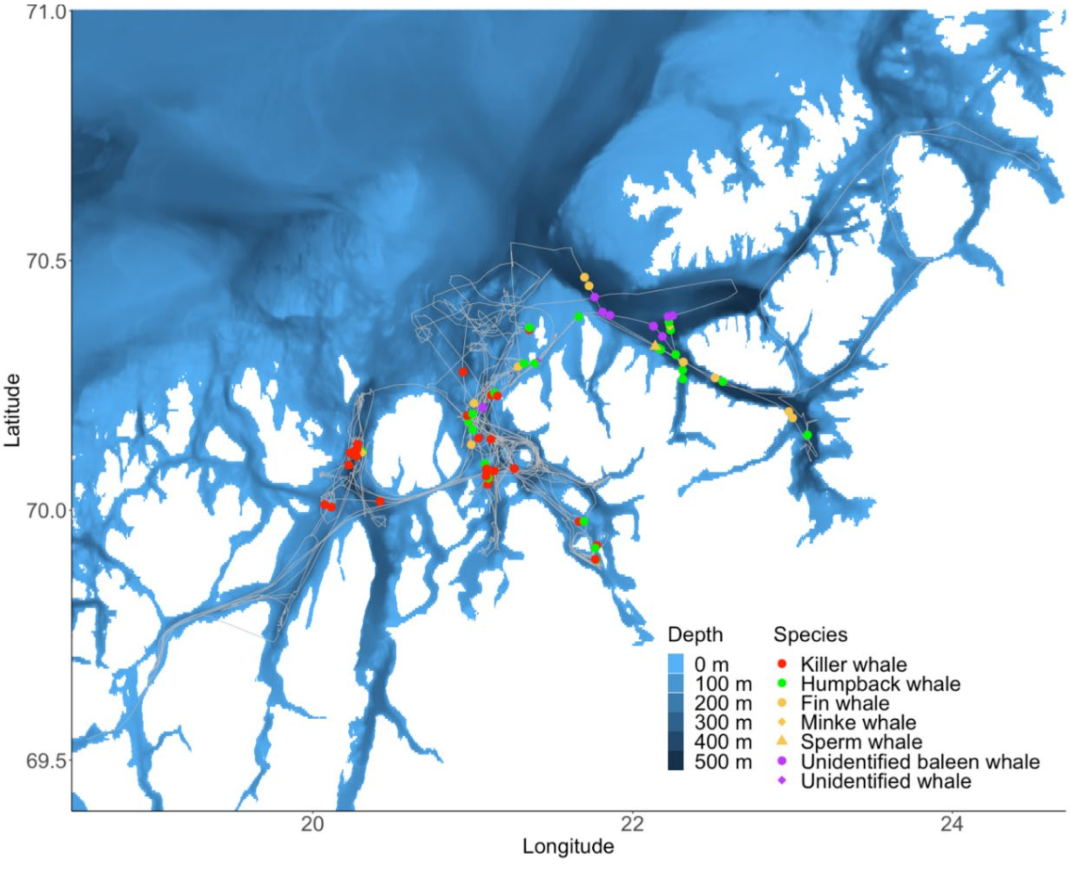


Figure 3.13 Map of marine mammal sightings made by the MMOs on HU Sverdrup during 3S-2024. Locations are based on the vessel position at the time of the sighting recorded in Logger.

Throughout the trial the window of daylight decreased, and weather conditions influenced visibility during morning and evening twilight. MMOs made sure to be on the observation deck before twilight started in the morning and stayed until dark in the evening to make maximum use of the limited daylight. Therefore, MMO effort varied strongly based on light, weather, availability of MMOs and whether tagging occurred around fishing vessels or not. As only one person was the dedicated MMO in each shift, this could lead to some hours of intense effort. However, generally this was not a problem, as other team members assisted as much as possible whenever they were not occupied with their primary tasks. In the second half of the trial, the observation deck was often very slippery due to snow and ice. On those days observations were mostly done from the bridge.

3.3.1 Sonar risk mitigation

For mitigation during experimental phases, full visual effort with 2-3 MMOs was continuously in place. All experiments were conducted during nighttime, requiring the ship's radar for safe navigation. Therefore, the OBS deck could not be used and observers were located on the lower front deck of HUS. A minimum of two observers were in place at any one time and used Pulsar Merger XP handheld night vision binoculars (herein referred to as "Mergers") to monitor a 500m zone in front of the ship. Observers split the area in half, with one person monitoring the port to front sector (270 to 0 degrees) and one the starboard side to front sector (90 to 0 degrees) of the ship. The Mergers were set to the red monochrome colour mode with the smallest magnification for the best images of whales. To stabilize the Merger it is ideal to use a monopod attached to the Merger. This helps to be able to carry out continuous mitigation throughout the 6 hr watches rather than holding the Merger with both hands. Rotation of MMOs was done every hour with the available staff from the watch team. Both MMOs used a radio to communicate sightings immediately to the CO or XO on the bridge. Because of the darkness and wind, communication between the two MMOs was difficult. Whales could be clearly seen, as well as birds. It was difficult to estimate exact distance while using the Merger, so the area monitored during periods of darkness was likely larger than the standard 500 m used for mitigation in periods of daylight. Any sightings within this zone were immediately relayed to the CO or XO on the bridge, who made the executive decision to turn off the sonar source if animals were at risk of getting within the 100m shut down range. There were 6 emergency shutdowns over the course of the 6 experiments, typically lasting a few minutes. The location of any fishing gear was also relayed to the bridge, but sightings of fishing gear were difficult, as the binoculars work based on thermal contrasts. Apart from the 6 emergency shutdowns several more sightings were made during mitigation and reported to the CO and XO. The cue used most often was a blow, however dorsal and fluke were also reported as sighting cues. Species observed during nighttime mitigation were humpback whale, killer whale, sperm whale and fin whale. Time of sightings from nighttime mitigation was logged on the bridge.

3.3.2 Visual data management

The Logger program works with an Access database to log positions, monitoring effort, tracking and sightings. Data are entered in real time from the observation deck, and a backup is created at the end of every observer rotation. Data are then quality checked by the lead MMOs. The data for the effort, sightings, re-sightings, VHF detections, and overall comments were transferred from Access into Excel, and each line was 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. A full summary of the logger procedure can be found in the 3S-2019 cruise report (Kvadsheim et al. 2020). An experiment timeline was also created based on event data entered into Logger. All on-effort events for each day were entered into an excel sheet, with the timing and data (UTC) from the effort form/comments. Experiment timing and timing of tag on/off can also be checked with the Socrates log, the Event log on the bridge or the tag data itself.

Table 3.6 Overview of visual effort. The total number of sightings as well as the number of cetacean species seen overall, maximum number of sightings in one day, max number of species seen in one day and the total number of mitigation shutdowns. BA = Balaenoptera acutorostrata (Minke whale); BP=Balaenoptera physalus (Fin whale)' MN=Megaptera noaveangliae (Humpback whale); OO=Orcinus orca (Killer whale); PM=Physeter macrocephalus (Sperm whale); B?=unidentified balenopterid; W?=unidentified whale.

DESCRIPTION	COUNT	COMMENTS
SIGHTINGS (TOTAL)	84	Reported sightings of single or multiple animals and species
CETACEAN SPECIES SEEN FROM OBS-DECK	5	(OO, MN, BP, BA, PM)
MOST SEEN SPECIES	34	*Orcinus orca, sightings*
MAX NUMBER OF SIGHTINGS IN ONE DAY	21	26/10/2024
MITIGATION SHUTDOWNS	6	3 CEEs with shutdowns, 1 CEE with 1 shutdown, 1 CEE with 2 shutdowns (cue; blow of large baleen whale), 1 CEE with 3 shutdowns

3.4 Collaboration with fishing vessels during tagging

Approaching purse seine vessels actively fishing is generally not allowed in Norway, and our activity to tag whales around the fishing vessels for research purposes is an exemption from the rule. As part of the requirement for the exemption, approval from the fishing boat captain is needed before we approach. We therefore established running contact with the herring fishery fleet working in the area close to us every day we were tagging. During the trial we made contact with more than 70 fishing vessels in the operation area (Table 3.7). Responses and communication were solely positive and in support of our research. During our tagging effort, mainly in Fugløyfjord, at Lopphavet and the fjord of Kvænangen, we approached about fifty percent of these vessels while they were pumping the herring catches into their fishing boats. The peak of this fishery is normally during dusk and dawn, when the herring aggregate closer to the surface, but we experienced active fishing also starting in the afternoon or extending until late morning. Other factors like the level of overcast and the moon cycle also play a role in the vertical migration of the herring. Thus, in contrast to the 3S-2023 trial (Kvadsheim et al. 2024), we also had several day-catches of herring during 3S-2024, where the tagging team was less dependent on the light from the fishing vessel, and as such could operate in the vicinity of the catching fleet. Other differences between the field season 2023 and 2024 were that the larger ocean going vessels finished with their quotas earlier in 2024, and the Fjordline restricting these vessels from entering inside the fjords was also removed earlier, resulting in the fishery being more concentrated into the fjords during the 3S-2024 trial. In the last week of the trial we were thereby able to operate in the fjords protected from bad weather off-shore. Due to this we also had contact with the smaller coastal fishing fleet in 2024, however with no operational consequences.

Both the ship movement based on AIS and the lanterns on the fishing vessels indicate to us which phase of their fishing operation they are in. When fishing vessels set their nets they make a characteristic circular movement before speed drops to zero. Then they indicate “restricted maneuverability” with their lanterns, which is helpful for us preparing the tagging operation. In this stage the fishing vessel is usually totally dark, with only navigation lights on, in order to avoid disturbing the vertical behaviour of the herring. The yellow lantern signals gave us roughly 1 hr to contact the specific vessel to get permit to approach and prepare the tags and tag team. We aimed to have the tag team on the water in time for the deck lights to be turned on by the fishing vessel when the catch was secured in the net and the pumping of the catch started.

A new AIS system was installed on the tag-boat MOBHUS to increase safety, and to improve communication and help guide the tag team to the right fishing vessels. In addition, extra lights were mounted in the bow of MOBHUS, so that the tag-boat team also could operate outside the lights from the fishing boats. The CO/XO on HU Sverdrup monitored other fishing vessels in the area in order to guide the tag-boat team to the next fishing vessels preparing for their pumping operation. Thermal night vision binoculars were also helpful to monitor the purse-seine stage of the fishing vessels. During this type of fishing the handling of nets is always from starboard of the fishing vessel, thus the tag-boat team often waited in the dark at port side. When the fishing vessel start the pumping phase, they turn on the deck lights and lights in the bow to light up the net. At this moment the tag-boat could operate in this light outside the pumping area, where killer whales and humpback whales feed on spillover herring from the fisheries. In this context when the whales are feeding, they are also more approachable, and thus it was possible to have better control of the tag placement. The timeline of the pumping operation is dependent on the size of the fishing vessel and the volume of the herring catch; thus it varies from 30 minutes to 2 hours, with most pumping operations lasting approximately 1 hour. In our experience, larger vessels had more lights and larger catches, which gave us more opportunities to tag, in some cases we also had help with extra light from some of the fishing vessels.

Table 3.7 List of fishing vessel contacted during 3S-2024

Vessel name	Vessel name	Vessel name	Vessel name	Vessel name	Vessel name
MS Andrea L	MS Eros	MS Jens Kristian	MS Meløyfjord	MS Saga Polaris	MS Sulebas
MS Arnøytind	MS Fiskebank	MS Johan Berg	MS M Ytterstad	MS Segla	MS Sunny Lady
MS Asbjørn Selsbane	MS Fiskeskjær	MS Ketlin	MS Norderveg	MS Seigrunn	MS Svanaug Elise
MS Ballstadværing	MS Gerda Marie	MS Kings Bay	MS Nordhavet	MS Selvåg Senior	MS Sæbjørn
MS Birkeland	MS Grimsholm	MS Klara B	MS Nybo	MS Sjarmør	MS Teigenes
MS Christine E	MS Gunnar K	MS Krossøy	MS Nystrøm	MS Skaar Senior	MS Topas
MS Dyrnesvaag	MS Gunnar Langva	MS Kvannøy	MS Olagutt	MS Slaaterøy	MS Trondskjær
MS Einar Erlend	MS Havglans	MS Lise Beate	MS Rav	MS Smaragd	MS Vea
MS Einarson	MS Hargun	MS Leinebjørn	MS Roaldsen	MS Steinvik	MS Vendla
MS Elisabeth	MS Herøyhav	MS Lofotfangst	MS Rogne	MS Storeknut	MS Vikanøy
MS Emma	MS Hepsøhav	MS Malene S	MS Runing	MS Strand Senior	MS Vestfart
MS Endre Dyrøy	MS Hovden Viking	MS Manon	MS Rødhlomen	MS Straumbas	MS Østbris

3.5 Mixed-DTAG^{++}

3.5.1 Tagging effort

We knew from previous experience that pole tagging killer whales away from the fishing vessels (“wild tagging”) requires much tagging effort and this approach could limit the overall success of the trial in terms of number of experiments conducted. Based on our experience of safely launching the mixed-DTAG^{++} with the ARTS system during 3S-2023 and the Iceland baseline trials (Appendix D), ARTS tagging was formally implemented during 3S-2024.

During day and twilight hours the ARTS was generally the tool of choice, resulting in 8 tag deployments on killer whales and 2 on humpback whales using ARTS, with similar tag retention times and GPS tracking success as the pole method (see next section). “Wild tagging” of killer whales during natural travelling, resting and carousel feeding behaviour remained challenging, but was successful on several occasions. The ARTS was particularly effective when fishing occurred in daylight and the whales were feeding on affected (stunned) herring further away from the nets.

The 5.4m hand pole remained the tool for tagging killer and humpback whales around the fishing vessels in the night, due to the overall effectiveness of pole tagging in these conditions and the difficulty of estimating distance in darkness, which is important during ARTS tagging. In the night the tagging team aimed to be on the water and near the purse seiner before the vessel would turn on its lights and start pumping the fish into the vessel, to maximise tagging opportunities. We sometimes used the Pulsar Merger night vision binoculars from the tagging boat to monitor for arriving whales. It was noticed that, when multiple vessels would be fishing in an area, most of the whales would often be at one specific vessel. We therefore tried to be where most of the whales were and regularly switched from one fishing vessel to another based on the number of whales observed.

3.5.2 Data collection

In total, 28 mixed-DTAG^{++} were attached to killer (N=20) or humpback (N=8) whales over the period 15 October to 04 November, recording a total of 448.7hrs of on-animal data (342.0 hrs with killer whales of which 297.4 hrs were with experiment subjects, 106.7 hrs with humpback whales, all baseline data). Ten of the 28 deployments were made using the ARTS system, and 18 using a hand pole with a 90° oriented tag robot (Figure 2.2). Average attachment durations were slightly longer for ARTS deployed tags (18.9hrs) vs Pole deployed tags (14.4hrs). All tags were recovered quickly after detachment from the whale, and no tags were lost during the trial. Tag recovery was greatly aided by both ARGOS and GPS-Goniometer receptions received after tags detached from whales. In some cases, the GPS locations could be used to locate and recover the floating tag using Sverdrup, but in most cases tags were recovered from the tag-boat using the VHF beacon.

Of the 28 deployments, 19 deployments (68% of all tags deployed) remained attached to whales for 13hrs or longer (Figure 3.14), which was long enough to complete the full experiment cycle plan. Indeed, the CEE experimental cycle was completed for 74% of these 19 deployments (6 as Focal 1, 4 as Focal 2, and 4 as non-Focal experimental subjects). It is noteworthy that tags deployed using both the ARTS tagging system and the hand pole had similar attachment durations, and were equally likely to be usable for experiments.

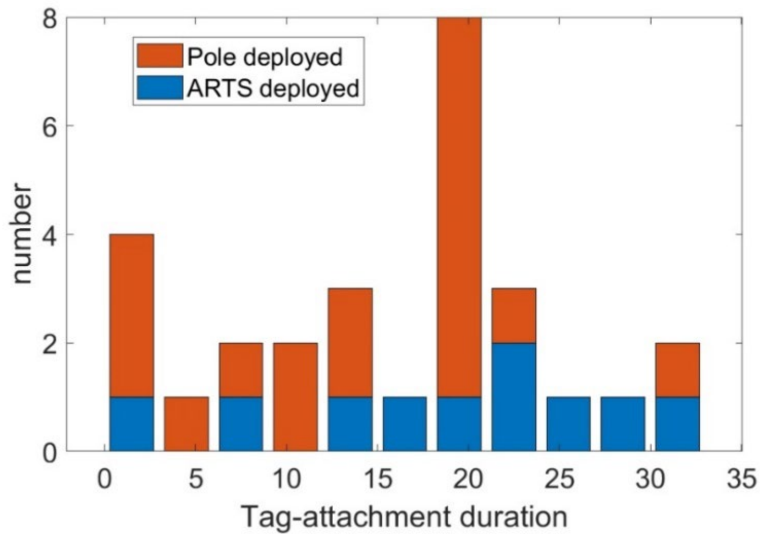


Figure 3.14 Durations of all 28 mixed-DTAG^{++}-deployments during the 3S-2024 trial. The color indicates the tag deployment method (Pole or ARTS)

Five of 28 deployments (18%) remained attached for 2-13 hrs duration. These deployments all contain useable baseline periods before sonar exposures started, and one record oo23_299b contained the initial part of the sonar exposure period. 4/28 tags (13%) detached 2hrs after the initial tag placement (Table 3.8, Figure 3.14). Such very short deployments are not desirable but are not too costly to the field effort as the detached tags can be quickly recovered by the tag-boat team and deployed again. Because the obtained data from such deployments is limited (and possibly influenced by ongoing tag-boat activities), those data are not expected to be used further for analyses to support the 3S4 study.

In conclusion, attaching suction cup tags was highly effective using the 90° pole system (chapter 2.1) so long as tagging was done in association with purse seine fishing vessels (chapter 3.4) while ARTS tagging was highly effective during daytime hours, including away from fishing vessels.

3.5.3 Data quality

The Mixed-DTAG data recordings were generally of high quality, with only a few issues noted. Core unit 311 was found to have noisy pressure data, so pressure data from those deployments will need to be replaced by the 24hr backup data set recorded by the Little Leonardo dataloggers, which was reliably recorded. During one deployment (Mn24_307a) the DTAG3 core unit stopped recording after 8.9hrs, though the tag remained attached for 23.5 hrs and the release system operated normally. For all deployments, GPS positions were logged consistently, and GPS relay using the Goniometer system was highly successful enabling us to complete our experimental program.

3.5.4 Little Leonardo video logger

The video logger is part of the Mixed-DTAG^{++} standard package deployed during the 3S-2024 trial. The Little Leonardo DVLW1300M-130-4R-VD3GT video and data logger reliably recorded depth and 3-axis acceleration data for up to 36 hrs, following a software update completed after the 3S4-2023 trial. Those data serve as a valuable backup in case the DTAG core unit depth data were faulty. The start time of the data recordings is noted in Table 3.9. Note that one of the video loggers used in 3S4-2024 was an older version logger which did not record sensor data. However, it was paired with a reliable DTAG3 core unit, so that did not affect overall data quality.

The camera collected data on social and prey interactions of the tagged whales (Figure 3.15). A variable number of video files was recorded for each deployment (Table 3.9), and no video was recorded for 6 deployments (oo24_291b, oo24_301a, oo24_306b, mn24_308b, mn24_309a, and mn24_309c) due to short deployment durations or device errors. Improving from the 3S4-2023 trial, recordings were made at reliable start times following a software update by the manufacturer (Little Leonardo). Figure 3.16 shows graphically the start times in relation to day/nighttime.

Figure 3.15 Screenshots from the recordings of the Little Leonardo camera unit on the mixed-DTAG++ showing fishing vessel interactions (oo24_290a, top left); prey field interactions (oo24_294b, top right); killer whale social interactions (oo24_294a, bottom left) and humpback whale social interactions (mn_308a, bottom right).

Table 3.8 Mixed-DTAG++ deployment table for 3S-2024 trial.

Date	Deployment ID /method	Tagon time and location	Resp	Hrs on animal	DTAG unit id	GPS/ARGOS LL device id	Why released	Exposure?	Comments
15.10.24	oo24_289a ARTS	14:46 UTC 70.0909°N 20.21778°E	0	14.9	Mixed-DTAG++ Elmo (C317)	161599 23007	Released early	YES (CAS 1) Focal 1	Deployed from 10m distance adult male, front tie of video logger came loose
16.10.24	oo24_290a Pole	23:16 UTC 70.204227°N 20.97141°E	0	32.5	Mixed-DTAG++ Marge (C330)	267240 20019	Released early	YES? (CAS 2) Non-focal	Adult male, tagged near fishing boat, excellent placement. one release loop only burned at its base with one tube still folded inside
17.10.24	oo24_291a ARTS	14:34 UTC 70.273317°N 21.267361°E	1	30.5	Mixed-DTAG++ Elmo (C317)	161599 23007	Released later than programmed, due to bad release	YES (CAS 2) Non-focal	Adult male. One release loop only burned at its base with both tubes still folded inside
17.10.24	oo24_291b ARTS	15:40 UTC 70.27335°N 21.2293°E	0	20.3	Mixed-DTAG++ Rocky (C302)	267242 23004	Released early	YES (CAS 2) Focal 2	Damage to back of LL Logger (near port), LL Logger recorded no sensor or video data
17.10.24	oo24_291c Pole	17:52 UTC 70.2567°N 21.231167°E	1	13	Mixed-DTAG++ Homer (C329)	161601 23006	Released early	YES (CAS 2) Focal 1	Tag deployed backwards (antennas towards animal's head), just behind the blowhole
20.10.24	oo24_294a ARTS	08:51 UTC 70.35585°N 21.24802°E	1 minor tail slap	26.3	Mixed-DTAG++ Elmo (C317)	161599 23007	Released as programmed	YES (PAS 1) Focal 1	Adult male resting within a large group, housing was broken near front-right suction cup
20.10.24	oo24_294b ARTS	11:38 UTC 70.362°N 21.33883°E	0	16.6	Mixed-DTAG++ Marge (C330)	267240 20019	Released early	YES (PAS 1) Focal 2	Tag deployed relatively ventral on adult male, on saddle patch, video contained carousel feeding
26.10.24	oo24_300a Pole	16:37 UTC 70.05437°N 21.09309°E	0	20.6	Mixed-DTAG++ Homer (C329)	183278 23006	As programmed	YES (CAS 3) Focal 1	Tag deployed near fishing boat, antennas facing backwards
26.10.24	oo24_300b Pole	16:55 UTC 70.05605°N 21.09309°E	1	19.2	Mixed-DTAG++ Marge (C330)	267240 20019	As programmed	YES (CAS 3) Focal 2	Tag deployed near fishing boat, at base and towards front of dorsal fin, antennas facing backwards

27.10.24	oo24_301a Pole	20:25 UTC 70.1218°N 21.22303°E	0	0.3	Mixed-DTAG++ Scooby (C311)	215144 23010	Released early due to broken release loop	NO	Tag deployed near fishing boat, antennas facing backwards
27.10.24	oo24_301b Pole	23:37 UTC 70.13575°N 21.2496°E	1 Tail slap	10.1	Mixed-DTAG++ Scooby (C311)	215144 23010	Released early	NO	Tag recovered from 301a, redeployed near fishing boat, antennas facing backwards
28.10.24	mn24_302a Pole	17:45 UTC 70.05788°N 21.29177°E	0	3.8	Mixed-DTAG++ Rocky (C302)	267242 23005	Release early, possibly due to rotated stem	NO	Tag deployed near fishing boat, antennas facing backwards, rear left suction cup was rotated upon recovery
29.10.24	oo24_303a Pole	23:32 UTC 70.14656°N 21.12101°E	1 banana back	10.8	Mixed-DTAG++ Elmo (C317)	264241 23007	Released early	NO	Large male feeding near boat (Nordhavet), tag placed high on body in front of dorsal fin
29.10.24	oo24_303b Pole	23:37 UTC 70.14569°N 21.20153°E	1 banana back	8.4	Mixed-DTAG++ Homer (C329)	161601 23006	Released early; Broken release loop	NO	Large male near boat (Nordavet), antennas backwards, one release loop was broken upon tag recovery
30.10.24	oo24_304a Pole	03:23 UTC 70.07586°N 21.5208°E	1	14.1	Mixed-DTAG++ Marge (C330)	267240 20019	Released early	NO	Large male feeding at boat by the net, antennas pointing backwards
31.10.24	oo24_305a ARTS	09:26 UTC 69.94964°N 21.1198°E	0	22.7	Mixed-DTAG++ Marge (C330)	267240 20019	Released early, one tube came loose from release loop	YES (PAS 2) Focal 1	Adult male possibly feeding near fishing boat, or possible searching for bycaught pod members, tag high on dorsal fin left side
31.10.24	oo24_305b ARTS	11:05 UTC 69.91926°N 21.04548°E	1 roll away	22	Mixed-DTAG++ Homer (C339)	161601 23006	Released early	YES (PAS 2) Non-focal	Adult male resting in large group carousel feeding, high on body in front of dorsal fin, tag went on sideways
31.10.24	oo24_305c ARTS	11:44 UTC 69.91317°N 21.03195°E	1 tail flinch	0.9	Mixed-DTAG++ Elmo (C317)	267241 23007	Released early	NO	Adult male in the same group as 305b, tag placement far back on body near the tail
1.11.24	oo24_306a Pole	16:22 UTC 70.11234°N 20.26766°E	0	20.4	Mixed-DTAG++ Elmo (C317)	267241 23007	As programmed	YES (PAS 3) Non-focal	Adult male near fishing boat, tag placement ideal but sideways with antennas to the left

1.11.24	oo24_306b Pole	16:44 UTC 70.12072°N 20.24429°E	1	19.1	Mixed-DTAG++ Rocky (C302)	267242 23005 (no video recorded)	As programmed	YES (PAS 3) Focal 1	Adult male near fishing boat, tag went on with antennas facing forward, then slipped to face sideways with antennas to the left
1.11.24	oo24_306c Pole	17:36 UTC 70.12169°N 20.30123°E	0	19.3	Mixed-DTAG++ Scooby (C311)	215144 23010	As programmed	YES (PAS 3) Focal 2	Adult male near fishing boat, tag placement sideways with antennas to the left
2.11.24	mn24_307a Pole	20:08 UTC 69.97547°N 21.56247°E	0	23.5	Mixed-DTAG++ Homer (C329)	161601 23006	As programmed	NO	Whale feeding near fishing boat, antennas facing backwards, DTAG only recorded until 5:00 UTC, 8.9 hrs
2.11.24	mn24_307b Pole	21:04 UTC 69.96811°N 21.5801°E	0	20.8	Mixed-DTAG++ Marge (C330)	267240 20019	Released early, releases had started burning	NO	Whale feeding near fishing boat, antennas facing backwards
3.11.24	mn24_308a Pole	16:57 UTC 69.908583°N 21.67464°E	1	20.5	Mixed-DTAG++ Scooby (C311)	215144 23010	As programmed	NO	Tag deployed on whale feeding near fishing boat, tag went on sideways
3.11.24	mn24_308b Pole	17:50 UTC 69.909912°N 21.655338°E	0	1.7	Mixed-DTAG++ Rocky (C302)	267242 No video logger	Released early	NO	Whale feeding near fishing boat, antennas facing backwards
4.11.24	mn24_309a ARTS	08:30 UTC 70.12426°N 21.40922°E	0	7.1	Mixed-DTAG++ Rocky (C302)	267242 23006	Released early	NO	Whale near fishing boat, tag high just behind blowhole centre mid-line, tag re-sighted around 11:00 UTC low on flank on left side
4.11.24	mn24_309b ARTS	08:57 UTC 70.10602°N 21.40776°E	1 Tail slap	28.1	Mixed-DTAG++ Marge (C329)	267240 20019	As programmed	NO	Whale near fishing boat, tag high up between blowhole and dorsal fin, re-sighted lower on body. Whale approached Sverdrup just before tag off
4.11.24	mn24_309c Pole	16:02 UTC 70.13786°N 21.33715°E	1	1.2	Mixed-DTAG++ Elmo (C317)	267241 23007	Released early	NO	Whale near fishing boat, whale nearly hit boat right before tag deployment

Table 3.9 Details of Little Leonardo sensor and video recordings from the 3S4-2024 trial. 33:51:48 hours of video from tagged Humpback whales and 104:25:50 hours of video from tagged Killer whales, 138:17:38 hours of video in total.

Deployment	Logger ID	Exposure?	10+ hour deployment?	Sensor Data?	Logger Start Time (UTC)	Video (Number of Files)	Video Start Time (UTC)	Interval Settings	Duration of Video (hh:mm:ss)	Duration of Logger Data (DD:hh:mm)
mn24_302a	23005	NO	NO	YES	28-Oct-24 18:20:02	YES (15)	28-Oct-24 ~04:17	None	7:06:49	00:19:44
mn24_307a	23006	NO	YES	YES	2-Nov-24 19:50:08	YES (16)	3-Nov-24 ~06:49	None	7:46:33	01:01:03
mn24_307b	20019	NO	YES	NO	N/A	YES (13)	3-Nov-24 ~06:43	None	05:30:49	N/A
mn24_308a	23010	NO	YES	YES	3-Nov-24 13:26:42	YES (16)	4-Nov-24 ~04:26	None	7:32:06	01:01:16
mn24_308b	N/A	NO	NO	NO	N/A	NO	N/A	N/A	N/A	N/A
mn24_309a	23006	NO	NO	YES	4-Nov-24 08:06:16	NO	4-Nov-24 ~08:08	N/A	N/A	00:10:58
mn24_309b	20019	NO	YES	NO	N/A	YES (12)	4-Nov-24 ~09:11	None	5:55:31	N/A
mn24_309c	23007	NO	NO	YES	4-Nov-24 15:51:14	NO	5-Nov-24 ~03:50	N/A	N/A	00:03:14
oo24_289a	23007	YES	YES	YES	15-Oct-24 14:27:36	YES (12)	15-Oct-24 ~20:27	1 hour	5:47:05	00:16:47
oo24_290a	20019	YES	YES	NO	N/A	YES (13)	16-Oct-24 ~03:05	None	6:07:16	N/A
oo24_291a	23007	YES	YES	YES	17-Oct-24 14:00:14	YES (9)	17-Oct-24 ~14:00	None	4:01:59	01:12:00
oo24_291b	23004	YES	YES	NO	N/A	NO	17-Oct-24 ~14:07	N/A	N/A	N/A
oo24_291c	23006	YES	YES	YES	17-Oct-24 17:21:03	YES (11)	17-Oct-24 ~23:20	1 hour	5:04:29	00:16:04
oo24_294a	23007	YES	YES	YES	20-Oct-24 07:02:15	YES (15)	20-Oct-24 ~07:01	None	7:17:52	01:08:08
oo24_294b	20019	YES	YES	NO	N/A	YES (13)	20-Oct-24 ~10:25	None	6:16:01	N/A
oo24_300a	23006	YES	YES	YES	26-Oct-24 14:59:12	YES (15)	27-Oct-24 ~03:59	None	7:18:37	01:00:27
oo24_300b	20019	YES	YES	NO	N/A	YES (13)	27-Oct-24 ~01:52	None	6:12:41	N/A
oo24_301a	23010	NO	NO	YES	27-Oct-24 19:55:23	NO	NO	N/A	N/A	N/A
oo24_301b	23010	NO	YES	YES	27-Oct-24 19:55:23	YES (16)	28-Oct-24 ~01:55	None	7:54:26	01:12:00
oo24_303a	23007	NO	YES	YES	29-Oct-24 20:27:30	YES (13)	30-Oct-24 ~06:29	None	6:04:53	00:16:05
oo24_303b	23006	NO	NO	YES	29-Oct-24 20:30:10	YES (8)	30-Oct-24 ~06:29	None	3:38:56	00:13:39
oo24_304a	20019	NO	YES	NO	N/A	YES (11)	30-Oct-24 ~05:43	None	5:17:46	N/A
oo24_304b	23005	NO	NO	YES	30-Oct-24 04:45:50	YES (2)	30-Oct-24 ~06:45	None	0:43:24	00:02:43
oo24_305a	20019	YES	YES	NO	N/A	YES (12)	31-Oct-24 ~08:00	None	5:59:44	N/A

oo24_305b	23006	YES	YES	YES	31-Oct-24 10:36:37	YES (17)	31-Oct-24 ~10:36	None	8:07:44	01:00:16
oo24_305c	23007	NO	NO	YES	31-Oct-24 10:40:59	YES (8)	31-Oct-24 ~10:40	None	3:49:27	00:03:49
oo24_306a	23007	YES	YES	YES	1-Nov-24 14:58:14	YES (14)	2-Nov-24 ~03:57	None	6:59:25	00:23:51
oo24_306b	23005	YES	YES	YES	1-Nov-24 15:46:35	NO	2-Nov-24 ~03:46	N/A	N/A	00:21:06
oo24_306c	23010	YES	YES	YES	1-Nov-24 17:59:35	YES (16)	2-Nov-24 ~03:59	None	7:44:05	00:20:52

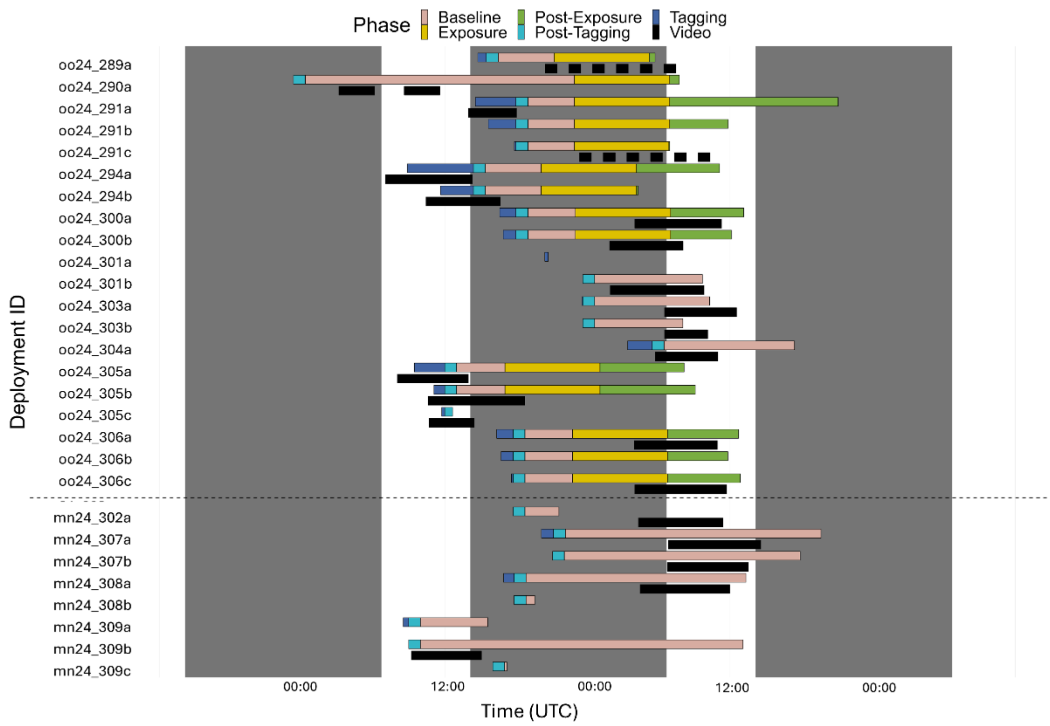


Figure 3.16 *Recording periods of each Mixed-DTAG deployment (colored bars, same as Figure 3.2) but with associated video recording periods also indicated (black bars). Note that video recordings were mostly made during daytime hours to maximize visibility conditions. Note that some video recording periods were from times the tag wasn't attached to the whale, as indicated in the figure.*

3.6 Limpet SPLASH10 satellite tag data

Wildlife Computers Limpet SPLASH10-F-333B satellite tags, which include Fast-GPS and depth sensors, were deployed on the dorsal fin using a Dan-Inject JM25-SP airgun (Figure 3.17). Satellite tagging was conducted with four objectives in mind: 1) To guide us to new study subjects for mixed-tagging, 2) To understand the larger-scale movements patterns of killer whales in the study area, including interaction with herring fishing vessel, 3) To understand diurnal patterns in their behaviour, and 4) To document potential behavioural responses to sonar.

We deployed two satellite tags on 17 October before the second CEE and one satellite tag on 20 October before the third CEE (Table 3.10). Due to the increased focus on ARTS tagging in 2024, the first satellite tags were deployed slightly later into the trial than in 2023, but with relatively little effort. No behavioural responses by the tagged whales to tag deployment were observed.

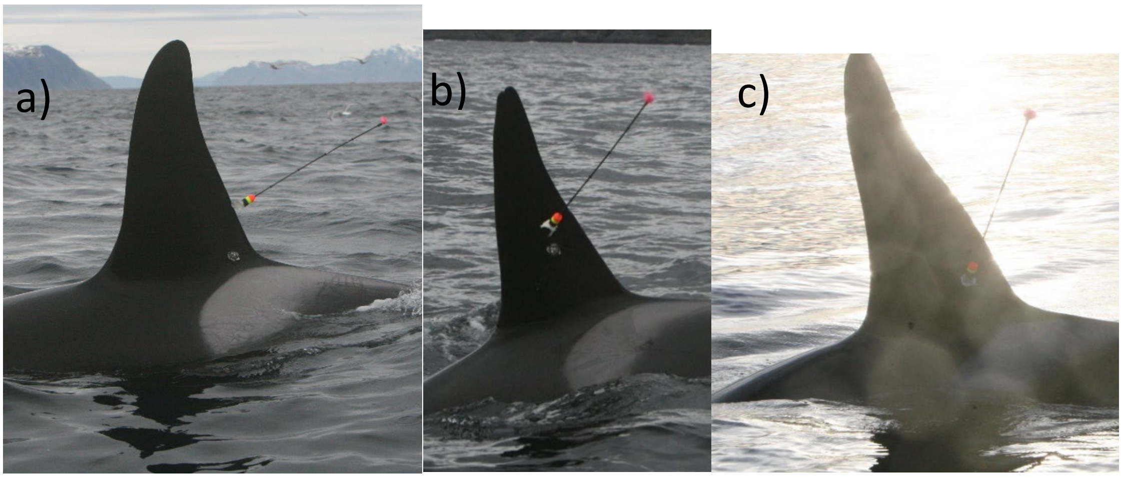


Figure 3.17 Placement of satellite tags on male killer whales, shown in chronological order: a) Oo24_291SAT#1, b) Oo24_291SAT#2, and c) Oo24_294SAT#3. All three individuals were males based on the size and shape of their dorsal fin. (Photos Ellen Hayward and George Sato).

A quick look at the tracks of the satellite tags (Figure 3.18) revealed that the whales varied in their movement patterns: Oo24_291SAT#1 (short deployment) and Oo24_294SAT#3 mostly stayed in the Kvænangen Canal and its inner fjords during the trial period, while Oo24_291SAT#2 moved across a much larger area, suggesting differences in the foraging strategies of these whales. Clear differences in dive behaviour can also be observed in the time-depth profiles of the whales (Figure 3.19)The movements of Oo24_294SAT#3 were strongly associated with purse seine fishing vessels. The tagged whales spent less times in offshore waters compared to the animals satellite-tagged in 2023.

Table 3.10 Limpet satellite tag deployments on killer whales during 3S-2024.

Tag ID	Dec. / Hex. PTT	Tag-on (UTC)	End (UTC)	Duration	Tag location	Tag placement	Side	Animal's reaction
Oo24_291SAT#1	36683 / 20313BE	17/10/2024 08:46	20/10/2024	3d 11h	N70.2825 E021.2901	Dorsal fin, base	Left	0, no response
Oo24_291SAT#2,	36685 / 20313D4	17/10/2024 10:15	*	>20d	N70.2955 E021.3671	Dorsal fin, 1/3rd up	Left	0, no response
Oo24_294SAT#3	183276 / 7AC89C7	20/10/2024 10:30	*	>20d	N70.3620 E021.3406	Dorsal fin, 1/5th up	Left	0, no response

Tags transmitted beyond the end of the research cruise.

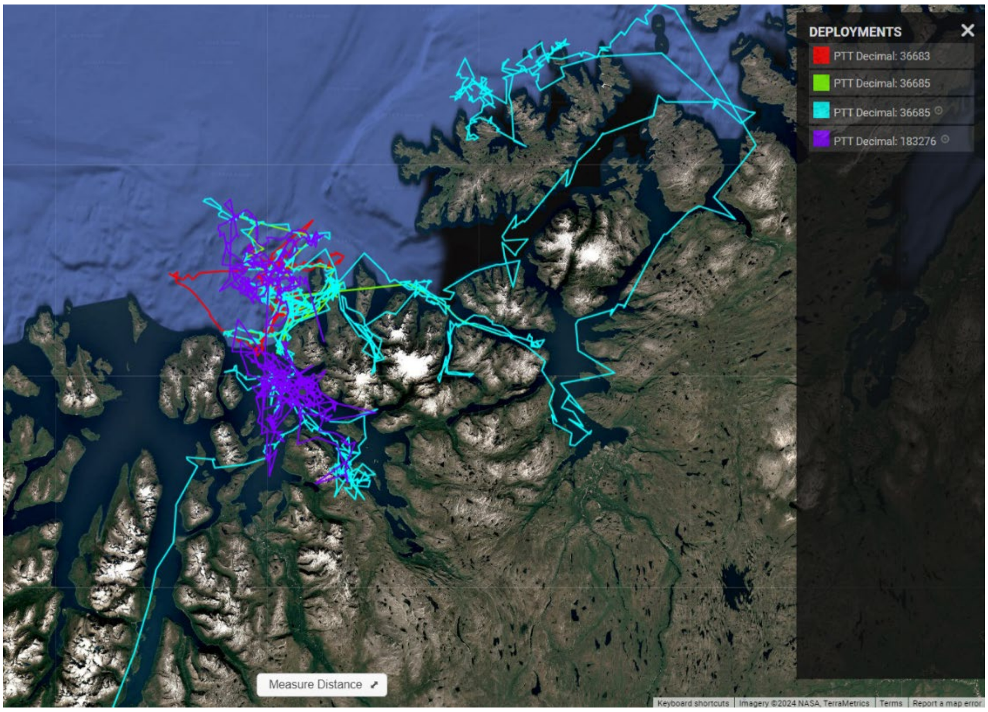


Figure 3.18 *Tracks of the 3 satellite-tagged whales until the end of the trial period (ptt 36685 are plotted in two colors due to a technical glitch). Tracks were created using Fastloc-GPS and ARGOS-quality locations (all ARGOS classes except B and Z).*

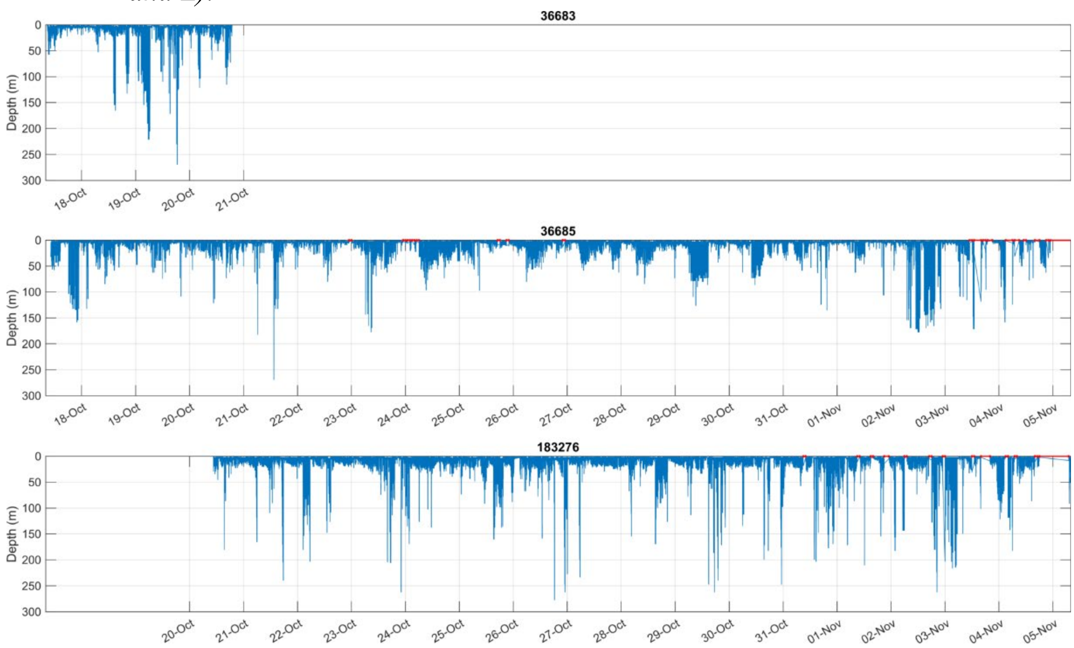


Figure 3.19 *Depth data collected by satellite tags during the trial period, i.e. excluding dive data in ARGOS messages received beyond the end of the fieldwork. Data gaps are indicated in red. The ticks on the horizontal axis mark midnight UTC.*

3.7 Prey field mapping and sampling

When analyzing potential responses to sonar, the whale's prey field in the immediate vicinity is important to consider as a co-variate that might also affect whale behaviour. The choice of whales to avoid the area or not might be influenced by the quantity or quality of available food, and these energetic choices are important when considering the responses. The quality of the prey field around the focal animals was monitored using three data sources; single beam echosounder on the source vessel, sampling of fish for energy content analysis and analysis of video recordings made by the tag (chapter 3.5.3). In addition, after the trial, we also collected herring survey data from Institute of Marine Research, who performed a larger scale and systematic survey of herring distribution in our larger operation area. We also collected catch data from the Fishery Directorate. Those data show the time, position and size of the catches reported from the herring fishing fleet.

3.7.1 Echosounder data

To characterize the prey field we used a Kongsberg EA640 echosounder at 38 kHz. This is a wideband single beam hull mounted echo-sounder on HU Sverdrup II. The data were collected opportunistically, thus no systematic survey patterns were used. However, Sverdrup targeted to stay within 1nmi of one of the focal whales in the baseline and post exposure periods (Figure 3.20 and 3.21)The echosounder was running continuously in the operation area, but was turned off during in-shore transits and in port. In total 64GB of echosounder data, both raw data and screenshots of echograms were collected. Details of the echosounder settings used are given in Appendix C (Table 3.9).

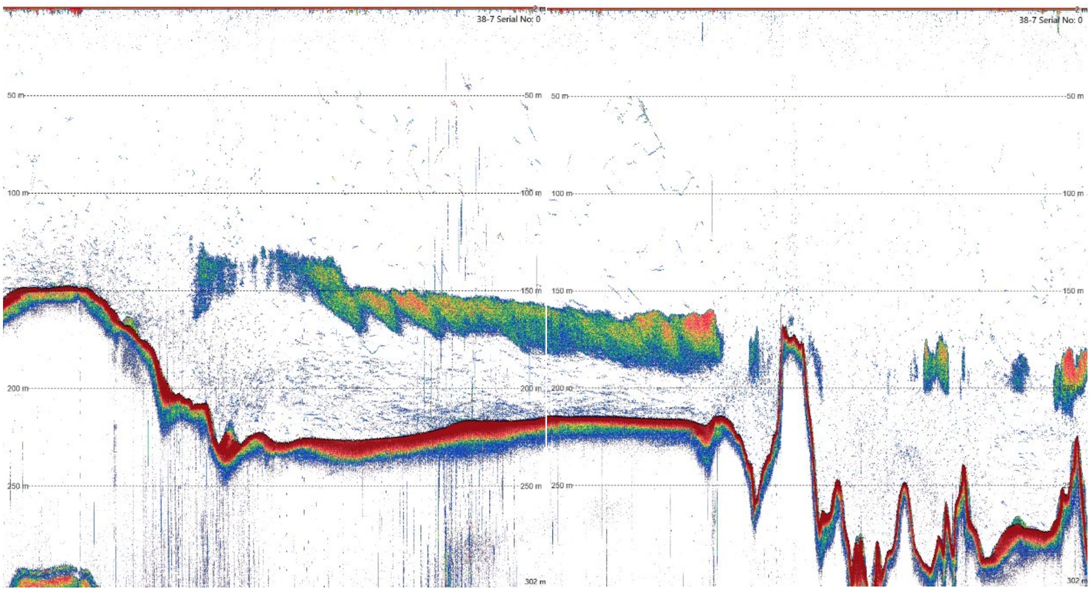


Figure 3.20 Echogram from Lopphavet showing 80min of data starting 20.10.2024 at 05:11UTC. The data shows a dense layer of herring slowly descending from 150 to 200m in the morning.

3.7.2 Herring fish sampling

During the tagging phase, herring were opportunistically collected in the vicinity of the commercial herring purse seiners or around feeding whales. Collection was done from Mobhus (tagging boat) using a handheld fishing net. After collection, the herring were kept in seawater before being brought onboard and processed prior to being frozen.

The sampling process onboard consisted of assigning herring with a number and date of collection, followed by measuring the length of each fish from the tip of the caudal fin to the tip of the mouth using a measuring tape. The fish were then stored in the freezer in a bag labelled with fish number, date, time and location of collection. Fish mass was not collected at sea but will be measured later.

A total of 19 herring were collected (Figure 3.22, Table 3.11), 17 around fishing vessels, and 2 around carousel feeding whales, away from fishing boats. The mean length of the fish was 34.0 cm (Min. 30.5 cm, Max. 36.5 cm) (Figure 3.23, Table 3.11). Following the trial, samples were transported to the UK for further analysis.

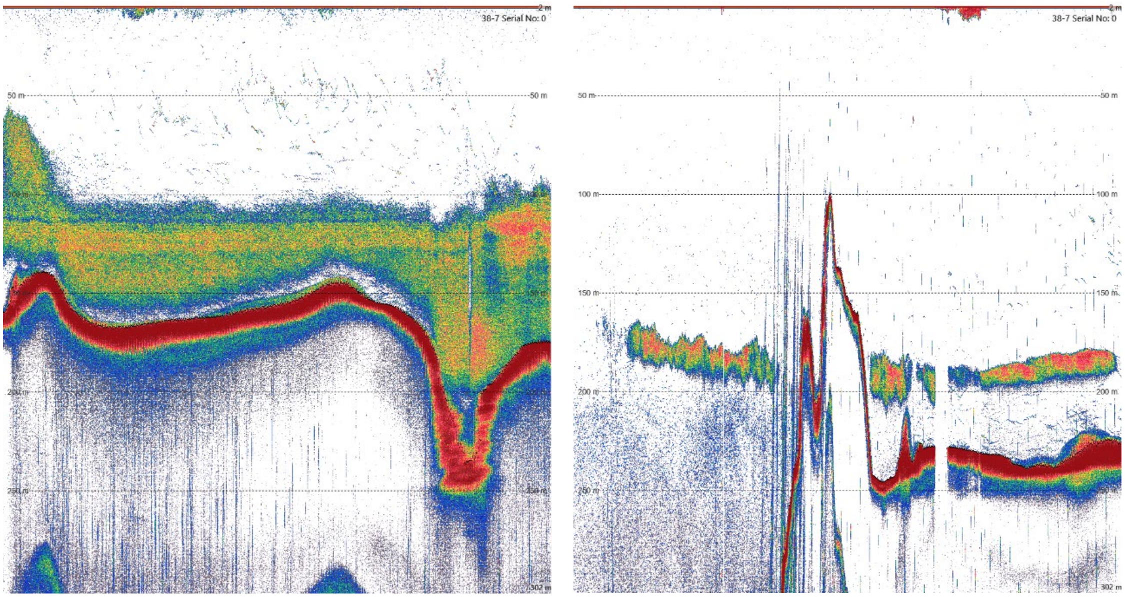


Figure 3.21 Left: Echogram showing 40 min of data starting at 26.10.2024 at 17:29 UTC in Reisafjord. The ecogram shows a very dense and thick layer of herring near the bottom (100-150m). The data is recorded near focal 1 and focal 2 during the pre-exposure period of CEE IV. Right: Echogram showing 40 min of data starting at 27.10.2024 at 07:29 UTC in Kvænangen. The echogram shows smaller patches of herring around 180m depth close to focal 2 whale in the post exposure phase of CEE IV. The vertical lines are most likely noise from other ship's echosounders nearby.

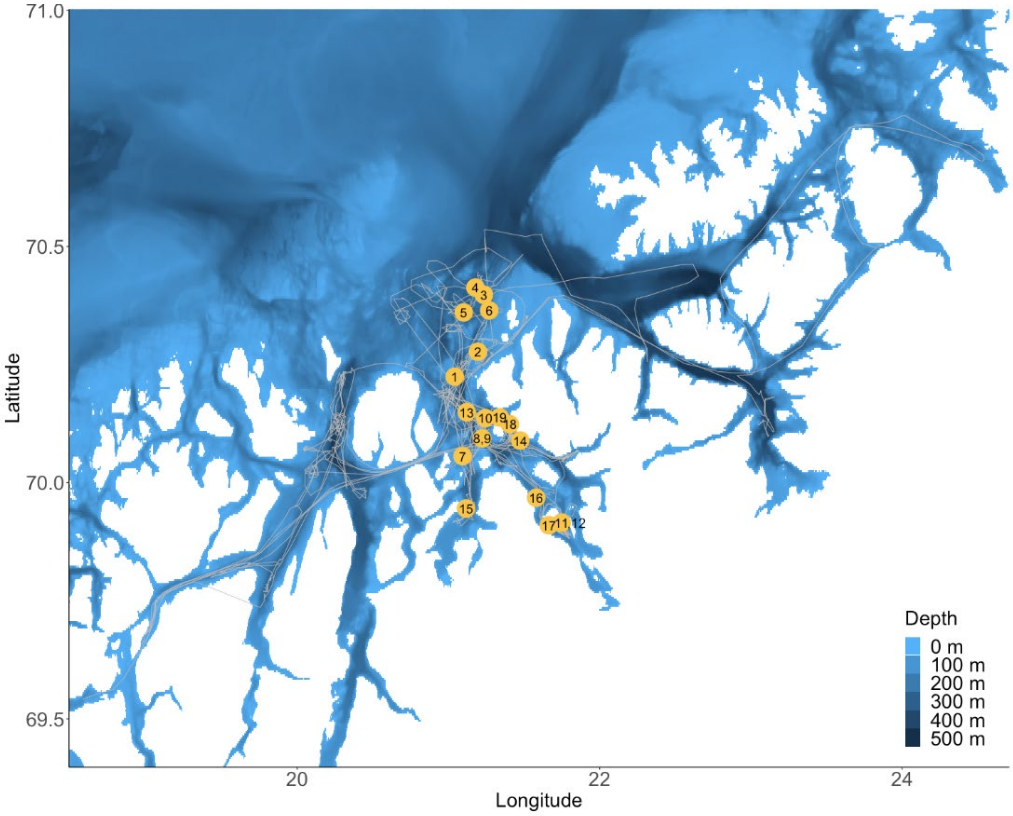


Figure 3.22 *Map of the herring sample collection during 3S-2024, with the sample numbers corresponding to those in Table 3.11. The track of the HU Sverdrup is shown in grey.*

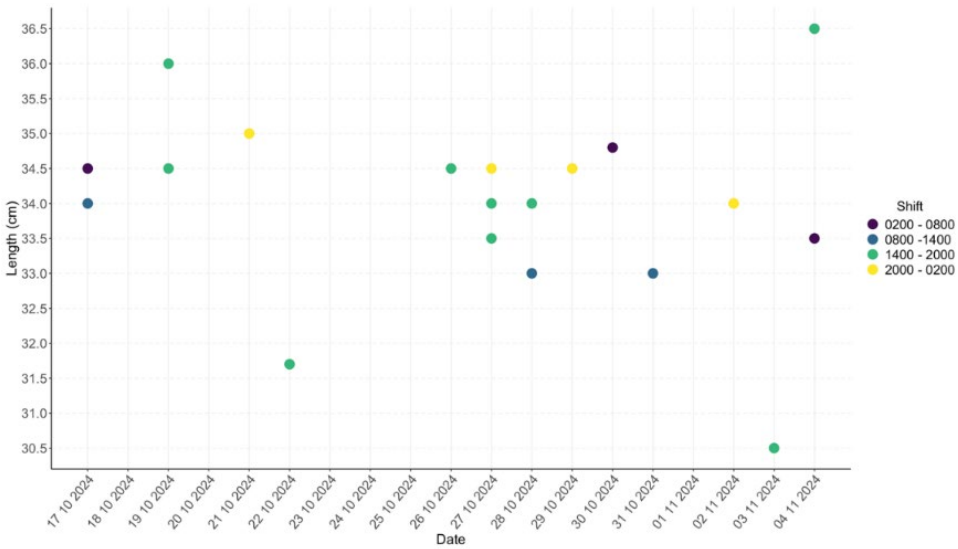


Figure 3.23 *Length of herring samples collected between 14th October and 4th November 2024. The symbol colors indicate which shift collected the sample.*

Table 3.11 Date, time, location (Latitude, Longitude), and length of the collected herring samples.

Fish N°	Date	Time (UTC)	Latitude	Longitude	Length (cm)	Comments
1	17/10/2024	06:50	70.22436	21.0414	34.5	
2	17/10/2024	13:51	70.277	21.19476	34.0	
3	19/10/2024	18:00	70.39758	21.23437	34.5	
4	19/10/2024	19:49	70.41286	21.17829	36.0	
5	21/10/2024	23:26	70.36028	21.10087	35.0	
6	22/10/2024	18:43	70.36449	21.26941	31.7	
7	26/10/2024	16:49	70.05605	21.09309	34.5	
8	27/10/2024	19:58	70.09359	21.22292	33.5	
9	27/10/2024	19:58	70.09359	21.22292	34.0	
10	27/10/2024	23:40	70.13666	21.24369	34.5	
11	28/10/2024	11:48	69.91549	21.74833	33.0	Carousel feeding
12	28/10/2024	14:30	69.91452	21.75273	34.0	Carousel feeding
13	29/10/2024	23:16	70.14916	21.12072	34.5	
14	30/10/2024	05:27	70.08908	21.47426	34.8	
15	31/10/2024	08:45	69.94525	21.1165	33.0	
16	02/11/2024	21:04	69.96811	21.5801	34.0	
17	03/11/2024	17:55	69.90991	21.66381	30.5	
18	04/11/2024	07:52	70.12361	21.4061	33.5	
19	04/11/2024	16:08	70.13815	21.33951	36.5	Partially eaten by birds

3.8 Environmental data

Measurements of sound propagation conditions were made in connection with each sonar exposure experiment. The mixed-DTAG^{++} contains 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 field in their environment. To achieve this, Sound Speed Profiles (SSP) based on in situ environmental data collected during the experiments are used as input to sound propagation models. Temperature profiles (XBT) were collected during each exposure run using Lockheed Martin T7 XBTs. After each exposure experiment a more accurate Conductivity Temperature Depth (CTD) measurement was conducted using SAIV STD/CTD SD204. Figures below show the measured SSP for each exposure run and the modelled propagation loss based on the measured CTD SSP using the Bellhop propagation software.

Table 3.12 Overview of XBT and CTD cast collected during 3S-2024

CEE	XBT/CTD name	Date & Time (UTC)	Max Depth [m]	Latitude	Longitude
TEST	CTD_std_depth_sec_Ser01.txt	13-10-24 17:01:46	280	69° 49.5863'N	19° 52.1835'E
CEE I	XBT_T7_00002.EDF	15-10-24 22:04:04	220	70° 07.6158'N	20° 14.9613'E
CEE II	XBT_T7_00003.EDF	17-10-24 23:43:54	380	70° 13.62305'N	21° 05.46167'E
	XBT_T7_00004.EDF	18-10-24 03:47:19	380	70° 14.94922'N	21° 03.57275'E
	CTD_std_depth_sec_Ser02.txt	18-10-24 07:48:47	410	70° 13.2536'N	21° 04.3639'E
CEE III	XBT_T7_00005.EDF	20-10-24 20:44:58	280	70° 26.96924'N	20° 56.49341'E
	XBT_T7_00006.EDF	21-10-24 00:56:34	280	70° 24.83594'N	21° 04.15869'E
	CTD_std_depth_sec_Ser04.txt	21-10-24 08:24:56	290	70° 24.7137'N	20° 59.1015'E
CEE IV	XBT_T7_00007.EDF	26-10-24 23:51:02	350	70° 04.31543'N	21° 16.30566'E
	XBT_T7_00008.EDF	27-10-24 03:01:02	350	70° 06.30078'N	21° 15.57812'E
	CTD_std_depth_sec_Ser05.txt	27-10-24 08:03:09	230	70° 06.7369'N	21° 15.2701'E
CEE V	XBT_T7_00009.EDF	31-10-24 16:53:48	280	70° 08.62451'N	21° 17.10669'E
	XBT_T7_00010.EDF	31-10-24 21:09:02	240	70° 06.7373'N	21° 06.89551'E
	CTD_std_depth_sec_Ser06.txt	01-11-24 07:37:34	370	70° 07.2400'N	21° 07.8147'E
CEE VI	XBT_T7_00011.EDF	01-11-24 22:45:58	210	70° 6.06689'N	20° 18.599'E
	XBT_T7_00012.EDF	02-11-24 02:55:14	234	70° 5.08789'N	20° 10.32495'E
	CTD_std_depth_sec_Ser07.txt	02-11-24 08:03:40	210	70° 05.23'N	20° 18.06'E

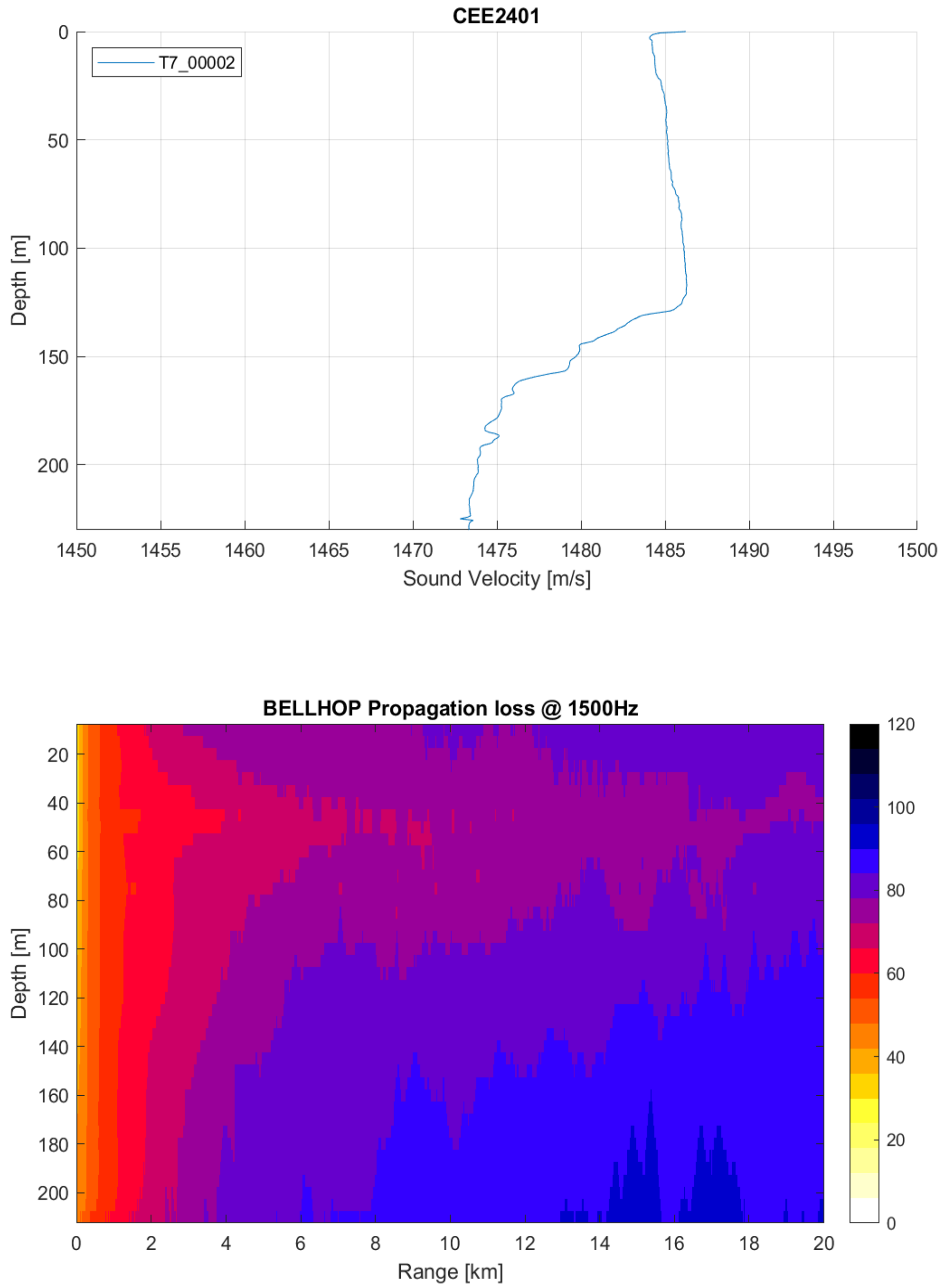
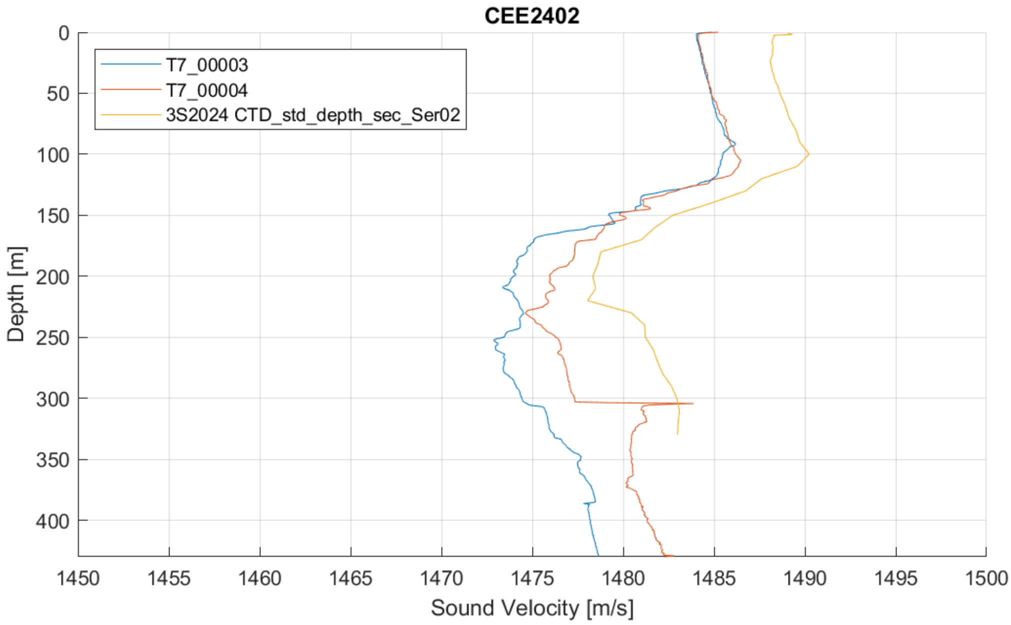


Figure 3.24 *Upper panel; XBT collected during CEE I. Lower panel; Bellhop propagation loss at 1500Hz based on the sound speed profile estimated from the measured temperature profile. Source depth is set to 100m.*



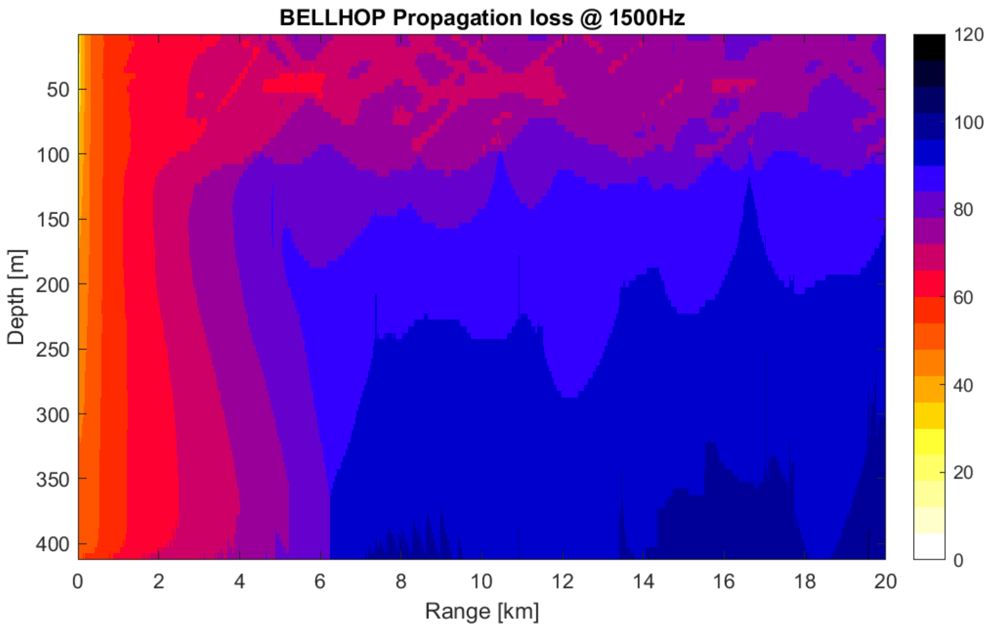
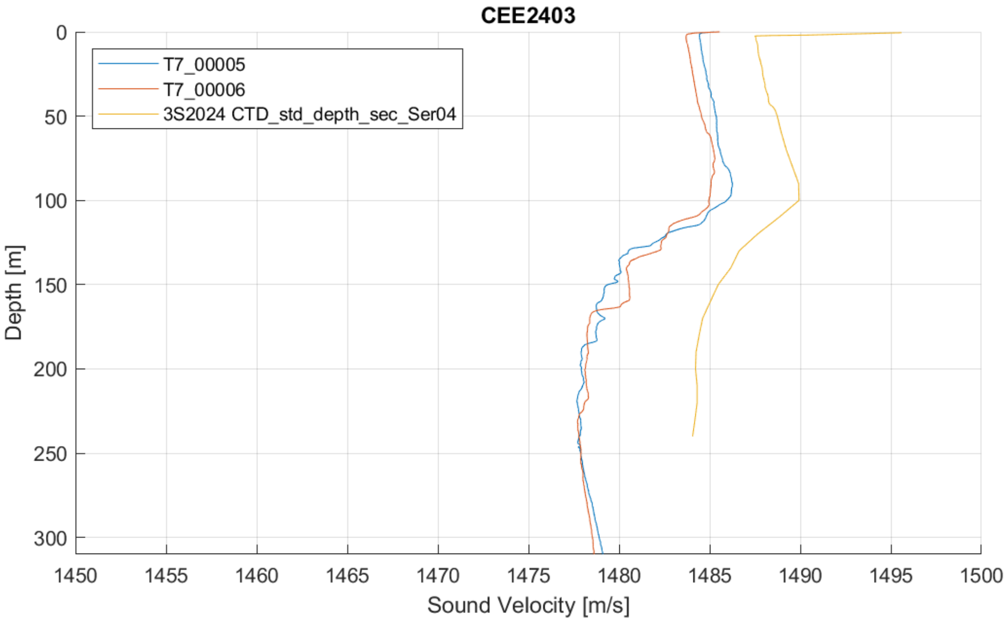


Figure 3.25 Upper panel; XBT and CTD collected during CEE II. Lower panel; Bellhop propagation loss at 1500Hz based on the sound speed profile estimated from the measured temperature and salinity profiles. Source depth is set to 100m.



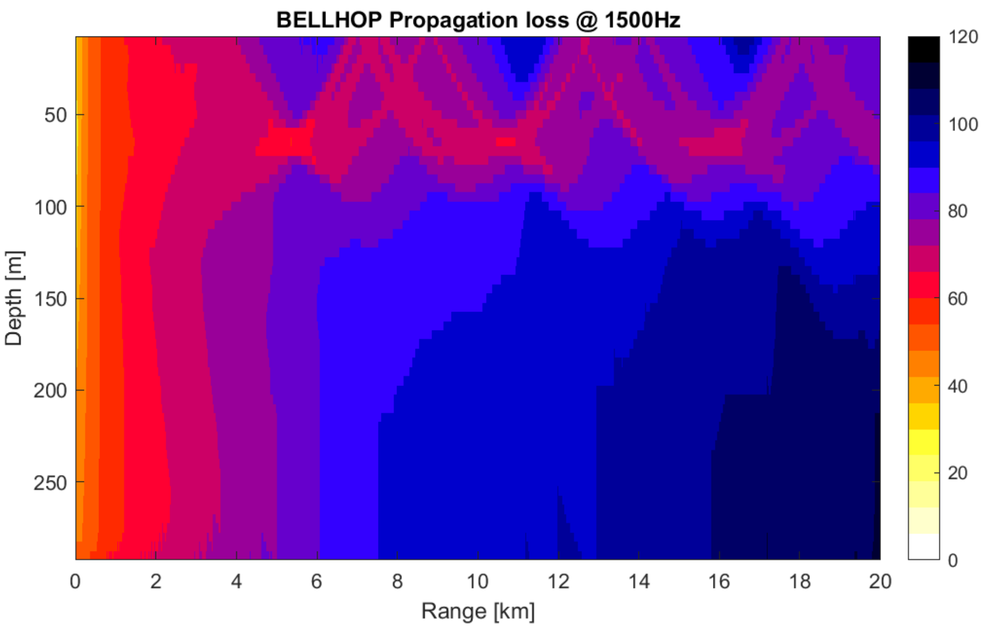
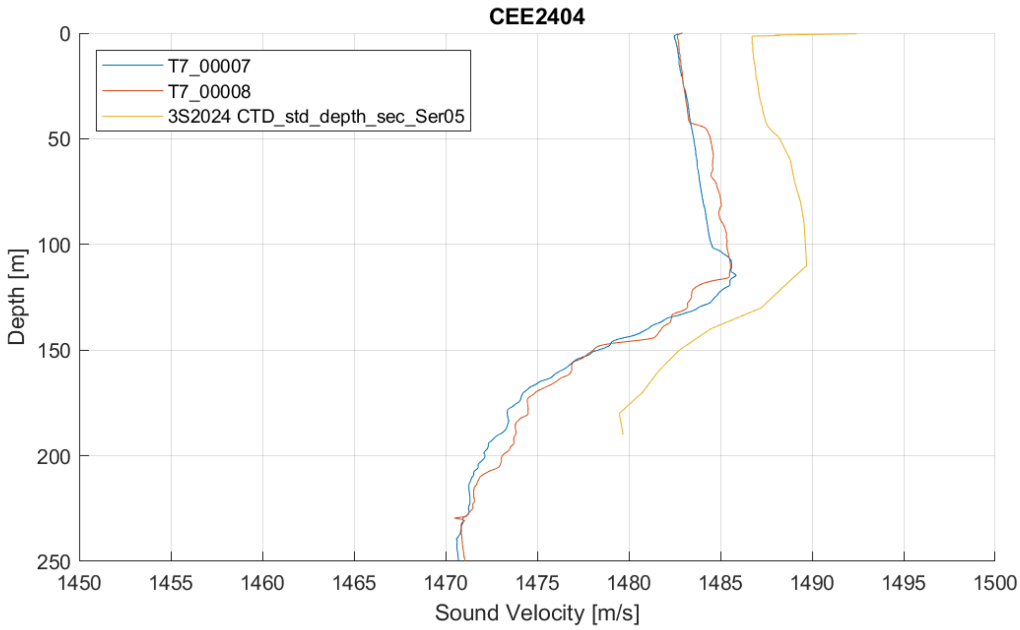


Figure 3.26 Upper panel; XBT and CTD collected during CEE III. Lower panel; Bellhop propagation loss at 1500Hz based on the sound speed profile estimated from the measured temperature and salinity profiles. Source depth is set to 100m.



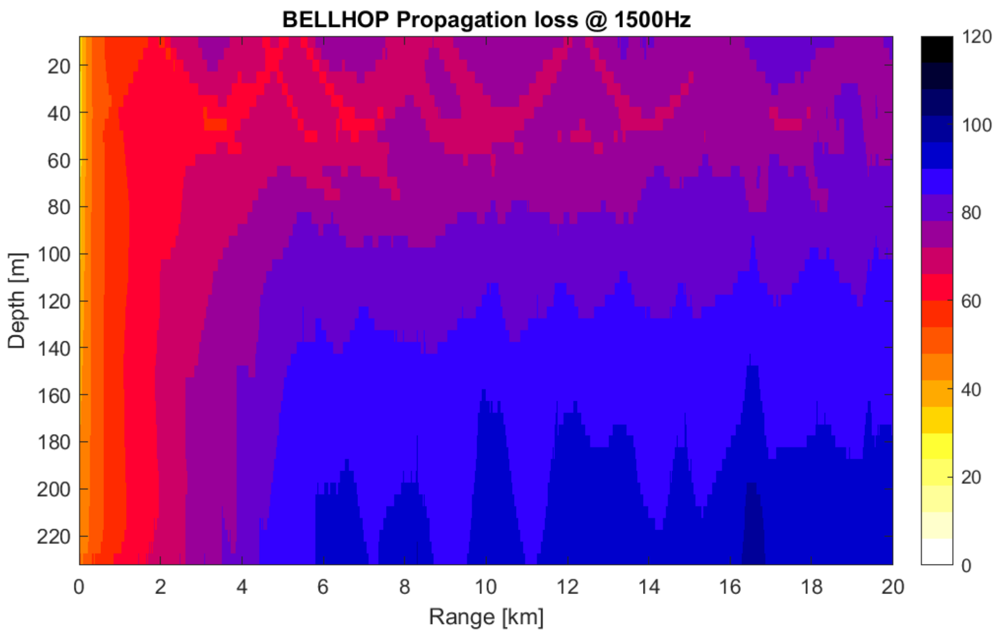


Figure 3.27 Upper panel; XBT and CTD collected during CEE IV. Lower panel; Bellhop propagation loss at 1500Hz based on the sound speed profile estimated from the measured temperature and salinity profiles. Source depth is set to 100m.

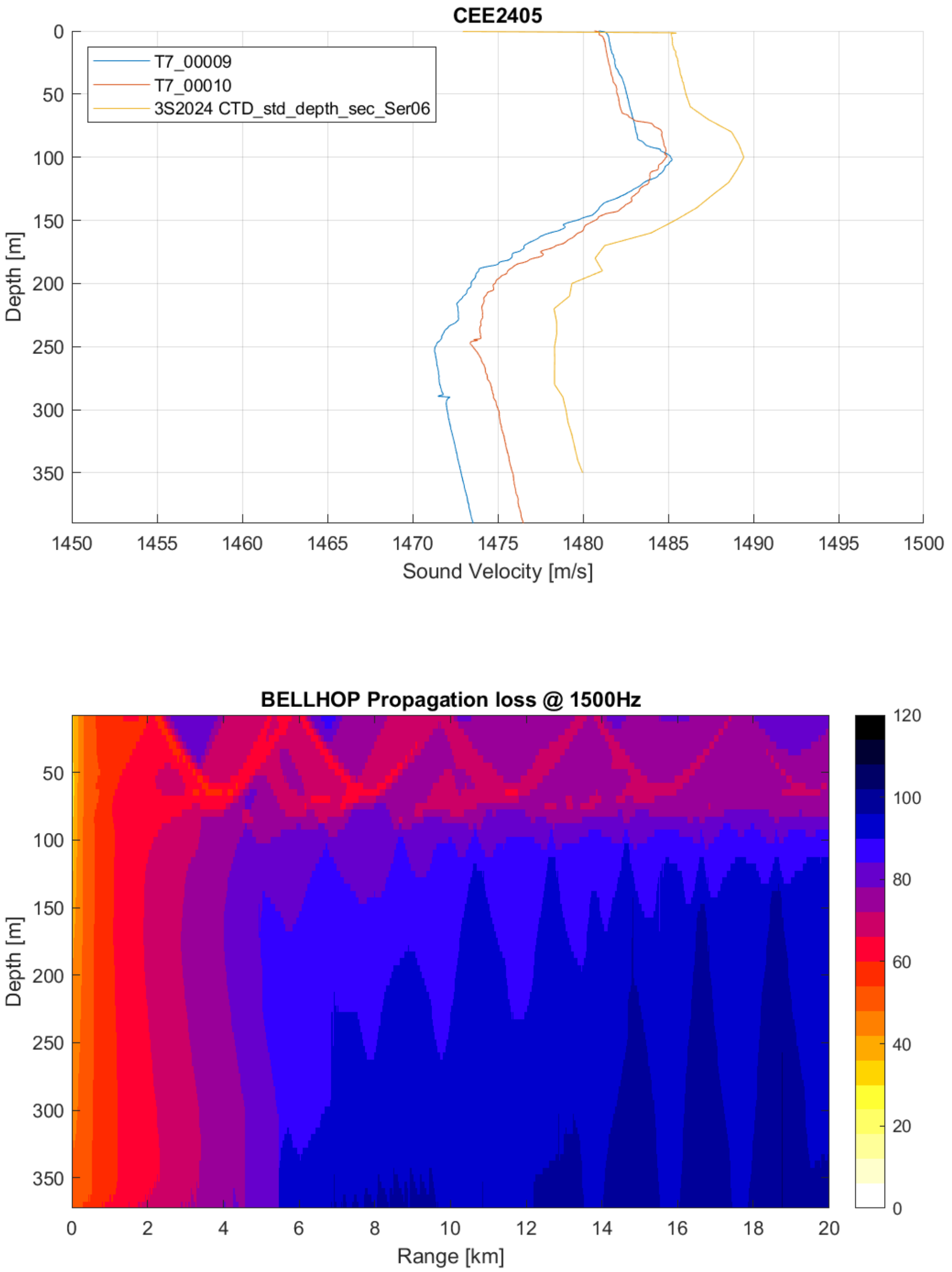


Figure 3.28 Upper panel; XBT and CTD collected during CEE V. Lower panel; Bellhop propagation loss at 1500Hz based on the sound speed profile estimated from the measured temperature and salinity profiles. Source depth is set to 100m.

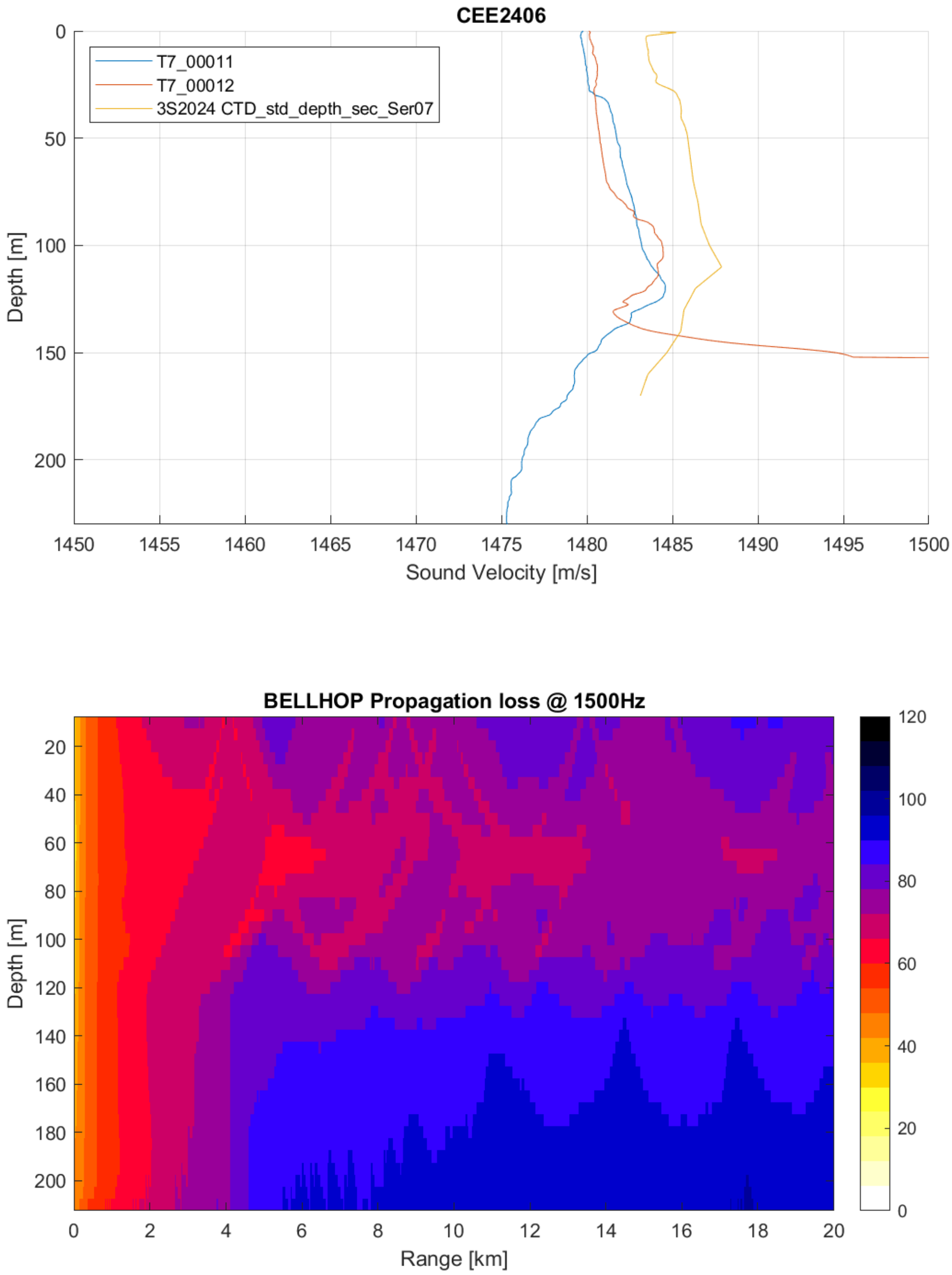


Figure 3.29 *Upper panel; XBT and CTD collected during CEE VI. Lower panel; Bellhop propagation loss at 1500Hz based on the sound speed profile estimated from the measured temperature and salinity profiles. Source depth is set to 100m.*

3.9 Photo documentation

One person on the tag-boat (MOBHUS) was dedicated to taking pictures of the tagging process, tag placement and photo identification of the tagged and nearby whales using a DSLR camera during daylight hours. High-definition video (e.g., 4K@30fps) was recorded both day and night using an action video camera (GoPro) mounted with a head strap on the driver and, or the tagger's head.

Photo documentation of all three SPLASH tags was achieved. This was because the SPLASH tags were deployed during the daytime, and that several SPLASH-tagged whales were re-encountered, providing additional photo opportunities (i.e., hours or days after).

Although low light-lens were used for photo documentation using Canon EOS 30D, photo documentation of DTAGs still proved challenging due to the limited light available during the predominantly nighttime tagging near fishing vessels. As suggested in the 3S-2023 cruise report (Kvadsheim et al. 2024), the DSLR camera had limited use under these conditions; instead, the GoPro served as the primary tool for photo documentation.

GoPros can record videos of crucial tagging moments while automatically adjusting the ISO. This feature allows us to extract snapshots of the tagging moment, which may be used for assessing tag placement and for photo identification. The GoPro videos were used to evaluate the tagging process and the behavioural response of the animal. Photo identification was used to ensure that the tagged animal was not previously tagged. Photos of SPLASH tags were useful to assess how tag placement affected the acquisition of GPS Positions and relaying of data through the Argos Satellites.

For future cruises, it is recommended to continue using DSLR cameras for tag documentation during the day and GoPro as the primary tool at night.

The footage and pictures collected during the trial were edited together into a 20 min promo video showing the activities during the 3S-2024 trial. Link to this video can be found in the Summary on page 3.

Figure 3.30 Photo of a SPLASH-tag deployment on a killer whale using the Dan-Inject (Oo24_291SAT#1). The picture was taken with a low-light lens DSLR camera during day-time tagging (Photo: Ellen Hayward).

Figure 3.31 Photo of a Mixed-DTAG^{++} deployment on a killer whale taken during daytime tagging. (Photo: George Sato).

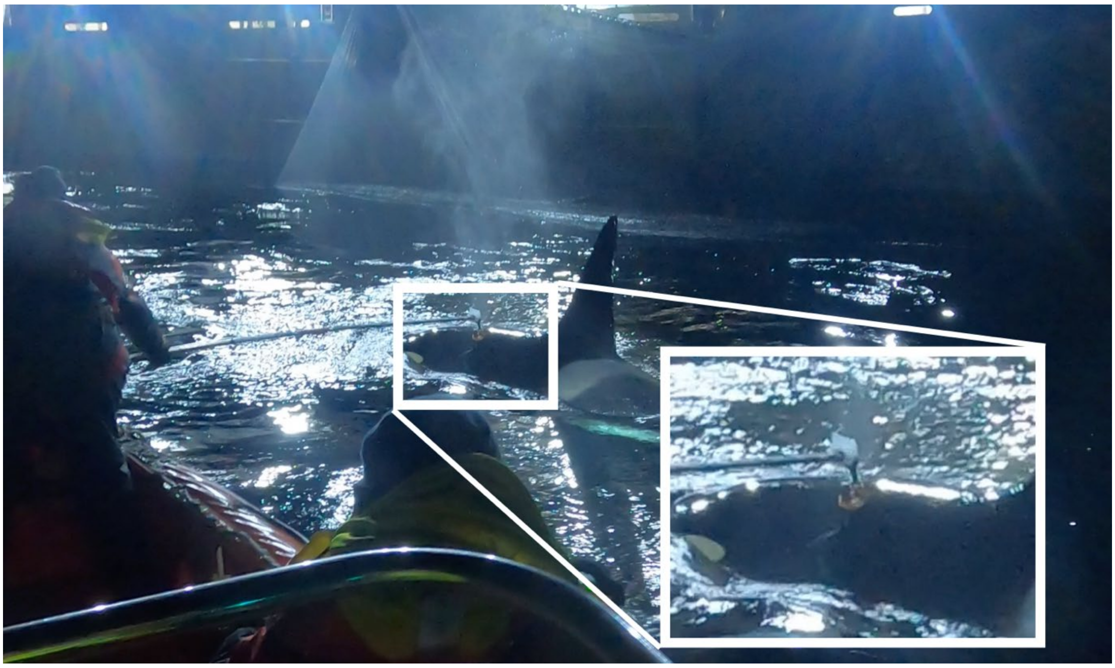


Figure 3.32 Still image exported from GoPro video recorded from the boat driver during nighttime tagging.

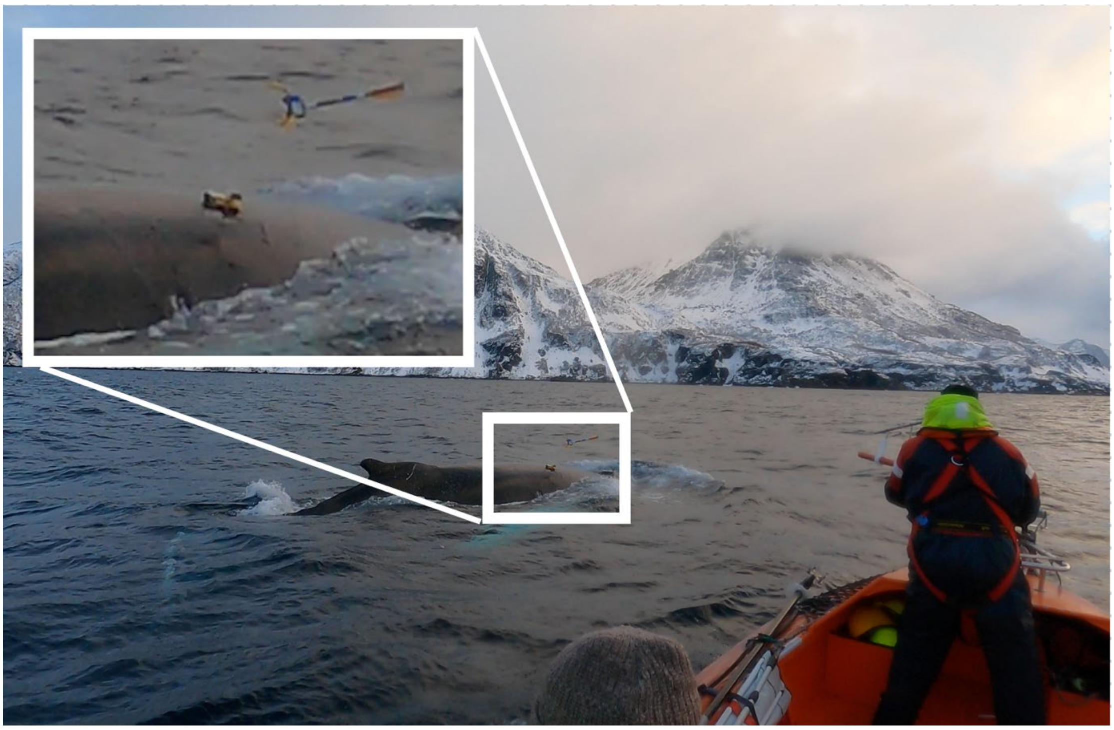


Figure 3.33 Still image exported from GoPro video recorded from the boat driver during day-time tagging.

3.10 SOCRATES harmonics test

Low frequency harmonics tests were performed during the 2016 cruise to characterize the SOCRATES 2 source (Lam et al. 2018). In 2016 it was expected that most of the harmonics are caused by the transducer, but some of the harmonics could also be caused by the amplifier being driven to the design limits. In recent years the amplifiers have been replaced and after the 2023 trial the low frequency source has been repaired. To be sure that the source behaviour has not changed the harmonic tests conducted in 2016 was repeated in 2024.

The measurements were performed on October 23rd between 07:32Z and 09:05Z in Lyngenfjord. The hydrophone recorder OWID was deployed off MOBHUS which was drifting with the engine turned off. HU Sverdrup sailed in circles around them at 550 m range (radius) towing the SOCRATES source transmitting continuous waveform pulses (CW). Transmissions started with a ramp up and mitigation observers were in place during the entire test. The source transmissions are recorded by the OWID system. OWID has a dynamic range of 90dB (16bit) and was set to a gain of 24dB.

CW pulses used for the analysis had the following settings:

- Frequency 1000, 1500, 2000 Hz
- Pulse length 0.01, 0.1, 1s combined in one 3 second wav
- Pulse repetition time 10s
- Source Level 214, 208, 201 dB re 1μPa^{2}m
- Source Depth ~110m
- Cable Scope 200m

The power spectral density (PSD) is used for the analysis of the data averaged over multiple transmissions (Table 3.13). The data is normalized to get a good comparison independent of the source distance. Some measurements were clipped and not used in this analysis.

Table 3.13 Number of pulses used for the analysis

Frequency [Hz]	Source Level 201dB	Source Level 208dB	Source Level 214dB
1000	30	26	27
1500	30	32	17
2000	28	27	6

The analysis shows that the number of valid measurements for the high source level pulses was very small, due to clipping of the recorded signals. Lowering the gain of the recorder during transmissions of higher source powers can solve this problem.

Table 3.14 shows the relative received levels of the 1st and 10th harmonics for different source levels compared to the harmonics test of 2016 (Lam et al. 2028). Figure 3.34 shows the graphs of the relative received level for all frequencies and source levels.

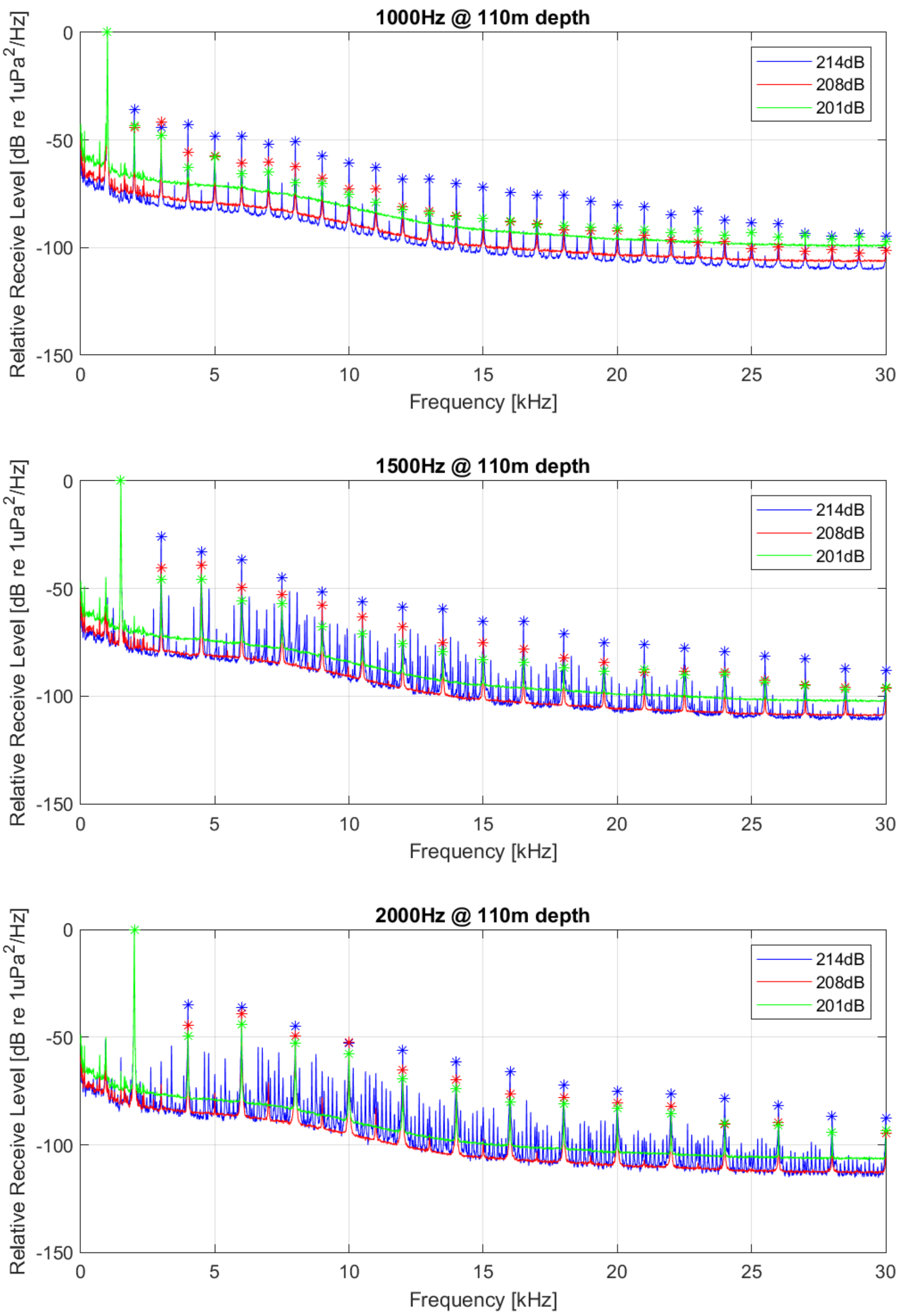


Figure 3.34 Averaged spectral levels at various frequencies and source levels. Stars mark the peak harmonic levels, and are overlapping for the first peak.

Table 3.14 Normalized results of 1st and 10th harmonics for different source levels from 2024 tests of harmonics. Results of the 2016 tests are given in parenthesis.

Frequency [Hz]	Source Level 201dB		Source Level 208dB		Source Level 214dB	
	1st harm	10th harm	1st harm	10th harm	1st harm	10th harm
1000 Hz	-43 (-29)	-79 (-74)	-44 (-39)	-73 (-73)	-36 (-37)	-63 (-67)
1500 Hz	-46 (-45)	-84 (-76)	-40 (-40)	-78 (-74)	-26 (-36)	-65 (-65)
2000 Hz	-49 (-44)	-85 (-76)	-44 (-41)	-82 (-72)	-35 (-36)	-77 (-68)

An increase in the harmonic levels is visible when the source level increases. This increase is in the order of 1-2 dB. There is some spectral leakage visible especially at higher source levels in the 1500Hz and 2000Hz pulses.

The results of the relative received levels at the 1st and 10th harmonics are comparable to the results of 2016. The first harmonics of the lower source levels are lower than the results of 2016. For higher source levels the relative received levels are comparable to the 2016 results

On average the harmonic levels are:

- 1st harmonics: -40.3±11.5 dB
- 10th harmonics: -76.2±11.0 dB

3.11 Observations of a bycatch incident

On the morning of 31st October the 3S team approached fishing boat MS Smaragd to attach Mixed-DTAG++ to killer whales. We observed that 5 killer whales were trapped inside their purse seine fishing net. We immediately offered to help release the whales, and contacted the Fishery Directorate sea service. They arrived on the scene 2.5 hrs later, and deployed a RHIB which approached the fishing net with the entangled whales. Meanwhile MS Smaragd had pulled the net together, with the outcome that 4 whales drowned. The 3S team attempted to assist with the effort to release the whales from the net, but had no other involvement in the incident. Upon request of the Fishery Directorate we provided a report with our observations (FFI 2024).

4 Discussion

4.1 Outcome of the trial

The 3S-2024 trial had two primary tasks (1-2) and eleven (3-13) secondary tasks. Below we summarize the achievements under each task:

1. Tag killer whales with mixed-DTAG^{++} and expose them to dose escalating 1.3-2.0 kHz CAS or PAS twice over an extended period (8 hrs) during daytime or nighttime.
   - ✓ *Twenty killer whales were tagged with mixed-DTAG^{++}. Six long-duration controlled exposure experiments (3 CAS and 3 PAS) on multiple (N=14) animals (5 focal and 2 non-focal exposed to CAS and 5 focal and 2 non-focal exposed to PAS) were conducted successfully. All exposures were 8 hrs duration and all of them were conducted during nighttime when the animals are feeding in order to minimize contextual variation.*

2. Tag killer whales with SPLASH tags in the core operation area (higher priority early in the trial).
   - ✓ *Three Splash tags were deployed the first week of the trial. The tags collected data over periods from 4 to >20 days.*

3. Tag humpback whales with mixed-DTAG^{++} and expose them to dose escalating 1.3-2.0 kHz CAS or PAS twice over an extended period (8hrs) during daytime or nighttime.
   - ○ *Tagging of humpback whales were a lower priority this year. Nevertheless, eight animals were tagged with mixed-DTAG^{++}. No CEE was conducted, either because the deployments were planned to be baseline records (n=3) to not interfere with primary tasks, because of premature tag release or intermittent GPS tracking (n=4) or because the animal was in an area where CEEs were not possible due to bathymetry restrictions (n=1).*

4. Tag killer whales or humpback whales with mixed-DTAG^{++} and expose them to dose escalating 4-6 kHz CAS or PAS twice over an extended period (8hrs) during daytime or nighttime.
   - ○ *No experiment was conducted using the MFAS (4-6kHz) signal this year. This was primarily meant as a back-up in case the 1-2kHz LFAS transducer failed as last year.*

5. Tag killer whales and humpback whales with mixed-DTAG^{++} and expose them to short duration CAS or PAS.
   - ○ *No such experiment was conducted. This was only meant as a back-up in case the long duration exposures turned out to be unfeasible, either because the Socrates source could not do the longer duration transmissions or if the real time tracking of the whale did not work as intended. Everything worked as planned, and therefore this back up plan was not needed.*

6. Collect 24 h duration baseline data records of target species.

✔ *The 3 Splash tags collected data on diurnal patterns of killer whales over periods from 4 to >20 days. In addition,* mixed-DTAG++ *collected 149 hrs of baseline data from 20 killer whales and 8 humpback whales, of which 4 records were over extended periods of >12 hrs.*

7. Collect echosounder data and fish samples to monitor the prey field.

✔ *Echosounder data were collected opportunistically within 1nmi of one of the focal animals during pre-exposure and post exposure phases of the CEEs. In total 64GB of echosounder data were collected. In additional 17 herring samples were collected for analysis of energy content of the prey.*

8. Collect drone footage of tagged subjects for body condition characterization.

○ *No drone flights were attempted, primarily due to weather and daylight limitations as most of the tagging was done in the dark.*

9. Collect information about the environment in the study area (CTD, XBT).

✔ *11 temperature profiles (XBTs) and 6 sound speed profiles (CTDs) were collected in the area where the exposure experiments were conducted.*

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

✔ *A total of 84 sightings of five cetacean species were recorded during the trial. The most sighted species were killer whales and humpback whales.*

11. Perform sound source (SOC) long duration engineering test and harmonic characterization.

✔ *The long duration endurance test was done in Vågsfjord on October 12th before we transited to the operation area. The harmonics characterization was done in Lyngenfjord on October 23rd during the transit to Tromsø for the crew change.*

12. Collect photo documentation for photo id, tag documentation and public outreach purposes.

✔ *Photo id and documentation of the tag placement was done using GoPros or a Canon low light lens. Footage and pictures of our activity have been edited together in a 15min promo video of the 3S-2024 trial. This will be released on the FFI website as part of the cruise report.*

13. Record acoustic cues of fishing vessels and relate that to the different steps of the fishing activity.

✔ *This was done on October 27th between 21-23 UTC using the OWID hydrophone system deployed off MOBHUS. The system recorded sounds from the fishing process of MS Kings Bay from setting the nets to nets recovered at 100-300m range.*

4.2 Hot wash recommendations

At the end of the trial, the science team participated in a hot wash de-brief onboard the HU Sverdrup. The 3S4 project management board has secured funding for an additional low-frequency CAS/PAS trial focused on humpback- and killer whales. Funding has been secured for at least a three-week trial. The aim of the de-brief was to summarize the events of the trial, highlight achievements, and brainstorm possible improvements for future trials. A list of potential changes was compiled during the brainstorming sessions which will be considered during planning of the final 3S4 trial in 2025. The list comprises on-the-spot suggestions from members of the science team who participated in this year's trial and does not indicate that there is consensus within the group about each suggestion. The following list has not been prioritized but is organized in themes and presented in the order each suggestion was made. The list could be considered a 'wish list' and will have to be considered by the 3S board before implementation to assess the benefits and cost implications.

4.2.1 Experimental design and overall trial planning

- Do not schedule the trial with a later start date than this year
  - By the end of the trial more whale watching boats were present, and the fishing fleet moved into the fjords where CEEs were more difficult to do.
  - We recognize there are lots of factors with variability in the fishery and when the Fjordline is opened (hard to predict).
  - If the trial is scheduled earlier than this year, the fishery might not have started and we might need to do more open water wild tagging. That might be ok given the demonstrated effectiveness of ARTS tagging.
- Consider to conduct CEEs not only during nighttime feeding near fishing vessels to cover other behavioural contexts during exposure.
  - Counter point: Main question is to contrast PAS vs CAS within one specific context, and limit other variables to increase power of analysis.
- Consider to tag other whales, not just large male killer whales, to also collect data from females and calves.
  - Counter point: Tag performance is better on larger animals and groups mostly move together (males represent group response).
- Deliberately vary timing of CPA between first and second approach so that there is some variation between sonar activation time and CPA time.
  - Counter point: Changing the protocol now would introduce more variability.
- Collect more data on group structure, e.g., photo ID. A possible way of doing this is for the tag-boat to go out in post-exposure period to collect photo IDs. This might allow us to also see if the same animals are exposed multiple times over the course of the trial and to examine habituation/sensitization over longer timescale than just an individual CEE.
  - There might be lots of groups mixing together around fishing vessels, do they leave in the same group as they arrived in?

- Rethink how to record fishing vessel signature; consider floating passive acoustic recorders.

4.2.2 Tags, tagging, tag-boats

- Tagging worked well, including the combination of ARTS and pole tagging
- ARTS facilitated wild tagging away from fishing vessels
- More Splash tags could be useful to determine how whales are moving around on larger scale, especially between CEEs (would help to determine if they are being re-exposed), and to capture between year variability.
- Getting tags out during the day facilitated nighttime exposures.
- Consider increased use of ARTS also during nighttime tagging around fishing vessels
- Mount ARTS in MOBHUS (safely tucked away), so that it’s available if the situation requires, or to facilitate switch back to pole tagging quickly.
- Lights on MOBHUS functioned well for tagging and picking up tags.
- Examine positioning and deployment of tags on whales to determine if there are factors that would decrease tags slipping, resulting in infrequent position updates or loss of tracking entirely while attached to whales.
- Have ‘grab-and-go’ tags available.
    - Ensure that at least one tag is always available, so as not to lose tagging opportunities.
    - When tagging during watch change, have second team ready to go with new tags (if necessary) as soon as the tag-boat returns.
- Improve communication between science team groups; for example, bridge team should communicate to tag technicians and tag team that they need to be ready to go in 30 minutes, or if one tag should be held back for shift change.
- Establish protocol for what needs to be confirmed on the tag-boat for the tag to be deployed (e.g., VHF and GPS checks).

4.2.3 Sonar source

- Socrates worked great this year. During both CAS and PAS no problems experienced even at full power for the full 8 hr duration of the exposures.
- Better radio at SOCRATES station would improve communication with MOBHUS

4.2.4 CEE tool and tracking

- Consider to get rid off directional VHF antenna and DF-Horten box (it has not been required during 3S-2023 and 3S-2024, and performance is not consistent).
- Examine why real-time GPS tracking would not work sometimes as it has impacted ability to conduct CEEs
    - Fast GPS shows ephemeris not found error for several hours. Could be due to weather conditions, or that the signal gets reflected/blocked inside the fjords.
    - Careful examination of GPS error messages

- Change GPS receiver on the ship for optimal reception of ephemerous GPS data. Require longer cable.
  - Ephemeris can be found online, but functionality not included in processing code. Get source code from LOTEK so that we could try to develop the capability ourselves.
  - Consider dedicated internet connection.
- Move directional antenna to different location, not attached to a metal mast. Move the directional antenna to where VHF antennas are currently located.
- Consider to acquire new directional antenna (would be very useful to have bearings for tracking)
- Establish better methods to clean up the track database; after several days the map could become very cluttered with "old" tracks.
- AIS does not show all contacts. Mismatch between ID's and names. Ghost tracks show up.
- A functionality for recognizing fishing vessels and time of pumping could be added.
- Take the functionality of the ARGOS data ellipse on/off button out of the database, so it can be used by 2 users at the same time.
- Add bearing tool to add bearing lines, to make cross sections (and range estimate) for VHF-detections

4.2.5 MMO and mitigation

- Install wind screens on mitigation platform in the bow
- Changes were made this year to have fewer dedicated MMOs and increased tag technicians – this worked well but everybody need to support the MMO task when they can.
- Try to streamline confirmation of VHF and GPS checks on tags to not lose tagging opportunities.
- May be not worth bringing big eyes. They were only used once.
- Do we need to record sightings during mitigation
- The MMO can provide support to the tagging effort also during nighttime by doing observations from the bridge using fishing lights or moonlight.

4.2.6 Prey field mapping

- During pre-and post-exposure HUS should stay within 1nmi of the focal animal to collect data near the whale.

4.2.7 Safety

- Davit operators were very good when lowering/raising tag-boat
- Consider procedure for deployment and recovery of tag-boat
  - Consider separate people handling catch line and hook clip for recovery of tag-boat, as suggested by HUS sailors.

   - Counter point: If three people are needed for safe recovery of MOBHUS, more training and less rotation of crew would be needed.
- Treat ARTS as a gun (always point it out of the boat and release pressure when not in use).
- Crew were happy with our use of PFD and high visibility clothing on deck (don't forget the helmet).
- Establish sea state and weather limitations for conducting mitigation from the bow deck.
- Work permit is required every time someone need to climb the mast.
- In case of sudden unexpected weather deterioration;
  - Tag-boat driver should have eye protection (goggles, glasses and ski mask) available in tag-boat.
  - Safety glasses for the tag team.
  - Tag-boat driver should choose to turn out of the wind and wait until snow shower passes
- Place radio handset in a different position on MOBHUS to be able to quickly grab it and avoid inadvertently switching to Ch 16.
- Better maps on the tag-boat
- Do not stop the engine on MOBHUS, and never connect the emergency battery unless there is an emergency.

4.3 Status of data collection

The 3S-2024 trial achieved the primary tasks and the most important secondary tasks, and must be considered a great success. We collected significantly more data than during the 3S-2023 trial (Kvadsheim et al. 2024) and the key technical components worked well; ship, tag-boat, Socrates source, Mixed-DTAG^{++} and the real time tracking of whales using the Goniometer antenna and the CEE-tool.

The combined dataset collected during 3S-2023 (Kvadsheim et al. 2024) and 3S-2024 includes 10 long duration CEEs to a total 21 whales (Table 4.1). Thus, this is a huge and unique dataset. The data collection has been split between two different species, killer whales and humpback whales, with focus on killer whales. However, since the LFAS transducer of the SOCRATES source failed in 2023 (Kvadsheim et al. 2024), but worked well in 2024, exposures data have been collected using two different frequency bands with different source levels. Furthermore, the data collected so far show a very clear diurnal pattern, with animals generally feeding around purse seine fishing vessels at night and resting during the day. During the 3S-2024 trial all exposures were conducted during nighttime using the SOCRATES sonar source in the 1-2 kHz band at 214 dB energy source level (re $1\mu Pa^2 \cdot s \cdot m^2$). During the 3S-2023 trial (Kvadsheim et al. 2024), the exposures were all conducted during daytime, but at 197 dB source level and in the 4-6 kHz band. The focus of the data collection has been to contrast responses to CAS and PAS, and as such we have collected a balanced dataset. However, species, behavioural context (feeding or resting), sonar levels and frequency band are all potential factors affecting if and how animals respond. We have not analyzed the data in detail yet, but it seems clear already that more data are needed to fully account for such variables and get conclusive results on the difference in responses between CAS and PAS, and if the animals habituate or sensitize to long duration exposures.

Table 4.1 The 3S4 dataset split up by killer whales (panel A) and humpback whales (panel B), by LFAS exposures, MFAS exposures and Baseline data, by Daytime and Nighttime exposures, and by CAS and PAS exposures. F are focal whales and NF are non-focal whales. The sonar signals are specified by frequency band and maximum energy source level in dB (re 1µPa²·s·m²). Exposure data are collected using the mixed-DTAG⁺⁺, but baseline data are also collected using Splash tags.

A **Killer Whales**	**LFAS (1-2kHz @ 214dB)**				**MFAS (4-6kHz @ 197dB)**				**Baseline**	
	Daytime resting (F+NF)		**Nighttime feeding (F+NF)**		**Daytime resting (F+NF)**		**Nighttime feeding (F+NF)**		**Splash tag**	**Mixed-DTAG++**
	CAS	**PAS**	**CAS**	**PAS**	**CAS**	**PAS**	**CAS**	**PAS**		
3S-2023					2+0	3+1			6	7
3S-2024			5+2	5+2					3	7
Total	**0**	**0**	**7**	**7**	**2**	**4**	**0**	**0**	**9**	**14**

B **Humpback Whales**	**LFAS (1-2kHz @ 214dB)**				**MFAS (4-6kHz @ 197dB)**				**Baseline**	
	Daytime resting (F+NF)		**Nighttime feeding (F+NF)**		**Daytime resting (F+NF)**		**Nighttime feeding (F+NF)**		**Splash tag**	**Mixed-DTAG++**
	CAS	**PAS**	**CAS**	**PAS**	**CAS**	**PAS**	**CAS**	**PAS**		
3S-2023					1+0					4
3S-2024										8
Total	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**12**

4.3.1 In conclusion

We have so far collected a balanced dataset to address the CAS-vs-PAS question and the effect of longer duration exposures. However, the variation in behavioural context between exposures and the unintended variation in the tested sonar signal have introduced more variation in possible explanatory variables than first intended, indicating more data are needed to generate conclusive results. We therefore recommend that a third trial is conducted in 2025, with the aim to complement the existing dataset. When establishing the plan for the 3S-2025 trial, careful consideration must be given to optimize data collection to achieve the project objectives. The balance between killer whales and humpback whales, between LFAS and MFAS, between daytime and nighttime exposures and between CAS and PAS must be considered carefully.

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Appendix

A 3S-2024 Data inventory

Table A.1 The following data was recorded/created during the 3S-2024 cruise.

Folder	Description
Acoustic clips	Wav files containing recorded audio data of a tag with audible rampup and subsequent pulses.
acousticDataAndResults	Analysis scripts to verify if the rampup and subsequent pulses were audible in the recorded audio data of a tag. The script uses a matched filter analysis on specific wav files.
Bridge log	Logbook of the bridge, including daily orders published to the crew.
Briefs	Presentations of the crew briefing and closing hotwash meeting.
CEE Tool	Images, movies and screenshots made using the CEE tool, including day to day images of the Sverdrup track and sonar transmissions. This folder also contains the CEE tool databases, sorted per experiment.
CTD_XBT	Recorded CTD and XBT data during the trial.
Drone data	Drone recordings.
DTAG	All DTAG associated data
echosounderData	Data recorder by the H.U. Sverdrup II echosounder. Raw data and .TIFF of echograms
fishSample	Fish sample logs
Goniometer	Recorded data of the goniometer bearing and GPS positions of the tags.
GPSlogs	GPS and AIS logs of H.U. Sverdrup II
Logger	Logger logs, containing sightings and relevant events.
OBS deck	Useful info printed for obs deck about tags.
Pics and videos	Pictures and videos.
Satellite tags	Argos satellite data configuration.
SocratesLogs	GPS and transmission logs of the Socrates source.

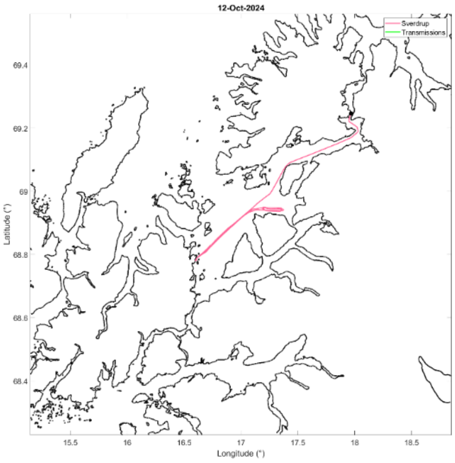
The data was shared between all partners using a software tool “Sync Toy”. The data was transferred from a laptop to 5 USB connected drives. Each drive had a capacity of 8 TB and >100 MB/s write speed.

B Daily activity and sail tracks

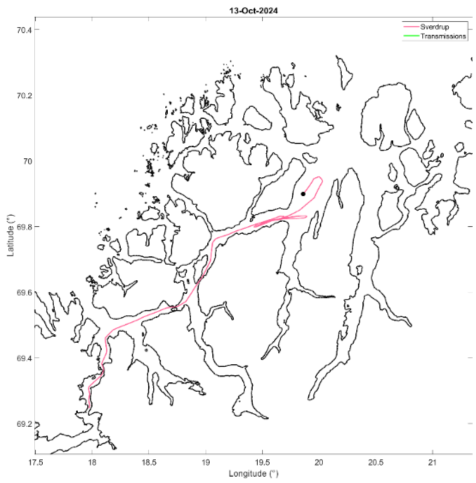
Figure B.1 Overview of sailed tracks for every day of the 3S-2024 trial. The red line indicates the sailed track of the H.U. Sverdrup II, where the black dot at the end of the line indicates the position of the Sverdrup at the end of the day. The green line indicates parts of the track where the sonar was actively transmitting. KW is killer whales and HW is humpback whales.

October 10 Harstad - Joint briefing, embarkment, mobilization (no map)

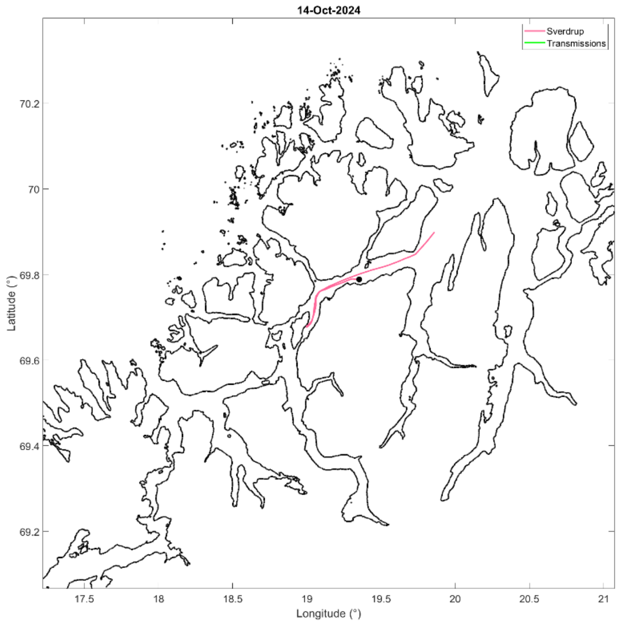
October 11 Harstad - Testing, training, safety briefs (no map)



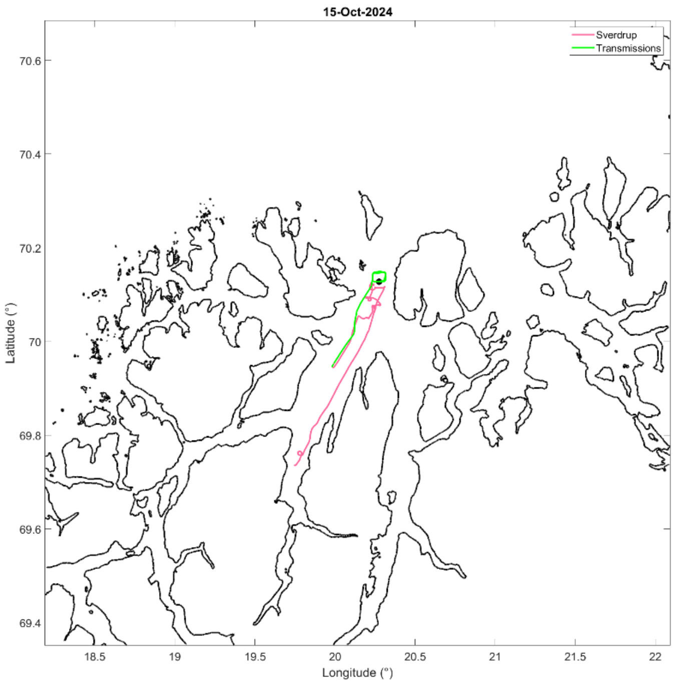
October 12 Vågsfjord-transit North - Endurance test of Socrates. Overnight transit to operation area.



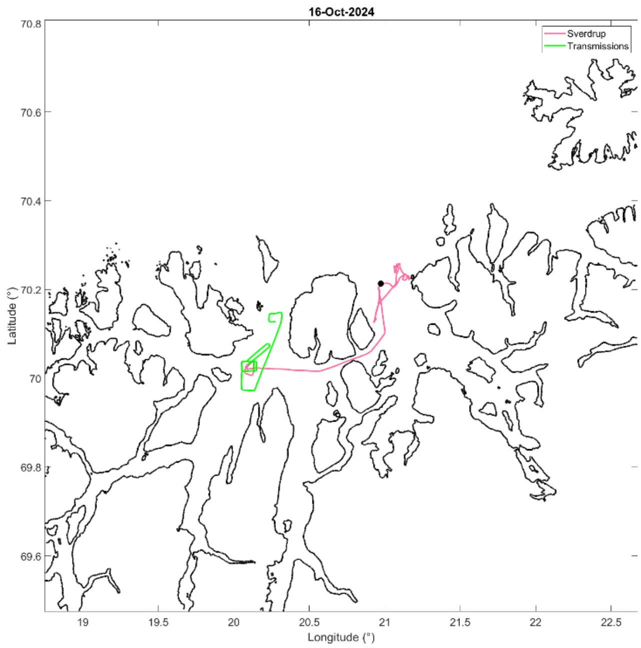
October 13 Grøtsundet-Ulsfjord - ARTS training, VHF and Goniometer range and bearing tests of tags.



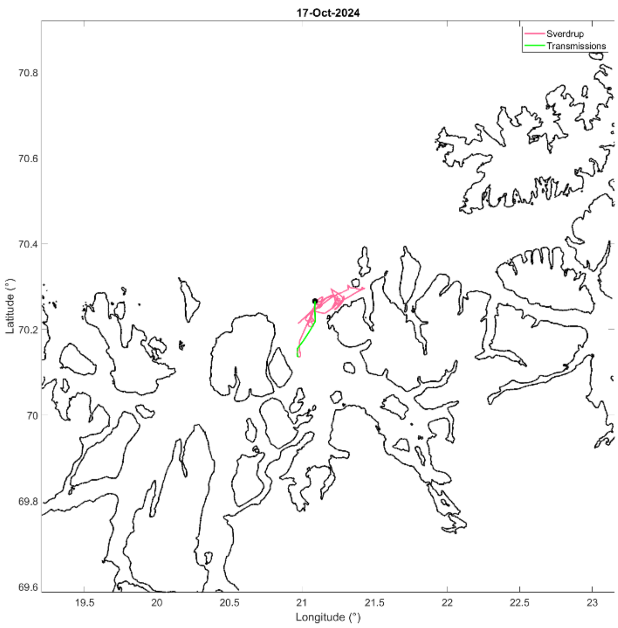
October 14 Tromsø – Port call to fix AIS on MOBHUS. Training with DanInject during transit out.



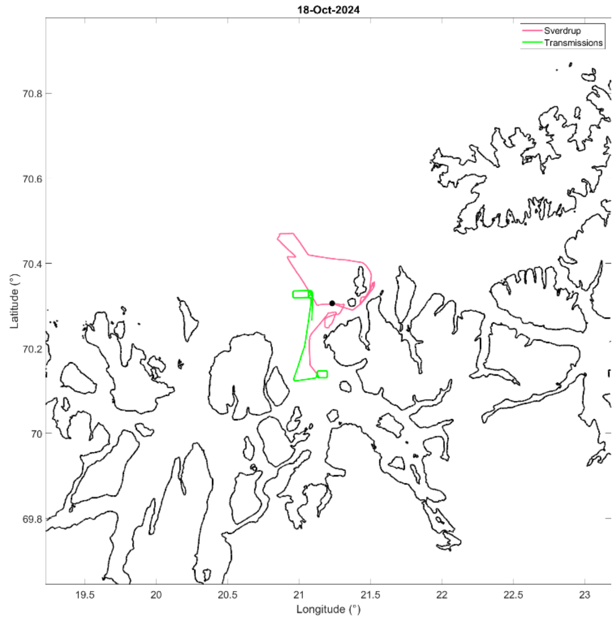
October 15 - Visual survey for target species in Fugløyfjord. Tagged a KW and started CEE I



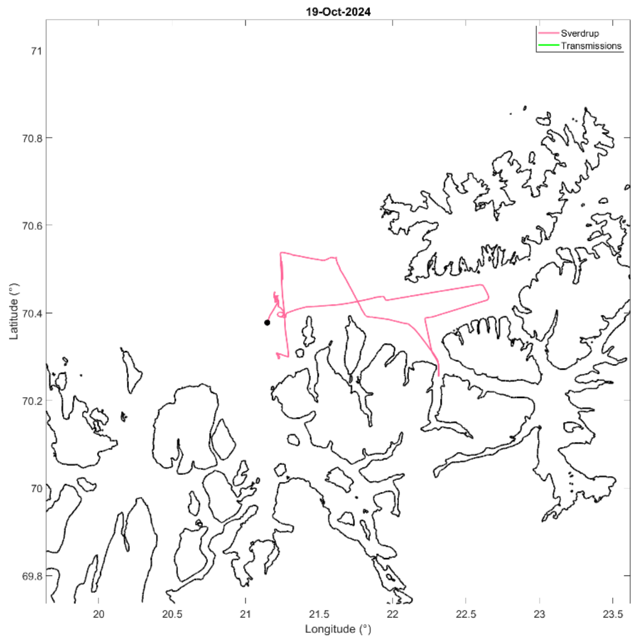
October 16 Fugløyfjord-Kvænangen – Finished CEE I, post exposure and recovering tag. Survey through Kvænangen, tagged a KW, preparing for CEE II.



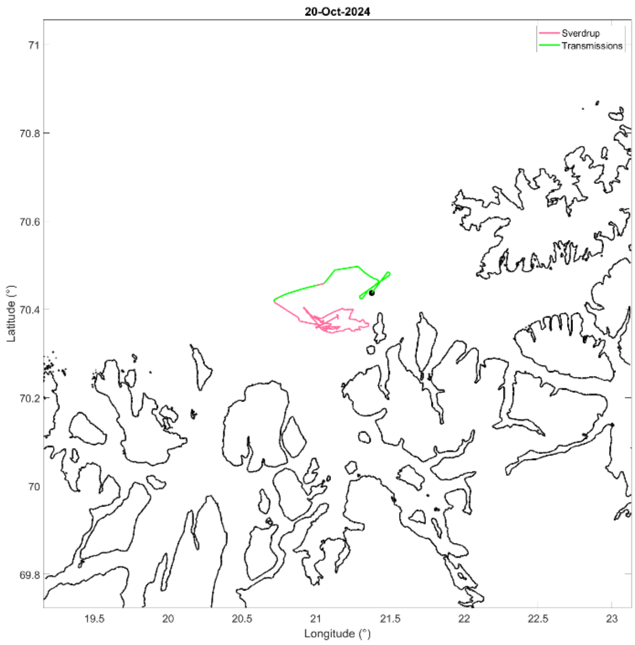
October 17 Kvænangen - tag slipped on the animal CEE cancelled. Started tagging again. Two splash tags and three more Mixed-DTAGs deployed. Started CEE II.



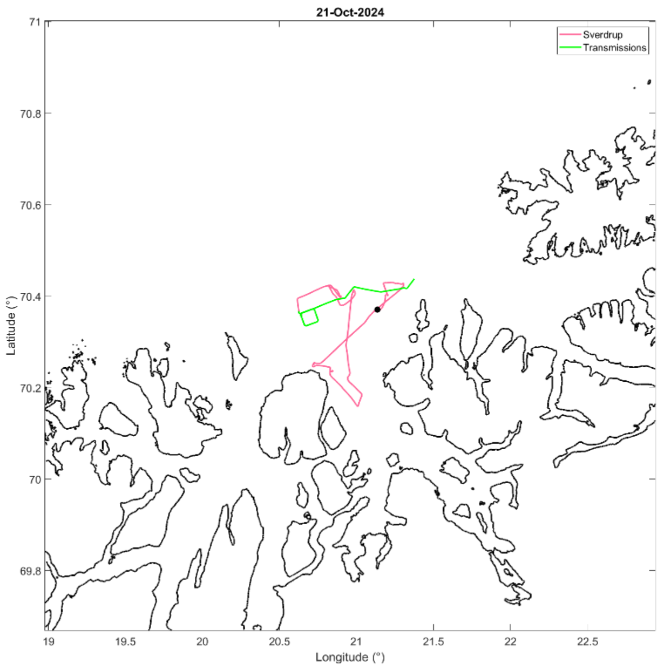
October 18 Kvænangen - Conducted nighttime CEE II with 2 focal KW and two non-focal KWs. Post exposure and recovered tags.



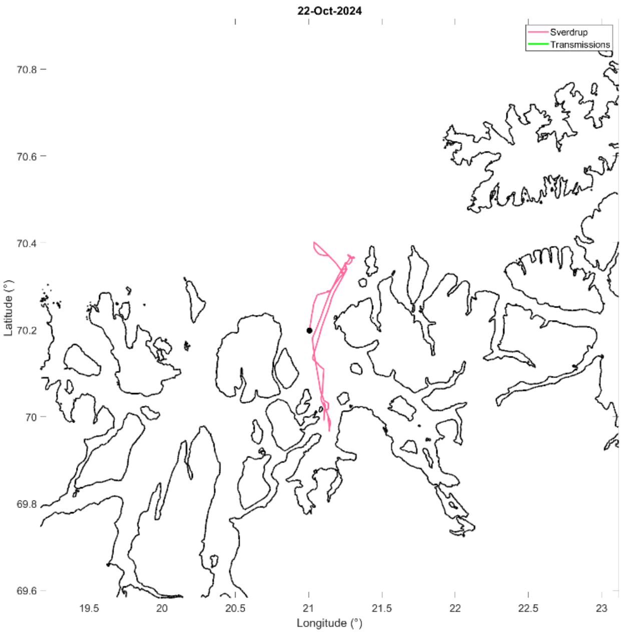
October 19 Sørøysundet-Lopphavet - Searching into deeper water in Sørøysundet. No fishing going on, and no killer whales, but lots of herring and baleen whales. Tagging around fishing vessels at Loppphavet. No success



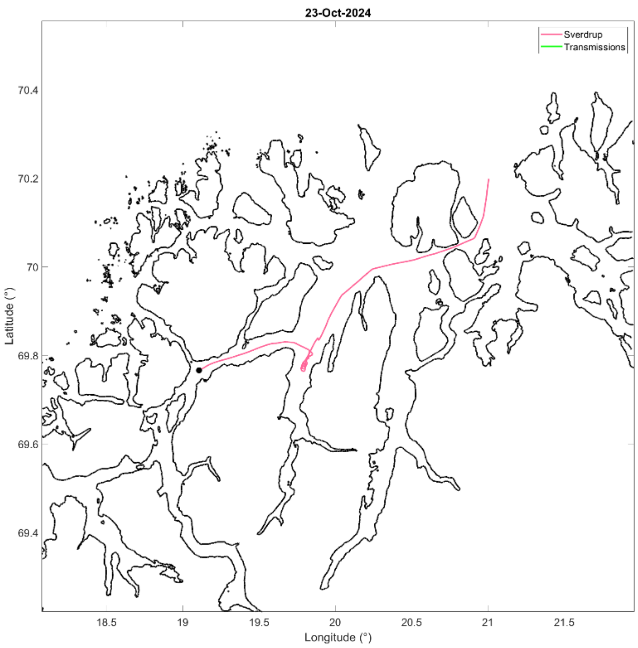
October 20 Lopphavet – Day time wild tagging. Deployed 1 splash tag and two Mixed-DTAGs. Started nighttime CEE III.



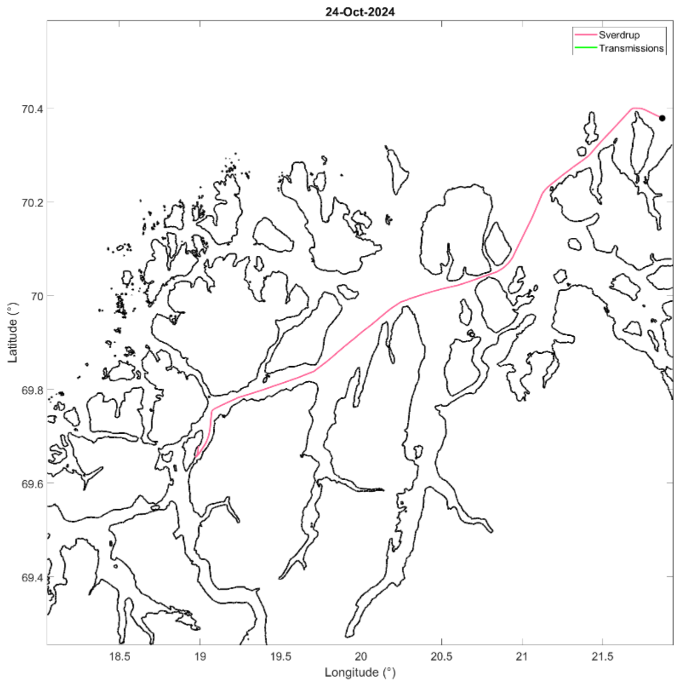
October 21 Lopphavet – Finished CEE III, post exposure and recovered tags. Seeked shelter from a storm. Tagging near fishing vessels without success.



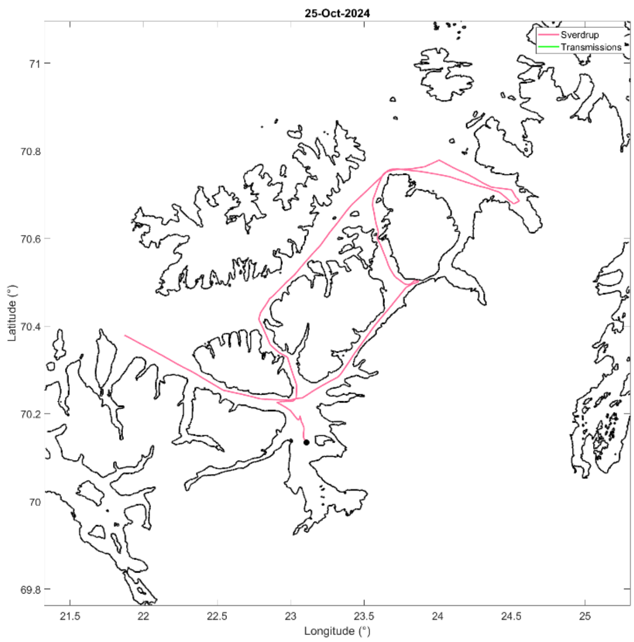
October 22 Kvænangen - Wild tagging in the fjord, and later around fishing vessels, but without success.



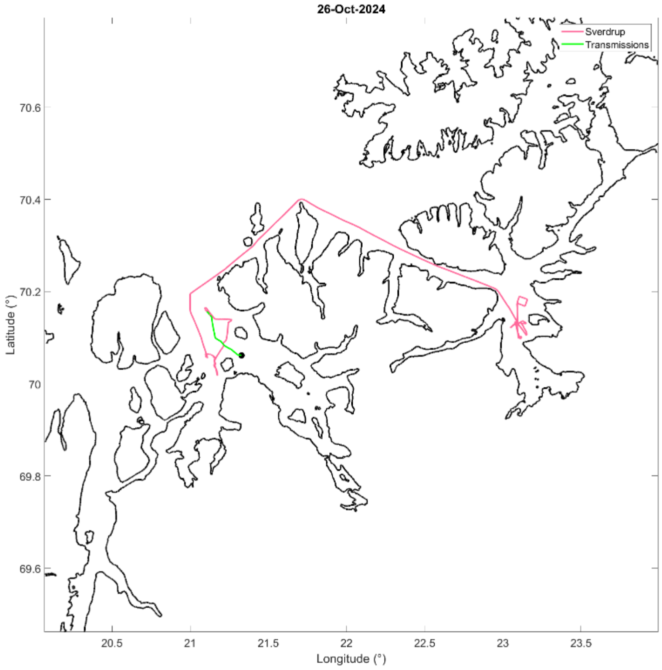
October 23 Ulsfjorden-Tromsø - Harmonics and source level test of the Socrates source èn route to Tromsø. Mid sail de-brief.



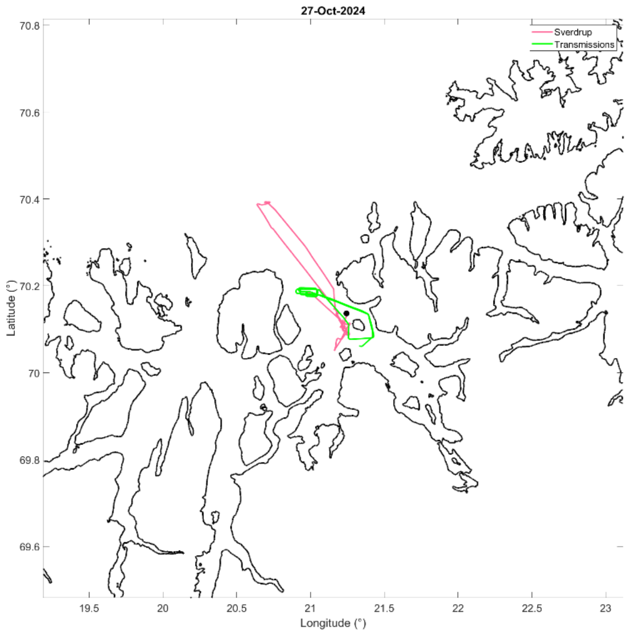
October 24 Tromsø-transit N - Crew change. Transit back to operation area.



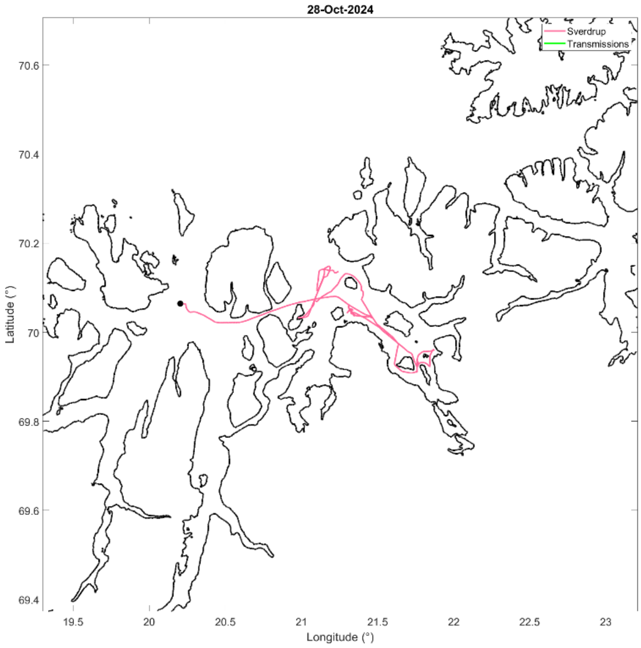
October 25 Sørøysundet–northern in-shore areas - Rough weather off-shore. Searching for whales in-shore based on position updates from Splash tags.



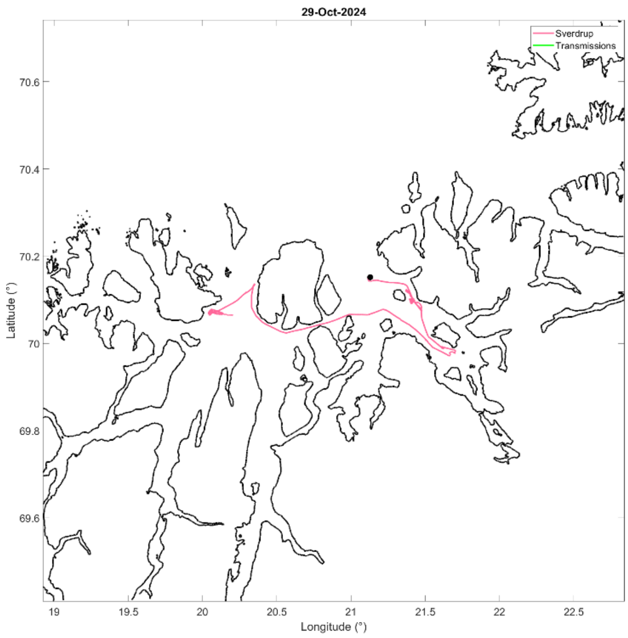
October 26 Altafjorden-Sørøysundet-Kvænangen-Reisafjord - Searching for whales in in-shore areas. Tagged 2 KW around fishing fleet. Started nighttime CEE IV.



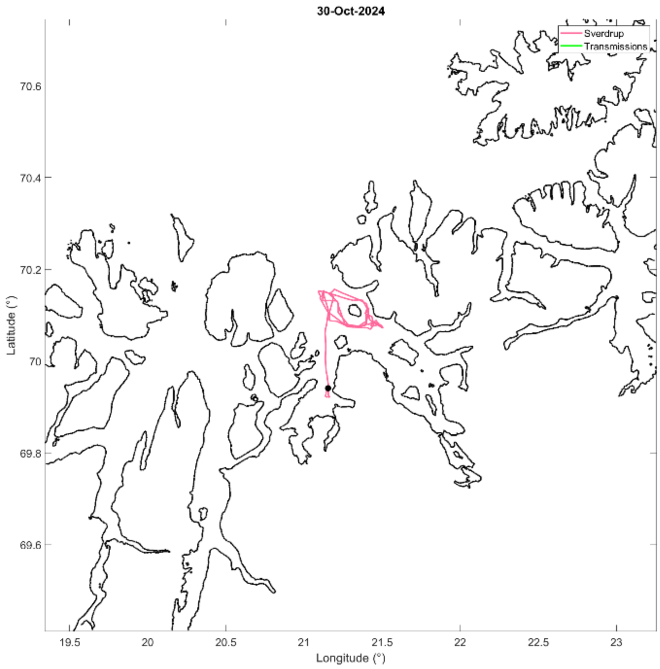
October 27 Kvænangen – Finished CEE IV, post exposure and tag recovery. A Mixed-DTAG deployed to a KW for baseline data collection. Recording of fish vessel sounds.



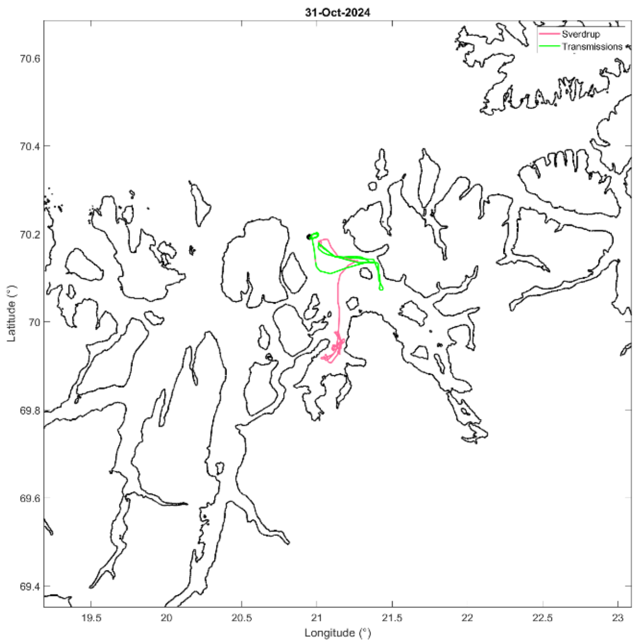
October 28 Kvænangen-Fugløyfjord - Tagging a HW with Mixed-DTAG in very rough weather for baseline data collection.



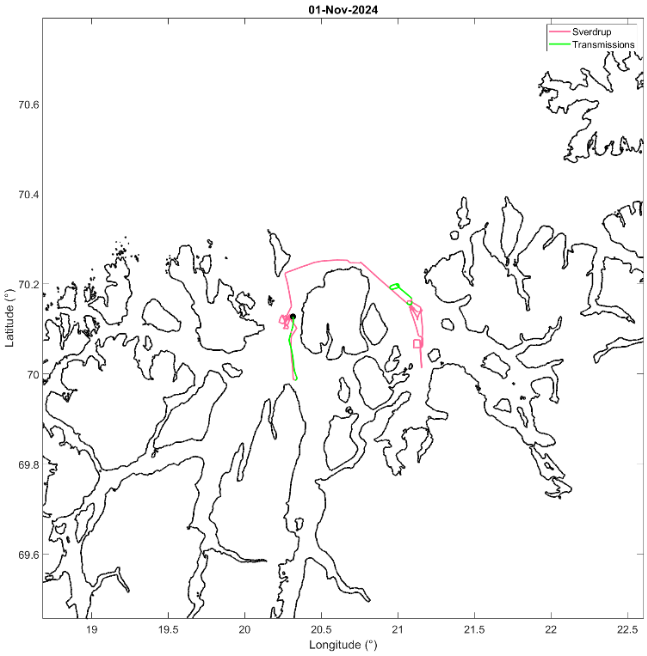
October 29 Fugløyfjord-Kvænangen – Recovering baseline tag. Three new Mixed-DTAGs deployed on KWs around fishing vessels for baseline data collection.



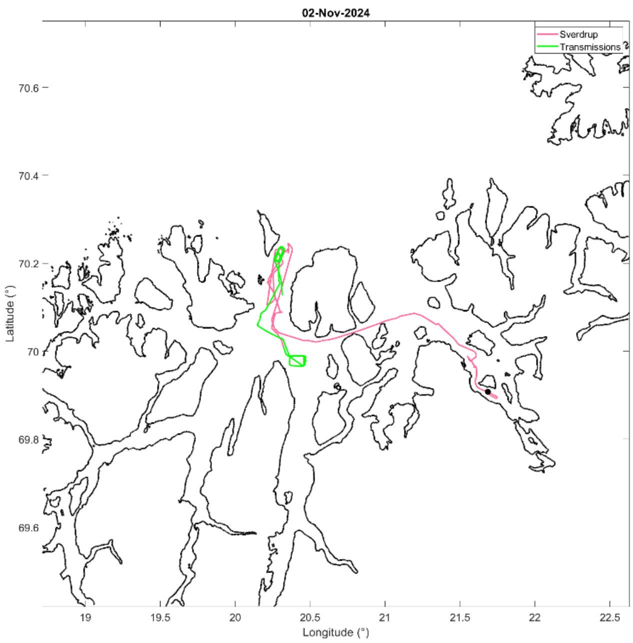
October 30 Kvænangen-Reisafjorden - Tracking and recovering baseline tags. Tagging for new CEE.



October 31 Reisafjorden-Kvænangen – We witnessed a sad by-catch incident where 4 whales drowned in a purse seine net. Later 3 tags were deployed to KW. Started CEE V.



November 01 Kvænangen-Fugløyfjorden – Finished CEE V, post exposure and recovered tags. Tagged 3 KWs, started CEE VI in different area.



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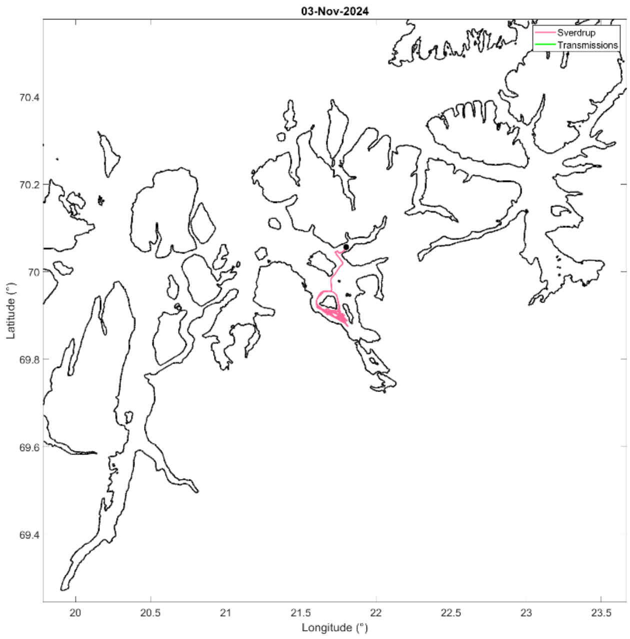
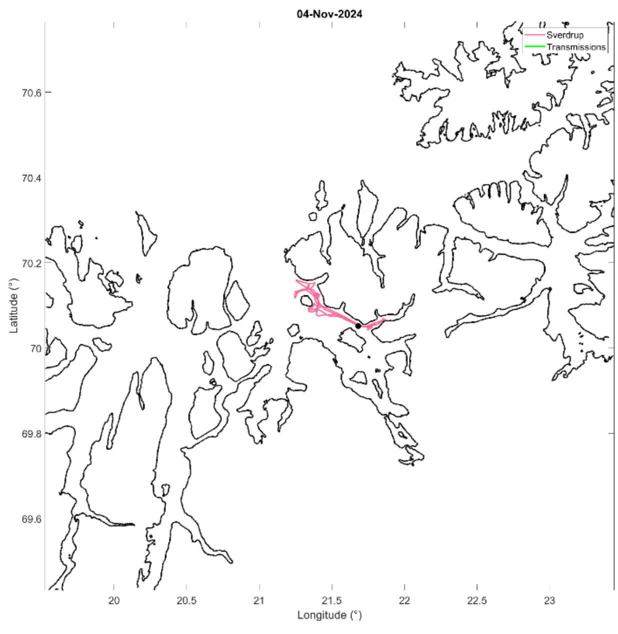
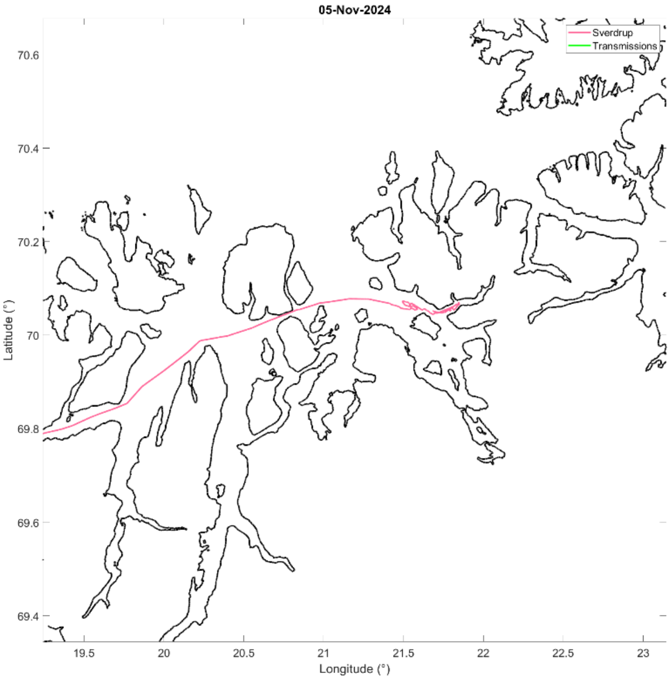
November 02 Fugløyfjord-Kvænangsfjord – Finished CEE VI, post exposure and recovered tags. Baseline tagging of HW, two tags deployed



November 03 Kvænangsfjord - Tracking baseline tags on HWs. Recovered tags. Deployed 2 new tags to HWs for baseline. CEE not possible in the area due to bathymetry restrictions.



November 04 Kvænangen - Recovered baseline tag. Deployed 3 new tags for CEE, but tags comes off or tracking failed.



November 05 Kvænangsfjord-Tromsø - Recovering remaining tags. Hot wash de brief. Transit to Tromsø. Celebration of trial achievements!

November 06 Tromsø - De-mobilization (no map)

November 07 Tromsø - Off-loading, dissembarkment, end of trial (no map)

C 3S-2024 Cruise plan

3S-2024
Cruise Plan

Final version

The 3S-2024 research trial is conducted by the 3S-consortium as part of the 3S4-project.

CONTENT

LIST OF ABBREVIATIONS

3S	Sea mammals and Sonar Safety project
3S4	Fourth phase of the 3S project 2023-2026
AORI	The Atmosphere and Ocean Research Institute at the University of Tokyo
ARTS	Aerial Rocket Tagging System for remote deployment of whale tags
BRS	Behavioral Response Study
BW	Bundeswehr, the German Defense Organization.
CAS	Continuous Active Sonar
CEE	Controlled Exposure Experiment / CEE Exposure coordinator
CO	Commanding Officer
COMMIT	Materiel and IT Command (formerly DMO)
CPA	Closest point of approach
CTD	Conductivity-Temperature-Depth, sensor to measure density/sound speed profile
Delphinus	TNO towed array system for acoustic detection and tracking of marine mammals
DGA	The Direction générale de l'armement, part of the French Ministry of Defence
DM	Data management
DMO	NL Defence Materiel Organization (now COMMIT), part of NL Ministry of Defence
DP	Drone Pilot
DRDC	Defence Research and Development Canada
DTAG	DTag, as originally developed by WHOI. Currently provided by Univ of Michigan
FFI	Forsvarets forskningsinstiutt / Norwegian Defence Research Establishment
GPT	General Purpose Transceiver, contains the transmission and reception circuitry for echosounders
HF-Cetacean	High Frequency cetacean hearing specialist (killer-, pilot-, sperm whales and dolphins)
HFM	Hyperbolic Frequency Modulation (type of sonar signal/sweep)
HUS	R/V H.U. Sverdrup II, research vessel of FFI
HW	Humpback Whales
KW	Killer Whales
LF-Cetaceans	Low frequency cetacean hearing specialist (baleen whales)
LFAS	Low Frequency Active Sonar signals, in this document referred to as 1300-2000 Hz HFM signals
LKARTS	Private consultant company in Norway
LMR	Living Marine Resources program of USN
MDTAG+	DTAG core unit, ARGOS satelitte transmitter and Fast GPS logger
MDTAG++	DTAG core unit, ARGOS satelitte transmitter, Fast GPS logger and video logger.
MFAS	Mid Frequency Active Sonar signals, in this document referred to as 4000-6000 Hz HFM signals
MMO	Marine Mammal Observer
MOBHUS	small boat, Man-Overboard-Boat of HUS
MOD	Ministry of Defence
MSC	Marine Science & Communication
NARA	Norwegian Animal Research Authority (Mattilsynet)
NAVFAC	Naval Facilities, branch of USN hosting LMR-program
PAS	Pulsed Active Sonar
PAM	Passive Acoustic Monitoring
PFM	Prey Field Mapping
PI	Principal Investigator
PTS	Permanent hearing Threshold Shift
SATT	SATelitte Tracking
SMRU	Sea Mammal Research Unit, part of St.Andrews University, UK
SL	Source Level (of sonar source)
SOC	SOCRATES sonar source
SPLASH	Wildlife Computers Limpit SPLASH tag (model SPLASH10-F-333)
TAG	Tagger
TBD	Tag Boat Driver
TNO	NL Organization for Applied Scientific Research
TT	Tag Technician
TTS	Temporary hearing Threshold Shift
UAV	Unmanned Aerial Vehicle
USN	US Navy
VHF / DDF	Digital Direction Finder using VHF
XBT	eXpandable BathyThermograph, probe to measure temperature profile of water column
XO	Executive Officer

3S4 PROJECT BACKGROUND AND OBJECTIVES

Modern long-range anti-submarine warfare sonars transmit powerful sound pulses which can have a negative impact on marine mammals. The biological relevance or severity of behavioral responses depends upon the duration of responses. A key challenge exists to extrapolate results from the short duration (30-40min) experimental exposures used to date in BRS studies to the typically longer duration operational activities of navies using sonar typically lasting 6-12 hrs. If animals habituate over time, the severity of behavioral responses based on BRS would be overestimated. Conversely, if animals sensitize over time, the severity would be underestimated. Furthermore, all BRS research so far, except the third phase of the 3S-project, has been conducted using pulsed active sonars (PAS), typically transmitting at a 5-10% duty cycle. Recent technological developments imply that, in the near future, naval sonars will have the capability to transmit almost continuously (Continuous Active Sonar, CAS). This technology leads to more continuous illumination of a target and therefore more detection opportunities, even at a substantially lower source level. However, the feature of CAS's high duty cycle raises imminent questions about the environmental impact of such sonar systems. Robust results from sperm whales investigated during 3S3 (2016-2023) indicate that the severity of reduced foraging response during CAS exposures is similar to responses to PAS when the ping-by-ping cumulative signal energy is the same, but knowledge from other species is needed.

The objectives of the fourth phase of the 3S project (3S4) are to:

1. 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 in killer whales and humpback whales.
2. Investigate empirically if responses from short duration experiments predict responses from longer duration exposures conducted over an operationally relevant duration.

The 3S4 study will address CAS vs PAS (objective 1) and longer vs shorter duration exposures (objective 2) by conducting both short- and long-duration CAS and PAS exposures to species for which the responses to short-duration PAS have already been investigated. The study is a 4-year project as the base option, starting January 2023, ending December 2026 with two 4-week field trials (October-November 2023 and October-November 2024). We are also planning an optional expansion of the project with a third trial in 2025. This extension of the project is currently not funded.

3S-2024 CRUISE TASKS AND PRIORITIES

Primary tasks:

1. Tag killer whales with mixed-DTAG^{++} and expose them to dose escalating 1.3-2.0 kHz CAS or PAS twice over an extended period (8 hrs) during both daytime and nighttime.
2. Tag killer whales with SPLASH tags in the core operation area (higher priority early in the trial).

Secondary tasks:

3. Tag humpback whales with mixed-DTAG^{++} and expose them to dose escalating 1.3-2.0 kHz CAS or PAS twice over an extended period (8hrs) during both daytime and nighttime.
4. Tag killer whales or humpback whales with mixed-DTAG^{++} and expose them to dose escalating 4-6 kHz CAS or PAS twice over an extended period (8hrs) during both daytime and nighttime.
5. Tag killer whales and humpback whales with mixed-DTAG^{++} and expose them to short duration CAS or PAS (mostly back up if long duration exposure is not feasible).
6. Collect 24 h duration baseline data records of target species.
7. Collect echosounder data and fish samples to monitor the prey field.
8. Collect drone footage of tagged subjects for body condition characterization.
9. Collect information about the environment in the study area (CTD, XBT).
10. Collect sightings of marine mammals in the study area.
11. Perform sound source (SOC) long duration engineering test and harmonic characterization.
12. Collect photo documentation for photo id, tag documentation and public outreach purposes.
13. Record acoustic cues of fishing vessels and relate that to the different steps of the fishing activity.

Priorities:

- Primary tasks are higher priority than Secondary tasks. Secondary task should not interfere with our ability to accomplish primary tasks.
- Killer whales are higher priority than humpback whales.
- Primary focal whales are a higher priority than secondary focal whales.
- CAS exposures are higher priority than PAS exposures, but optimize contrast.
- LFAS exposures (1.3-2.0 kHz) are higher priority than MFAS exposures (4-6 kHz).
- Mixed-DTAG^{++} deployments are higher priority than SPLASH tag deployments.

3S4-CONSORTIUM

<u>Table 1.</u> *The partners, sponsors and associated partners of the 3S4-project*

3S4 partners	3S4-sponsors	3S4 Associated partners
FFI (NO)	*US Navy / LMR*	*Dalhousie Univ. (CA)*
TNO (NL)	*NL COMMIT*	*LK-ARTS, Norway (NO)*
SMRU (UK)	*FR DGA*	*CEREMA (FR)*
Univ. Iceland (IS)	*CA DRDC*	*Univ. Michigan (US)*
DRDC (CA)		*AORI (JP)*
		Marine Science & Communication (NL)
		Bundeswehr (GE)

OPERATION AREA

We have proposed to target focal species in areas and periods where killer whales and humpback whales aggregate to feed on herring in the herring overwintering area of northern Norway (Figure 1). The operation area and period of the trial was determined based on a thorough analysis of expected weather conditions, available daylight, herring fishery activity and available knowledge on whale migration patterns. Based on the experience from 3S-2023 (Kvadsheim et al. 2024) we have moved the 3S-2024 operation area a bit further north.

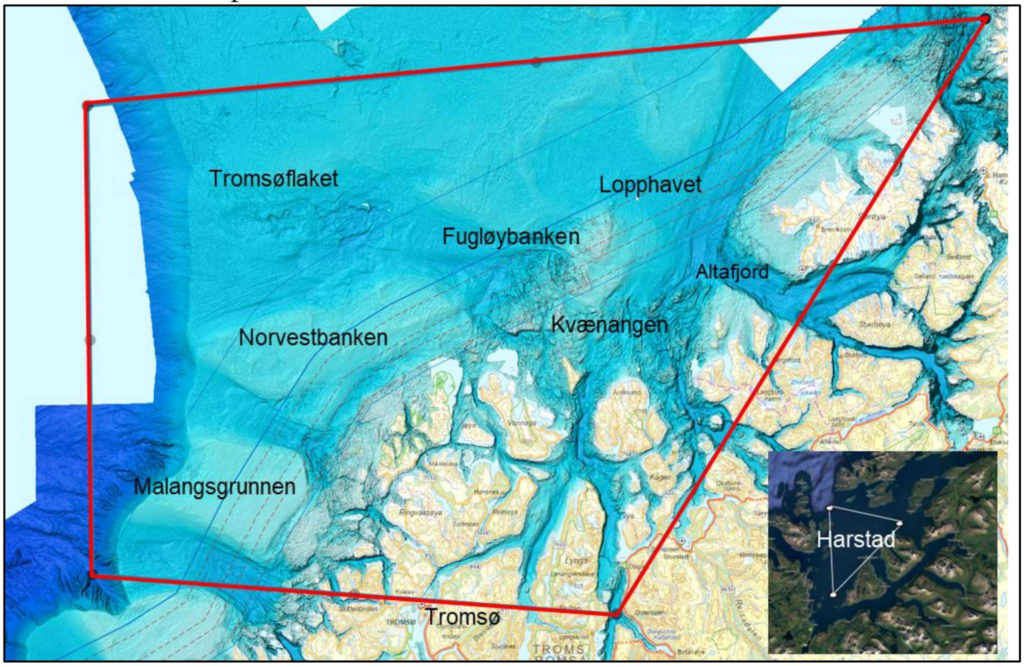


Figure 1. The 3S-2024 operation area.

Table 2. Underwater warfare object clearance for 3S-2024

Vågsfjorden SOC testing	
Start time: 120600zOct2024	*End time: 130600zOct2024*
Coordinates; *68.759016N - 16.727842E* *68.972172N - 17.301070E* *69.007589N - 16.749703E*	
3S-2024 operation area	
Start time: 130600zOct2024	*End time: 060000zNov2024*
Coordinates *71.0N - 24.0E* *69.6N - 20.4E* *69.8N - 16.4E* *71.0N – 16.4E*	

SAILING SCHEDULE

Table 3. Sailing schedule of the 3S-2024 trial.

Date	Time	Event
Wed Oct 9th	 19:00	Rendezvous in Harstad. Joint no-host dinner
Thur Oct 10th	08:00 12:00	General brief at local hotel Embarkment HU Sverdrup II at Stangnes terminal, Harstad Loading and technical installation
Fri Oct 11th		Finalize technical installation, training of MMOs, safety training of tag boat crew, brief of ship's crew, safety briefing. Assess weather and fishery activity to decide on where we should start searching for whales.
Sat Oct 12th	08:00 20:00	Planned departure Harstad. Transit to Vågsfjorden for engineer test of SOC-source and drill of operation. Transit back to Harstad.
Oct 13th	08:00 20:00	Departure Harstad, transit to operation area if all systems GO Switch to regular watch plan **Fully operational**
Oct 24th	08:00 17:00	Latest arrival in Tromsø for scheduled crew change. Earliest possible departure time from Tromsø
Oct 25th Nov 5th		**Fully operational**
Wed 6th Nov	 08:00	Transit back to Tromsø Latest arrival in Tromsø De-brief, de-installation and packing Celebration
Thurs Nov 7th	08:00 12:00	Off-loading. Disembarkment in Trosmø Return travel

CRIEW PLAN

Table 4. Crew plan and roles during the 3S-2024 trial. Mark von Spellen will join us for the installation and testing of the SOCRATES source on October 10-12. He will be staying at a local hotel.

1st period Oct 10th – Oct 24th	2nd Period Oct 24th – Nov 7th	Main role	Secondary roles	Affiliation
Petter Kvadsheim	Petter Kvadsheim	CO	CEE, MMO, PFM	FFI
Frans-Peter Lam	Frans-Peter Lam	XO	CEE, SOC, MMO	TNO
Patrick Milller	Patrick Milller	TAG	PI, MMO	SMRU
Paul Wensveen	Paul Wensveen	TAG	MMO, SATT	Univ.Iceland
Lars Kleivane	Lars Kleivane	TBD	MMO, TAG	LKARTS
Rune Roland	Rune Roland	TBD	MMO, Photo	RRH
Eef Brouns	Eef Brouns	SOC	CEE tool, hard eng, MMO	TNO
Cecile van der Stappen	Cecile van der Stappen	SOC	CEE tool, soft eng, DM, MMO	TNO
Ellen Hayward	Ellen Hayward	TT	MMO, photo	SMRU
Alec Burslem	Alec Burslem	TT	MMO, photo	SMRU
George Sato	George Sato	TT	MMO, TAG, photo	SMRU
Giorgia Giovannini	Giorgia Giovannini	TT	MMO, photo	SMRU
Marije Siemensma	Carolyn Binder	Lead MMO	DM	MSC/DRDC
Anna Selbmann	Anna Selbmann	Lead MMO	DM	Univ.Iceland
Martijn van Riet (Software training)	Stefan Ludwig	CEE-tool, SOC	MMO	TNO/BW

ROLES: CO=Commanding Officer, XO=eXecutive Officer, CEE=Exposure coordinator, PI=Principal Investigator, MMO=Marine Mammal Observers (visual and VHF tracking), SOC=SOCrates source operator, PAM=Passive Acoustic Monitoring, TT=Tag Technician, SATT=SATelitte Tracking (Goniometer, ARGOS), DP=Drone Pilot, PFM=Prey field mapping, TAG=Tagger, TBD=Tag Boat Driver, DM=Data Management.

MAIN COMPONENTS OF THE TRIAL

HU Sverdrup II (HUS)

Figure 2. HUS

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

HUS will be outfitted with the Socrates source and operating software, VHF and GPS-ARGOS tracking systems, tag boat with cradle for loading/off-loading. In addition, HUS will also carry equipment to measure sound speed profiles. Visual search for marine mammals, VHF, GPS-ARGOS and visual tracking of tagged animals, behavioural observations of tagged animals, operation of the 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.

Tag boat

We will only have one tag boat available during the 3S-2024 trial. MOBHUS I is a water jet propulsion Man Over Board (MOB) boat deployed using a dedicated davit. MOBHUS can be deployed and operated up to sea state 4. 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. MOBHUS is installed with navigation system, lights, 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 3. MOBHUS

Sonar source – SOCRATES

Figure 4. The SOCRATES source.

The multi-purpose towed acoustic source, called SOCRATES (Sonar CalibRAtion and TESting), will be used and operated from the HUS. We will use SOCRATES II or SOCRATES III owned by the Netherlands Navy. This source is a sophisticated and versatile source that was developed by TNO to perform underwater acoustic research and testing. Socrates has two free flooded ring transducers, one LFAS ring for the frequency band between 0.95 kHz and 2.35 kHz (source level 214 dB re 1 µPa @ 1m in PAS mode), and an MFAS ring 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 the risk of cavitation and damage to the source, it must stay below cavitation depth during operation. As a rule of thumb, LFAS PAS transmissions at full power should only be used at water depths >180m, LFAS CAS transmissions >100m, and MFAS transmission >50m depth. Appendix B describes further details of SOCRATES and gives detailed operational instruction. We will not use any acoustic towed array during the 3S-2024 trial.

Whale tags, deployment and tracking systems

Subject whales will be tagged with Mixed-DTAG^{++}. 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 Mixed-TAG^{++} contains a core DTAG unit built at the University of Michigan with stereo hydrophones, 3-axis acceleration, 3-axis magnetometer information, as well as depth. DTAG audio will be sampled at 240 kHz and other sensors at 250 Hz, allowing a fine-resolution reconstruction of whale behaviour before, during, and after sonar transmissions. In addition, the Mixed-DTAG^{++} also contains a LOTEK GPS-ARGOS unit, Little Leonardo video unit, and a VHF beacon (148 MHz band).

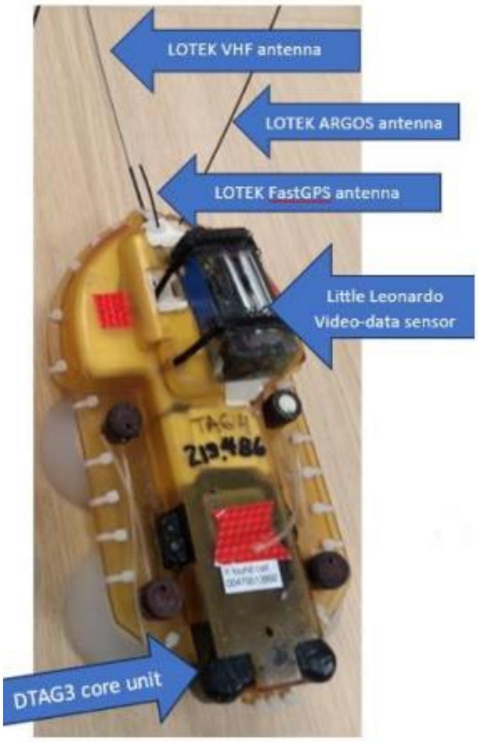


Figure 5. Mixed-DTAG^{++}.

The LOTEK unit logs Fast-GPS snapshot information used to calculate positions, and relays these GPS data via Argos transmissions. In addition to ~7 hours of video, the Little Leonardo video unit records 36 hours of depth and 3-axis accelerometer data, as a backup in case of data problems with the DTAG core units.

These additional sensors help track the whale during experiments using the GPS-Argos transmissions, and help to find the tag when it has released from the whale using Argos locations. GPS positions result in a more detailed track of the whale and video data in the Mixed-DTAG^{++} are useful to observe behaviour, and prey field characteristics. We will have 8 Mixed-DTAG^{++} units available, but 2 of them will be based on the new DTAG4 core unit without a release (the other 6 using the old DTAG3 core units).

In addition to the suction cup tags, we will have 6 Wildlife Computers SPLASH10-F-333B satellite tags with Fastloc GPS and depth sensors. These tags will be used to help us locate potential study subjects, and could also possibly be used for secondary or non-focal study subjects. However, as we are not sure that behavioural responses can be consistently documented using satellite tags alone, our preference will always be to have a suction-cup tagged whale as the primary focal subject of experiments. A dedicated team will focus on programming and deployment of the satellite tags.

Tag tracking systems will include handheld Yagi-Uda antennas and Automatic Direction Finder (ADF) for VHF signals, and Goniometer antennae for receiving Argos transmissions directly on the vessel. Two different Goniometer antenna systems will be used to receive the ARGOS signals directly on the Sverdrup, one with a high-gain antenna for GPS decoding, and one with a low-gain directional antenna for Automatic Direction finding. The ideal mounting positions for these antennae was established during 3S-2023. Finally, Argos quality, and GPS-Argos quality locations relayed via satellite can be received from the ARGOS webserver. Input from these tracking systems will be automatically made available to the CEE tool (see below).

MMO platform

The MMO platform on the flybridge of the SVERDRUP will be set up with 1 big-eye binocular, handheld binoculars, a rugged laptop with the program IFAW Logger or Pamguard for recording visual sighting information, and the DFHorten ADF station. During nighttime sonar exposures, mitigation observers will use Pulsar Merger LRF XP50 thermal imaging binoculars using the optimal setting for detection of marine mammals (Kleivane 2023).

EA600 Echosounder

HUS has a Kongsberg Maritime EA600 hydrographic echosounder mounted on a bracket under the hull. It operates on 12 kHz, 38 kHz and 200 kHz. The 38 kHz will be used for opportunistic prey field mapping.

UAV Drones

During daylight hours, when weather conditions allow, drones will be used to take photos of tagged whales and other footage which could be used for presentation and public outreach purposes. Ideally, we would like to collect calibrated measurements of the size and body shape of focal tagged whales, but because most of the tagging is expected to happen in the dark, we cannot expect to get footage of the tagged whales. Drone flights would occur during the tagging, post-tagging, or pre-exposure baseline period, but could also be done during the post-exposure monitoring period. The UAV drone can be launched and recovered from Sverdrup. Drone flights require a team of 2, the drone pilot and a drone handler.

CEE tool

The CEE tool is a newly developed software package designed to support the Controlled Exposure Experiments. The version that was used during the 2023 trial featured the following:

- Bathymetry (depth-contours) and coastlines.
- Own ship track
- AIS tracks of other vessels in the area
- Interactive Range-Bearing tool on the map
- Manual input of positions (markers)
- Tracks of tagged whales composed of the following sources:
    - Position information retrieved from the ARGOS satellite network (ARGOS quality positions with error ellipse).
    - Bearing and Position (GPS-quality) information via two CLS Goniometer antennae and receivers.
    - Position information via manual user input (for example Visual detections).

The tool consists of two screens; one screen shows a geographic overview of the above mentioned features and includes the user interface tools to edit some of these data (Figure 6). The second screen provides an overview of the historic and predicted range to the tagged whales and can be used to tune the course of H.U. Sverdrup II to comply with the planned experimental design (Figure 7).

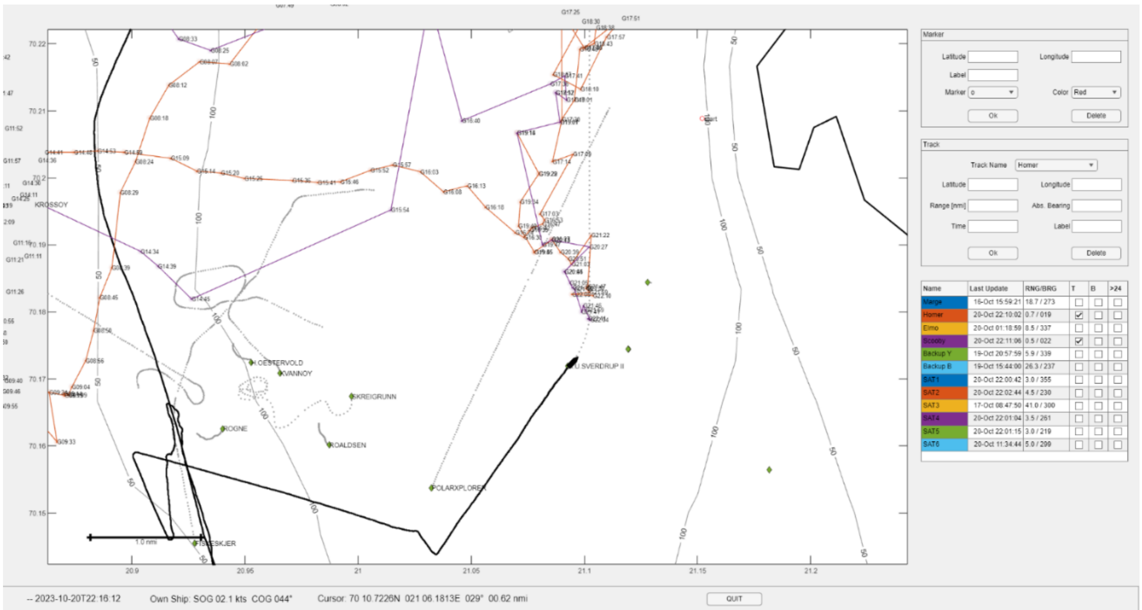


Figure 6. *Screenshot from CEE tool during one of the 3S-2023 exposures. Two tagged whale tracks are shown in orange and in purple. Track of H.U. Sverdrup II is shown in black and tracks of other ships are shown using AIS data in gray. Figure from Kvadsheim et al. 2024.*

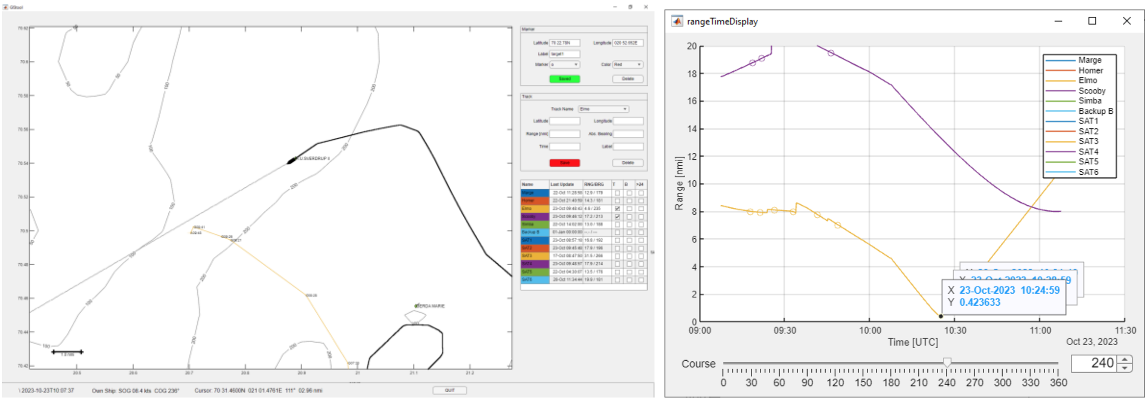


Figure 7. *Screenshot of CEE-tool during one of the approaches during 3S-2023. Left panel shows map with track of source vessel and focal whale. Right panel shows the Range-Time display. It depicts the range to a focal whale track for the last hour and a predicted range for the next hour based on the last known whale position, and the source vessel sailing with speed of 8 kts and a user defined course (240°). In this case the estimated CPA to the focal whale is 0.4nmi. Figure from Kvadsheim et al. 2024.*

Overall, the CEE tool was very useful during the 3S-2023 trial and helped significantly with the tracking of the whales, larger-scale planning, and the execution of the experimental vessel approaches. ARGOS cross-bearing data retrieved from the satellite network were rarely used for whales tagged with mixed-DTAGs, because we received many GPS-quality locations in near-real time via the Goniometer antennas. On the other hand, ARGOS data from the SPLASH tags were also visualised and these provided additional context about whale presence in the larger area. The line-of-sight reception of the tag locations using the Goniometer worked above expectations. The position updates were received reliably at regular intervals and ranges were well suited for the experimental design.

RESPONSIBILITIES

Table 5. Responsible partner for staffing and equipment during 3S-2024.

	Staff	Vessel	SONAR	IR	Ocean.equip	Tag boat	Tags	Tagg Equip	Tracking	CEE tool	MMO-station
FFI	✓	✓		✓	✓	✓			✓		✓
TNO	✓		✓	✓						✓	
SMRU	✓			✓			✓	✓	✓		✓
Univ Iceland	✓										
LKARTS	✓							✓			
Univ. Michigan							✓				
DRDC, DGA, BW	✓										

DAILY WORK PLAN

The 3S-2024 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.

The operation goes through different phases which require very different staffing from the different teams. The main phases are: search phase, tagging phase, pre-exposure phase, exposure phase and post exposure phase. After the tags have detached from the whales and have all been retrieved, we start over searching for new subject animals.

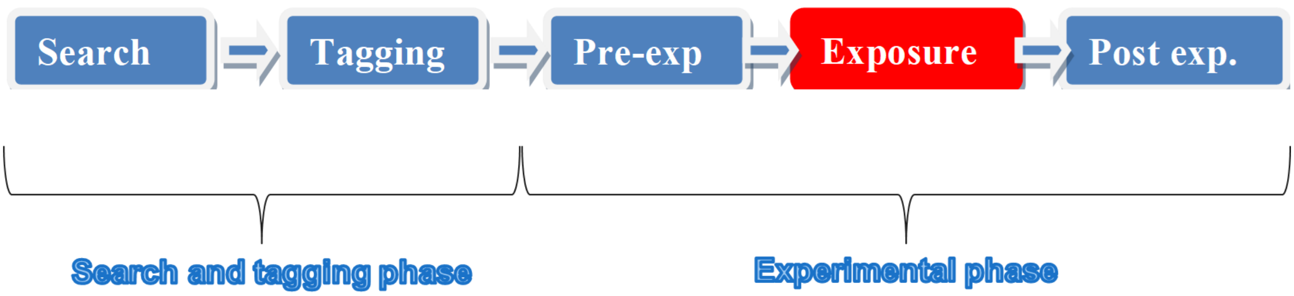


Figure 8. Main phases of the operation.

The complexity of the operation 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 meetings

Every day at 07:00 the chief scientists from the main 3S partners (Kvadsheim, Lam, Miller, Wensveen, Binder) will convene on the bridge to plan the activities for the coming 24 hrs. Search areas and patterns, species priority, tag 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 before 08:00. 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.

Watch plan

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 in all phases of the operation. The available daylight drops from 10 hrs at the start of the trial to only 5 hrs at the end, so the visual and tagging effort has to be adapted to this in search and tagging phases. However, we plan to tag whales feeding around purse sein fishing vessels, so tagging will primarily happen in the dark period. The fishing happens in two waves from 06-12 and 18-00 with peaks from 06-09 and 20-22.

Table 6. The 3S-2024 watch plan

Watch period	08 – 14	14 - 20	20 - 02	02 - 08
Kvadsheim	■		■	
Lam		■		■
Miller	■		■	
Wensveen		■		■
Brouns	■		■	
van der Stappen		■		■
Selbmann	■		■	
Siemensma/Binder		■		■
van Riet /Ludwig		■		■
Roland	■		■	
Kleivane		■		■
Hayward	■		■	
Burslem		■		■
Sato	■		■	
Giovannini		■		■

It is part of our 3S-culture that each team member is expected to arrive on its post 5 min prior to the start of their 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 boat driver (Roland or Kleivane), a tagger (Miller or Wensveen) and someone in charge of photo documentation (usually one of the tag technicians).

The MMO effort included visual search for target species during daylight hours, VHF-tracking of tagged whales and mitigation monitoring during sonar exposures. A lead MMO

(Siemensma/Binder or Selbmann) will organize the effort and coordinate availability of secondary MMOs.

Kvadsheim and Lam are CEE coordinators on opposite watch shifts.

Hayward, Burslem, Sato and Giovannini are tag technician (two on each shift). Brouns and van der Stappen are the primary source operators, supported by van Riet/Ludwig.

All members of the staff also have secondary roles, including MMO when needed (Table 4).

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 9. 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!

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 or in dark periods without fishing activity in the area. 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 operation room and on the bridge.

DATA COLLECTION

Basic experimental design

The objectives of the fourth phase of the 3S project (3S4) are 1) 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 in killer whales and humpback whales; and 2) to investigate if responses from short duration experiments predict responses from longer duration exposures conducted over an operationally relevant duration.

In the 3S4-2024 trial, both of the objectives will be addressed with behavioural response data collected before, during and after 8-hour CAS and PAS exposures to killer and humpback whales.

Modifications from 3S-2023 protocol

The basic experimental design remains the same as the 3S-2023 trial with some adjustments made to the protocol to incorporate lessons learned from 3S-2023(Kvadsheim et al. 2024), without deviating too much from the initial design to facilitate pooling of the data.

During 3S-2024 we will focus even more on the killer whales and designate humpback whales as a secondary species.

Due to technical issues with the Socrates source during the 3S-2023 trial we only used the MFAS signal transmitted at 4-6 kHz at maximum energy source levels of 197 dB (re 1 $\mu Pa^2 \cdot s \cdot m^2$) (Kvadsheim et al. 2024). The analysis of the dataset collected during 3S-2023 is still not at the stage where we can identify response, but given the received levels achieved during 3S-2023, established dose response functions for killer whales (Miller et al. 2014) imply that we can only expect 1/3 of the animals to have responded. Even though changing the signal now will introduce additional variation to the design, we therefore need to switch to the higher level LFAS source transmitting 1.3-2.0 kHz signals at energy source levels of 214 dB (re 1 $\mu Pa^2 \cdot s \cdot m^2$). More MFAS exposures will only be done as secondary objectives, e.g. if bathymetry does not allow LFAS transmissions at a relevant source level or if the LFAS source should malfunction.

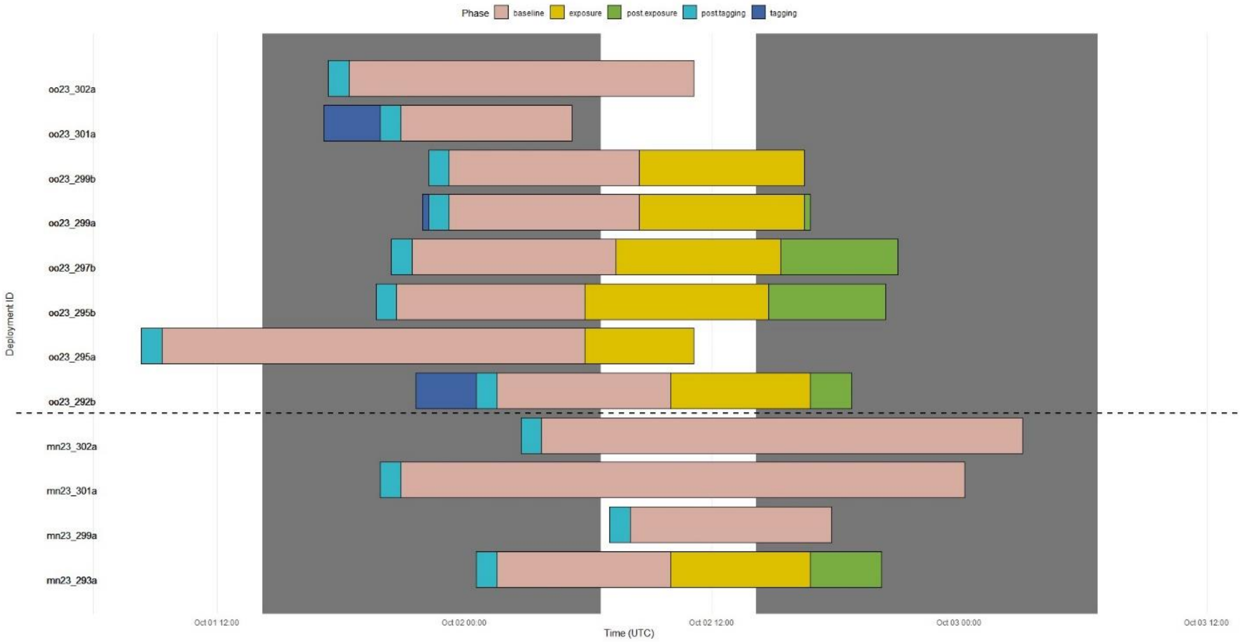


Figure 10. Timing of the data collection during 3S-2023. Note that exposures primarily happened during daytime and baseline data were primarily collected during nighttime. Killer whale and humpback deployments are grouped above and below the dashed line, respectively.

The data from the 3S-2023 trial did indicate that the animals have a very clear diurnal pattern in behavior, mostly feeding at night around fishing vessels, and resting during daytime (Kvadsheim et al. 2024). Partly because we targeted to avoid nighttime exposures during 3S-2023 and partly because tagging was mostly done at night, exposures happened primarily during daytime and most of the baseline data were collected during nighttime (Figure 10). In order to better understand how the animals are affected by sonar, we need to also expose them when they are feeding (at nighttime). During 3S-2024 we therefore need to spread the data collection effort across the diurnal pattern and do exposures during both daytime and nighttime periods (Table 7).

Table 7. 3S4 Data collection should cover both LFAS and MFAS exposures as well as baseline data during both daytime and nighttime. The killer whale data already collected during 3S-2023 is added to the table. During 3S-2024 LFAS exposures are higher priority than MFAS exposures, nighttime exposures higher priority than daytime exposures, and CAS exposures higher priority than PAS exposures. However, as data is being collected, we should prioritize balancing the conditions to maximize contrast.

	LFAS		MFAS		Baseline
	CAS	PAS	CAS	PAS	
Daytime			n=2	n=4	n=1
Nighttime					n=8

Since we still expect that most of the tagging will happen at night, more nighttime exposures will be achieved by extending the tagging period to early morning or by reducing or increasing the baseline period. During exposure experiments 4 hrs of baseline is still minimum because of individual variation in acoustic behavior. Exposure duration should stay fixed at 8 hrs at much as possible with deviations only based upon weather making mitigation impossible, or other factors outwith our control.

Increasing baseline duration implies extending the tag deployment time. Tag retention times beyond 24 hrs can be difficult to achieve. The feasibility of this was tested during the baseline trial off Iceland in July 2023 and 2024. Based on the experience from the baseline trials, we are comfortable that 24 hr tag deployments are feasible, but deployments beyond this was never really tested. Thus, we can't expect the tag to stay on and work reliable for >24 hrs. However, the risk of tag failure is acceptable because night time exposures are highly valuable and we would collect useful daytime baseline data, even if the exposure don't happen because premature tag release. Daytime exposures are however still higher priority than baseline, but both are important. Before deciding to extend the baseline period we should assess if we can rely on the tag attachment (good stick on adult animals with good placement).

The default strategy should be that the first part of the night (14-20 watch) we should use short baseline periods and shorter deployments (18hrs), later during the night (20-08 watches) we should aim for extended baseline periods and 36 hrs release times. In the morning (08-14 watch) we should use regular 8 hr baseline periods with 24 hrs release times. Generally exposure data are higher priority than baseline data, but baseline data are also important to collect. The strong diel behavioral pattern mean that within animal comparison are a lower priority with this dataset. Therefore baseline data could be collected during dedicated tag deployments (e.g. just before crew change and leave the tags).

The experimental design is a fairly strict program (Figure 11). To minimize risk of accumulated effects of sonar and to avoid habituation or sensitization of the experimental animals, experiments will not be conducted closer than 20 nmi of where HUS conducted previous exposure experiments within 48 hours (from start of previous exposure to start of next) as part of our risk mitigation protocol (Appendix A). If we have deployed a tag on a focal animal and the 48 hr rule dictates that the exposure will have to be delayed, the strict 2 hr second tagging window can be extended, still allowing enough time to complete the experiment. In such a scenario the tag release time should also be set to allow for the full experimental cycle (>24hrs)

In summary the following changes are made between the 3S-2023 and 3S-2024 protocol:

- Increased focus on killer whales, reduced focus on humpback whales
- Primarily LFAS exposures instead of MFAS.
- Try to achieve both day- and night-time exposures
- Shortening the baseline period (min 4 hrs) or extending it to achieve nighttime exposures
- Extended tag release time to allow more baseline and post-exposure.
- The 2 hr second tagging window can be extended if the 48 hr rule delays the start of the exposure anyway.

Experimental Cycle

The planned timeline for each experiment is detailed in Figure 11. Each experiment contains search and tagging phases, and an experimental phase which includes pre-exposure, exposure, and post-exposure periods.

Search and tagging phase

Searching for whales will be done visually and by tracking the movement of the fishing fleet. Search locations may also be aided by positions provided by satellite tags deployed on killer whales. During the search phases, the tag technician team should prepare mixed-DTAG^{++} to be fully charged and as prepared as possible.

Once whales are sighted and weather and light conditions allow for tagging, tags should be fully prepared, and the tag boat deployed to approach the whales. As a rule of thumb, tag teams should bring three tags and could deploy all three, only one of the three should be deployed on a humpback whale.

The current experimental design requires tag retention times on the whale close to or beyond 24 hrs, which is longer than most DTAG deployments. Tag retention time was tested during the baseline trials in Iceland in 2023 and 2024, and again during the 3S-2023 trial; in about 70% of the deployments, tag retention times of close to 24 hrs were achieved, but tag retention times beyond 24 hrs cannot be expected reliably. The retention time is better when the tags are deployed to adult animals compared to juveniles, and we should therefore focus tagging effort on adult animals as much as possible.
Suction cup tagging will primarily be done using handpoles, which maximizes control for optimal tag placement and orientation on the whale. Ideal placements are 1) on top of the body between the dorsal fin and blowhole with antennas facing backward, and 2) at the base of the dorsal fin with antennas angled slightly up. It is expected that handpole tagging should not be limiting when we tag near fishing vessels. However, during wild tagging of whales in daylight periods away from fishing vessels, handpole deployment is ineffective (Kvadsheim et al. 2024). ARTS tagging will therefore be used during wild tagging. ARTS tagging of killer whales with mixed-DTAG^{++} was tested during the baseline trial off Iceland in July 2024. There remains some concern that using ARTS can damage the Mixed-DTAG^{++}. Therefore we will use two mixed-DTAG^{++} that are dedicated for ARTS tagging.

The satellite tags will be deployed on killer whales using either the Daninject or ARTS tagging system using state of the art procedures. Barbs must be sterilized prior to deployment. Tags should be deployed targeting the dorsal fin, and only adult animals should be targeted for satellite tag deployment. Deployment of satellite tags will be a priority early in the trial, but we should avoid deploying more than 2 satellite tags during any one whale encounter. Normally the tag team will only consist of 1 tagger, but if we are deploying both SPLASH tags and Mixed-DTAGs at the same time we might use two taggers in parallel.

During each tagging event, the response of the whale will be scored as follows:

0. No reaction: whale continued to show the same behaviour as before the tagging attempt
1. Low-level reaction: whale modified its behaviour slightly (e.g. dove rapidly or small tail slap)
2. Moderate reaction: whale modified its behaviour in a more forceful manner over a short duration (single breach or spyhop), or a low-level reaction over a longer period (moving away)
3. Strong reaction: whale modified its behaviour in a succession of forceful activities (successive percussive behaviours such as breaches or strong tail slaps)

A tagging data sheet will be taken on the tagboat, and should be completed for each tag deployment, including time, location, size of animal, reaction, location of tag on the body, tag system and settings, and number of VHF beeps/surfacing. When possible, pictures should be taken of the tag on the whale body after attachment.

The first tagged whale will be considered the FOCAL-1 whale and MMOs and CEE-tool operators on SVERDRUP will track the whale and stay at 1-2 km distance. If additional tags are deployed, the FOCAL-1 or FOCAL-2 may be changed depending upon tag attachment and species. Normally, tagging effort will cease 2 hours after the first tag is attached and tag boats recovered. However, if the 48 hrs rule following an exposure event delays the next exposure in the same area, the second tagging window can be delayed, still allowing enough time for the experimental program (Figure 11).

Figure 11. *Default timeline of the 3S-2024 exposure experiments with a two focal animal scenario (top panel) and a one focal animal scenario (lower panel). * The second tagging window can be expanded if the 48 hrs rule delays the next exposure. ** The baseline period can be shorted to 4 hrs or extended to 12 hrs to achieve nighttime exposures. The default tag release time should be set to 24 hrs; however, if considered feasible this could be extended up to 30 hrs to allow for extended post exposure and baseline periods and nighttime exposures.*

2 focal animals scenario

Time (hrs)				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Phase	Tagging						Baseline**								Exposure								Post exposure					
Source	Off														ON								Off					
Events	T0; 1st tag on T0-T2; 2hr 2nd tagging period* T2-T3; 1hr post tagging T3-T11; 8 hrs baseline - HUS tracks F1 HUS stays >1km from focal whales														T11; 5min ramp up T11; 1st approach F1 HUS reposition T13; 1st approach F2 HUS reposition T15; 2nd approach F1 HUS reposition T17; 2nd approach F2								HUS stays >1km from focal whales T21; 1st tag off T23; all tags off Tag recovery					

1 focal animal scenario

Time (hrs)				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Phase	Tagging						Baseline**								Exposure								Post exposure					
Source	Off														ON								Off					
Event	T0; 1st tag on T0-T2; 2hr 2nd tagging period* T2-T3; 1hr post tagging T3-T11; 8 hrs baseline - HUS tracks F1 HUS stays >1km from focal whale														T11; 5min ramp up T11; 1st approach F1 T12-T15; HUS stays 10-30 km from F1 HUS reposition T15; 2nd approach F1 T16-T19 HUS stays 10-30km from F1								HUS stays >1km from focal whale T21; 1st tag off T23; all tags off Tag recovery					

Experimental phase

After tagging has finished, HUS will track and follow the tagged whale at 1-2 km distance for pre-exposure data collection. When daylight allows, visual tracking should also take place during this period in combination with the GPS-tracking using the CEE-tool.

Because each 8-hr exposure will be with different subjects, each exposure session should be as consistent as possible, following procedures specified in Table 8.

Near the end of the baseline period, HUS will move to ~10 km away from the whales to start the exposure phase which starts when the Socrates source starts active transmission and ends when transmission ends after 8 hrs. The target is to approach each focal whale twice from 10 km distance using CAS or PAS transmissions. There could be 1 or 2 focal whales during each exposure experiment.

This year we should try to also do some exposures during feeding around fishing vessels. This could be complicated to achieve due to navigation constrains if we have to manoeuvre between fishing vessels engaged in active fishing while towing the Socrates source. Manoeuvrability may also be limited by bathymetry, which should also be considered when planning source vessel movements during exposure periods. In order to achieve night time exposures, we should try to operate in the less crowded deeper off shore areas if weather and whale presence allow it.

When the exposure period has ended and the Socrates has ceased transmissions, the HUS will return to follow the FOCAL-1 whale at 1-2 km distance. Observations will continue until the tag detaches, at which point the FOCAL-1 tag and any other tags will be recovered.

Table 8. Summary of 3S4 exposure protocol specifications.

Parameter	Specification
Exposure types	LFAS or MFAS, LFAS is higher priority, MFAS is only back up CAS or PAS, CAS is higher priority but maximize contrast
Exposure condition	Nighttime feeding or Daytime resting, Nighttime exposures is a priority but maximize contrast
Target species	Killer whales (KW) or humpback whales, killer whales are higher priority
Target/Permitted sample size	N=26 KW, N=26 HW total (10 KW and 1 HW used during 3S-2023)
Exposure duration	8 hr max exposure; long duration exposures fixed at 8 hrs with shorter duration CAS-PAS contrast as back up
Exposure range	CPA – 30 km max, 10-30 km between approaches
Closest point of approach (CPA)	Target 1000 m CPA for both approaches for both KW and HW
Target exposure range, dB	LFAS 130-160 dB SEL_{20s} re $\mu Pa^2 \cdot s$, MFAS 110-140dB SEL_{20s} re $\mu Pa^2 \cdot s$
Number of focals	N=1-2, target is 2 (+ non focals), preferably in separate groups
Focal vs non focal range cut off	As a rule of thumb – F2 becomes non-focal if separated from F1 by less than 2 km and more than 30 km.
Approach distance	10 km
Approach speed	8 knots
Approach duration	40 min to CPA
Approach trajectory	Initial course of the source vessel should be set to intercept future CPA at a 45deg angle in front of the whale's heading. During approaches, turns are allowed twice (max 30 deg) towards new updated CPA estimate until 3 km range, after that the source vessel are only allowed to turn away from the animal towards target CPA.
Number of approaches	N=2 to each focal
Temporal approach separation	Approximately 4 hrs
Max SL and ESL	LFAS CAS/PAS ESL_{20s} =214dB re 1 $\mu Pa^2 \cdot s \cdot m^2$ MFAS CAS/PAS ESL_{20s} =197dB re 1 $\mu Pa^2 \cdot s \cdot m^2$ LFAS SL_{CAS}=201dB, LFAS SL_{PAS}=214dB re 1 $\mu Pa^2 \cdot m^2$ MFAS SL_{CAS}=184dB, MFAS SL_{PAS}=197dB re 1 $\mu Pa^2 \cdot m^2$
Ramp up	CAS ramp up before CAS exposures, PAS ramp up before PAS exposure. LFAS ramp up before LFAS exposures, MFAS ramp up before MFAS exposures. For LFAS 60 dB ramp up from ESL_{20s} 154-214dB re 1 $\mu Pa^2 \cdot s \cdot m^2$ within 5 min in linear steps for both CAS and PAS, after >5min shut down - restart ramp up. For MFAS 60 dB ramp up from ESL_{20s} 137-197dB re 1 $\mu Pa^2 \cdot s \cdot m^2$
Transmitted signal	LFAS 1300-2000 Hz HFM, MFAS 4000-6000 Hz HFM
Pulse repetition time	20 s
Pulse duration	CAS 19 s, PAS 1s
Mitigation action zone	500 m ship-based monitoring range using visual observers equipped with thermal binoculars during nighttime
Shut down range	If any marine mammals are detected within 100 m of the source, it will be shut down
Max expected weighted exposure levels for non-focal animals (SEL_{20s})	During LFAS exposures 100 m shut down range implies max 174 dB weighted SEL_{20s} re 1 $\mu Pa^2 \cdot s$ for LF cetaceans and seals, max 149 dB for HF cetaceans and 144 dB for very high frequency cetaceans. During MFAS exposures similar values are max 157 dB weighted SEL_{20s} re 1 $\mu Pa^2 \cdot s$ for LF cetaceans and seals, max 147 dB for HF cetaceans and 142 dB for very high frequency cetaceans.
Max expected weighted exposure levels for focal animals (SEL_{cum})	During LFAS exposures 1000 m CPA implies max 178 dB weighted SEL_{cum} re 1 $\mu Pa^2 \cdot s$ for humpback whales and max 153 dB weighted SEL_{cum} re 1 $\mu Pa^2 \cdot s$ for killer whales. During MFAS exposures similar values are max 159 dB weighted SEL_{cum} re 1 $\mu Pa^2 \cdot s$ for humpback whales and max 150 dB weighted SEL_{cum} re 1 $\mu Pa^2 \cdot s$ for killer whales
Weighted TTS and PTS onset according to Southall et al. 2019	For LF cetaceans (humpbacks and other baleen whales) TTS=179 dB, PTS=199 dB re 1 $\mu Pa^2 \cdot s$. For HF cetaceans (killer whales, pilot whales, sperm whales and dolphins) TTS=178 dB, PTS=198 dB re 1 $\mu Pa^2 \cdot s$. For very high frequency cetaceans (porpoises) TTS=153 dB, PTS=173 dB re 1 $\mu Pa^2 \cdot s$. For seals TTS=181 dB, PTS=201 dB re 1 $\mu Pa^2 \cdot s$.

Marine mammal risk mitigation during sonar exposure

During active sonar transmissions, the responsible CEE coordinator (Kvadsheim or Lam) will assure that no marine mammals are closer to the source than the 100 m required by the permit.

MMOs on the source vessel HUS will monitor the vicinity of the ship (500m mitigation zone), focusing on the direction of travel. During sonar transmissions in the dark, MMOs will use the Pulsar Merger thermal binoculars which enable them to detect marine mammals in the dark using the optimal setting for detection of marine mammals (Kleivane 2023).

If any animals are approaching the 100 m safety zone, an emergency shut-down of sonar transmission will be ordered. The source might be switched back on as soon as the animals are out of the danger zone. Sound exposure experiments will also be terminated if animals show signs of distress, disorientation or extreme responses, such as consecutive breaching behavior, and also if the animals swim dangerously close to the shore or enter confined areas that will strongly limit their escape routes.

The 100 m shut down range implies maximum sound exposure levels over the 20 s transmission cycle (weighted SEL_{20s} dB re 1 uPa2·s) of 174 dB for humpback whales and max 149 dB for killer whales during LFAS exposures and somewhat less during MFAS (Table 8). However, the tagged focal animals will not be approached closer than 1000m. Computer simulations of the study design predicted that focal animals will experience maximum weighted cumulative sound exposure level over the entire 8 hr period (SEL_{cum}; dB re 1 Pa^2·s) of 178 dB for humpback whales and max 153 dB for killer whales during LFAS, and less than that during MFAS (Table 8). These levels are well below established criteria for hearing injury in our study species (PTS=199 dB re 1 uPa^2·s for humpback whales and PTS=198 dB re 1 uPa^2·s for killer whales; Southall et al. 2019) (Table 8). The difference between the two species is caused by differences in the hearing weighting functions (Southall et al. 2019), i.e. killer whales have lower hearing sensitivity at 1-2 kHz than humpback whales. Other marine mammals expected to occur in the area (seals, porpoises, dolphins and other baleen whales) will also be well under the injury criteria with these planned risk mitigation measures (Table 8).

The decision to stop transmission outside the protocol is made by Kvadsheim or by Lam and Miller whom he has appointed to be responsible for permit compliance in his absence.

Prey field mapping

The echosounder system will operate continuously and record data using the configuration established during 3S-2023 (Table 9). The vessel will not be driven specifically for prey field mapping, rather data will be collected opportunistically. Two staff members on different watch periods will be trained to check the system is operating and recording properly during the trial, and will be trained how to restart the system in case it ceases working. The system should be checked during each crew change and once during each shift.

In addition to the echosounder data, we will also collect prey samples. Herring or other prey species will be collected by the tag boat teams using a handheld fishing net. After collection, fish will be brought onboard and processed prior to being frozen, and a standard data sampling sheet will be filled out.

Table 9. KONGSBERG EA640 single beam echosounder settings used during 3S-2023.

Setting Category	Setting Name	Value	Unit	Description
User	Range – Max	300	m	Current depth plus 300 m ‘below’ sea floor.
User	Range – Min	2	m	Start depth of the hydrophone.
User	Gain	-70	dB	Sensitivity of the echosounder's receiver.
User	Power	200	W	Power used for the transmitted sonar pulse.
Operations	Ping Mode	Interval	-	The mode of operations, set to interval
Operations	Ping Interval	600	ms	Time interval between each sonar ping.
Transceiver	Pulse Duration	0.256	ms	Duration of each sonar pulse.
Transceiver	Sample Interval	0.064	ms	Time interval between samples within a ping.
Transceiver	Power	200	W	Power of the sonar sample
Transceiver	Frequency	38	kHz	Frequency of the sonar signal.
Transceiver	Slope	0	%	Slope setting for signal processing
Transceiver	Noise Estimate	-132.5	dB	Estimated noise level in the received signal
Transceiver	Eq. Ambient Noise	298.7	dB	Equivalent ambient noise level
Transceiver	Sound Speed	1500	m/s	Speed of sound in water used for calculations
Transceiver	Ping Rate	0.8	pps	Rate at which pings are emitted
Active	TVG	20 Log	-	Setting for Time Variable Gain for log display

Sound speed profiles (XBT, CTD)

A temperature profile (XBT) should be taken by the source vessel (HUS) during all sonar runs (close to CPA). 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. After an exposure experiment, Socrates is 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. Bellhop).

Hydrophone measurements

Early during the trial the Socrates source will be tested to check that it can transmitted PAS and CAS signals at full power over the duration of the exposure experiments. Part of the test is to record harmonic spectral side lobe level of the Socrates source. This will de bone by using a hydrophone recorder system deployed of MOBHUS which has dynamic range of ≈ 90dB (16bit).

Sverdrup will sail circle around MOBHUS with turn-rate of 15°/min and speed of 4-5 kts. This would result in circle with radius of ≈ 0.3 nmi. During the test SOCRATES will transmit CW signals at different frequencies (1000, 15000, 2000 Hz) and levels (201, 208, 214 dB re 1 $\mu Pa^2 \cdot m^2$).

To investigate possible acoustic cues from the purse seine fishing vessels used by the whales to arrive at the fishing vessels at the right time to take advantage of the fishing to feed, we will use the same acoustic hydrophone system used to record harmonics of the source to also record acoustic signatures of fishing vessels. The hydrophone system will be deployed off MOBHUS who will station 100-500m from a fishing vessel who just set their purse seine nets. They will record until the nets is fully recovered. A datasheet will be used to track the distance to the vessel and timing of different phases of the fishing operation (e.g. throwing net, net fully deployed, starting pulling the nets, start/stop of pumps, net recovered, fish boat leaves).

BASELINE PILOT STUDY TRIALS

Baseline pilot study trials have been conducted in Iceland in the summers of 2021, 2022, 2023 and 2024 focusing on killer, humpback and long-finned pilot whales in a herring spawning ground near the Westman Islands, Iceland. These trials collect valuable baseline data on the natural behaviour and interspecific interactions of the study species. Importantly, the pilot study trials used the same tags (Mixed-DTAG++) and Goniometer tracking equipment that will be used in the 3S-2024 trial. The results of the 2024 Pilot Study are consistent with those of previous years, and reinforce the recommendations made for 3S4-2023. The Mixed-DTAG^{++} is highly effective for 3S4, with long duration times and 36 hr backup sensor sampling (increased from 24 hr) with the Little Leonardo video units. An ARTS deployment of a Mixed-DTAG^{++} was successful, with an effective deployment duration, no notable tag damage, and successful data recording. However, a Dummy DTAG broke apart during ARTS testing. The goniometer automatic GPS tracking system worked very well as it did in 2023, and a spare receiving system has been ordered for 3S-2024. During the 2024 pilot trial intensive training was also accomplished for tag technicians and taggers.

CHAIN OF COMMAND

Operational issues

Operational planning is made by the trial management group (Kvadsheim, Miller, Lam, Wensveen, Binder) during a daily meeting. Between meetings the CO/XO execute operational decisions. The cruise plan is the overarching management document, and should be followed as much as possible. Any deviations from the protocols specified in the cruise plan will only be made with consensus of all 5 chief scientists on board (Kvadsheim, Lam, Miller, Wensveen, Binder).

The cruise leader is the commanding officer on board and makes final decisions if consensus is not reached within the management group. However, the cruise leader is obliged to consult with the chief scientists of the 3S-partners on decisions affecting their area of interest or responsibility.

Safety issues

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

Permit issues

The permit holders are Petter Kvadsheim and Patrick Miller. They make final decisions on permit issues.

Sonar operation safety issues

A Risk Management Plan for the operation of Socrates is specified to minimize risk to this high value equipment (Appendix B). Final decisions on issues related to the safety of Socrates 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 (Table 10) 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.

During the trial, some data should be sent via internet to project partners on shore. For example, DTAG data can be transferred to U Iceland to begin acoustic analyses with the auditor team.

At the end of the trial the entire data record will be copied to all partners who should bring a fast USB drive (>100 MB/s write speed) with a capacity of at least 4 TB.

Table 10. Folder structure of the central data server

Folder	Description
acousticDataAndResults	Analysis scripts to verify if the rampup and subsequent pulses were audible in the recorded audio data of a tag. The script uses a matched filter analysis on specific wav files.
Bridge log	Logbook of the bridge, including daily orders published to the crew.
Briefs	Presentations of the crew briefing and closing hotwash meeting.
CEE Tool	Images, movies and screenshots made using the CEE tool. This folder also contains the CEE tool databases, sorted per experiment.
CTD_XBT	Recorded CTD and XBT data during the trial.
Drone data	Drone recordings.
DTAG	All DTAG associated data
echosounderData	Data recorder by the H.U. Sverdrup II echosounder.
fishSample	Fish sample logs
Goniometer data	Recorded data of the goniometer bearing and GPS positions of the tags.
GPSlogs	GPS and AIS logs of H.U. Sverdrup II
Logger	Logger logs, containing sightings and relevant events.
ObsDeck	Useful info printed for obs deck about tags.
Pics and videos	Pictures and videos.
Satellite tags	Argos satellite data configuration.
SocratesLogs	GPS and transmission logs of the Socrates source.
Software	Some useful software tools.
TrialOverviewPictures	Day to day images of the Sverdrup track and sonar transmissions.

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). 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 boat must bring a spare handheld VHF. Close to the coast cell phones can be used as back up, but offshore there is no coverage.

The radio call signals for the different units will be:

"Sverdrup"	Sverdrup (HUS) bridge (HQ) (answered by CO/XO, or captain/first officer if CO/XO not on the bridge)
"MOBHUS"	Water jet propulsion MOB (MOBHUS)
"SOCRATES"	Sonar operator on HUS (Socrates)
"Obs deck "	Marine mammal visual observation deck on HUS

A main working channel and an alternative channel 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. MMOs should also report over radio that they have safely arrived on station when they climb up there in the dark. Due to risk of radiation navigation radars need to be powered down before entering the MMO station. The first person who enters need to MMO deck need to inform the bridge before going up. Everyone should check if the radars are running when they arriving on the MMO station.

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

Main working channel	**Maritime VHF channel 72**
Alternative channel	**Maritime VHF channel 73**

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 a 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 A) has been made specifically for this trial. 5 types of risk are identified and mitigation measures and responsibilities 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 system)
- Risk to humans involved in the operation

All liability issues should be sorted/signed before embarkment. Medical seafarer certificate and safety training of all 3S-staff will be mandatory during 3S-2024

Since the operation includes animal experimentation, we will operate under permits from the Norwegian Animal Research Authority (permit no 23/110085) acquired by Petter Kvadsheim and approval from the University of St. Andrews ethical committee acquired by Patrick Miller. The permits include tagging and acoustic exposure of up to 26 killer whales and 26 humpback whales according to the protocol described here. The exposure experiments are permitted under the condition that we maintain a 100 m risk mitigation action zone around the sonar source during active transmission. If any animal enters this 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. Kvadsheim and Miller will be field operators responsible for permit compliance in the field.

Procedures to mitigate environmental risk will be implemented as described in this document, in the permit documents and in the risk management plan. Risk to humans should be minimized through the regular safety regime implemented for all relevant working operations on board. Appendix B of this document specifies procedures to mitigate risks to expensive equipment, such as the SOCRATES system. 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. 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 in the area. They will be informed about our operation, but if necessary we might do some public outreach meeting during the trial.

GENERAL ADVICE TO MEMBERS OF THE SCIENTIFIC CREW

The scientific trial you will be involved 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 October-November the air temperature will already be relatively cold at sea in these Arctic oceans (0-5 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.

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.

Experimental methods and procedures have been fixed in advance, and need to be kept in compliance with permits. 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 your 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 at sea.

Prepare yourself mentally that we might be at high sea without even sight of land for weeks 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. The ship has continuous satellite based internet connection and internal wireless network, so communication with home should always be possible. 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

The planning of this trial has been very thorough and has involved the full field team and other relevant experts to maximize our chances of achieving the trial and project objectives. All necessary permits have been acquired. All equipment, materials and staff required for the planned research effort have been obtained or are scheduled for delivery in time for the trial start. After consultation with the sponsors, the 3S board approved this cruise plan on September 4th 2024 as ready for execution in the time-frame specified.

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APPENDIX A

Risk assessment and management plan for the 3S-2024 research trial with HU Sverdrup II

Introduction

This document describes the risk identified for the 3S-2024 research trial. The trial will primarily take place off the coast of Northern Norway at Kvænangen-Lopphavet-Fugløybanken-Tromsøflaket-Nordvestbanken between October 10th and November 7th 2024 using FFI research vessel HU Sverdrup II (HUS).

The objectives of the trial 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 in killer whales and humpback whales, and investigate empirically if responses from short duration experiments predict responses from longer duration exposures conducted over an operationally relevant duration.

The objectives of the trial will be achieved deploying Mixed-DTAG++ or SPLASH tags to killer whales and humpback whales and do short- and long-duration CAS and PAS exposures using real-time GPS location data of multiple tagged subjects. A high powered sonar source will be moved to achieve repeated dose escalations twice over 8 hrs, and responses to the first approach will be compared to subsequent approaches.

The operation is described in detail in the 3S-2024 cruise plan.

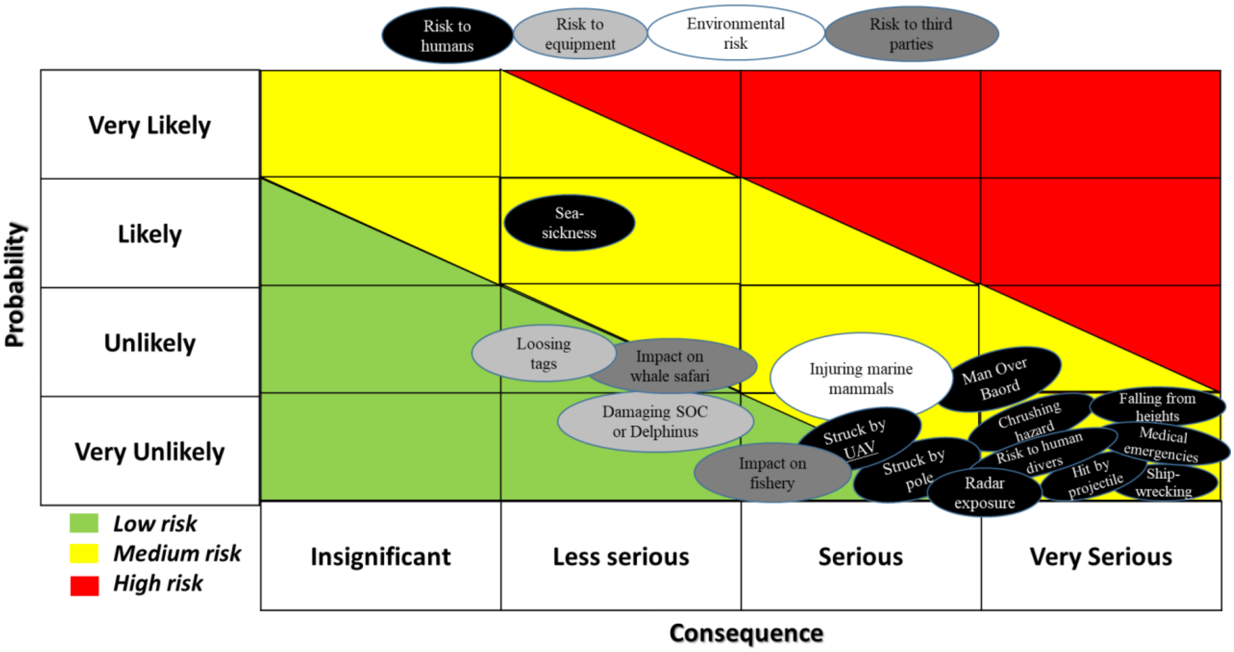

Figure 1. BLUF. Risk diagram summarizing the different risks associated with the 3S-2024 trial. Risks are categorized as low, medium or high based on the scored probability that the incident might happen given appropriate procedures defined herein are followed, and the consequence should it happen.

Risk inventory

The risk considered is risk to 3S staff involved in the trial on HUS, risk to third parties as a result of the 3S-2024 trial, risk to the environment, and risk of damaging or losing valuable equipment. Five types of risks are identified and mitigation measure and responsibility specified:

1) **Risk to the environment (injury to marine mammals)**
   Very Unlikely/Unlikely *x* Serious consequence = Medium risk

2) **Risk to third party human divers**
   Very Unlikely *x* Very serious consequence = Medium Risk

3) **Risk of impact on commercial activity (whale safari and fishery)**
   Very Unlikely/Unlikely *x* Less serious/Serious consequence = Low/Medium risk

4) **Risk of losing or damaging expensive equipment (Tags, Socrates and Delphinus)**
   Very Unlikely/Unlikely *x* Less Serious consequences = Low risk

5) **Risk to humans involved in the operation**
   Very Unlikely/Likely *x* Less Serious/Very serious consequence = Low/Medium risk

1. Risk to the environment

During the planned 3S-2024 experiment we will use an active sonar system transmitting 1-2 kHz sonar signals at 214dB energy source level (re 1 $\mu Pa^2 \cdot s \cdot m^2$) in an area with high density of herring and marine mammals, particularly killer whales and humpback whales which are also our study subjects. Extensive research has been conducted to assess the risk of such naval sonar systems to the Norwegian marine environment (Nordlund and Kvadsheim 2021). The Norwegian Navy has implemented science based procedures to minimize risk to the environment (Berdal 2024), and are using an operational risk mitigation tool (SONATE) to plan sonar operations and comply with their procedures (Nordlund and Kvadsheim 2021). The 3S-2024 operation will follow these procedures to assure minimal risk to the environment, but with some carefully considered modifications to allow us to address the scientific objectives of the experiments.

Extensive research has shown that naval sonar has little or no effect on fish nor on fish populations (Sivle et al. 2014). With the exception of clupeid fishes like herring, fish can generally not hear sounds in the 1-2kHz band and are therefore not affected by it. There are high densities of herring in the study area, but previous studies specifically looking at the impact of 1-2kHz sonar signals on overwintering herring (Doksæter et al. 2009) have concluded that there is no risk of any population level impact (Sivle et al. 2014).

The objective of the study is to investigate behavioural responses of cetaceans to the transmitted sonar signals. Some level of disturbance should therefore be expected and accepted. The Norwegian Animal Research Authority has reviewed the experimental protocol and permitted the 3S-2024 experiments (NARA 23/110085). They classify the impact on the experimental animals as mild. The experimental procedures have also been reviewed and approved by the University of St Andrews Animal Welfare and Ethics Committee. As part of the permitting process criteria for human end points, monitoring requirements and mitigation measures have been established. The study populations, North East Atlantic humpback whales and North East Atlantic killer whales, are not considered threatened or endangered by IUCN nor the Norwegian Artsdatabanken.

To predict the potential impact on the hearing of experimental subjects (killer whales and humpback whales) and other non-focal marine mammals in the area during our exposure experiments, we estimated the cumulative sound exposure level over the full 8hr experimental cycle (Table 1). The assumption for these estimates are that focal animals will be exposed during the entire exposure session but never closer than the 1000 m planned closest point of approach, whereas non-focal animals will be exposed only shortly, but never closer than a 100m stand off range. These simulations show that as long as the 100m shut down range is maintained, the exposure levels will be significantly lower than the threshold of hearing injury (PTS) for focal and non-focal animals. Focal humpback whales are exposed to levels close to their TTS-threshold, and could experience some temporary hearing loss, which they are expected to recover from within minutes if it did occur.

Table 1. Estimated weighted sound exposure levels (SEL) for focal animals (humpback whales and killer whales) and non-focal animals compared to the temporary hearing shift (TTS) and permanent hearing shift (PTS) criteria of Southall et al. (2019). The SEL estimates are based on simulations of ship movement, animal behavior and sound propagation. The assumption is a 1000m closest point of approach for focal animals and a 100m shut down range of the sonar for all marine mammals.

Marine mammals	Weighted SEL_{cum} dB re 1 μPa²·s	Southall et al. (2019) threshold criteria	
		PTS dB re 1 μPa²·s	TTS dB re 1 μPa²·s
Focal humpback whales	$SEL_{cum-8hrs}$ = 178 dB	199 dB	179 dB
Focal killer whales	$SEL_{cum-8hrs}$ = 153 dB	198 dB	178 dB
Non-focal LF cetaceans	$SEL_{cum-20s}$ = 174 dB	199 dB	179 dB
Non-focal HF cetaceans	$SEL_{cum-20s}$ = 149 dB	198 dB	178 dB
Non-focal VHF cetaceans	$SEL_{cum-20s}$ = 144 dB	173 dB	153 dB
Non-focal seals	$SEL_{cum-20s}$ = 174 dB	201 dB	181 dB

Risk mitigation measures

- Sonar transmissions will start with a 5min ramp up (gradual increase of source level) to reduce risk to marine mammals in the area by giving them time to move away. The ramp up procedure is specified in the cruise plan.
- A 500m mitigation action zone will be monitored by marine mammal observers on the source vessel during sonar transmissions. During transmission in the dark the observers will be equipped with thermal binoculars (Kleivane 2023). If any mammals appear within 100 m from the source, the source will immediately be shut down. The source might be switched back on as soon as the animals are out of the danger zone.
- Sonar exposure experiments will be terminated if marine mammals show signs of distress, disorientation or extreme responses, such as consecutive breaching behavior, and also if the animals swim dangerously close to the shore or enter confined areas that will strongly limit their escape routes.

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 and Frans-Peter Lam (PI, CO and XO on HUS) will be field operators responsible for environmental risk and permit compliance in the field.

2. 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. However, some whale watching operators allow snorkelling or scuba diving with whales. Human divers are a marine mammal and can be injured by exposure to high levels of acoustic energy. The main concern with exposure of scuba divers is however, that divers might experience a high stress level during the exposure because they are unacquainted with the sonar sounds. The risk of such stress is much lower for free diving snorkelers. NATO guidelines (NATO 2006) 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 214 dB re 1μPa·m 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 4km for the source vessel HUS. This number includes a factor 2 safety margin.

Risk mitigation measures

- We will stay away from known diving sites.
- During sonar transmission there will be visual observers on the source boat. Any observed diving activity should be reported to the CO/XO on watch instantly, if any diver comes within 4km the transmission will be stopped.
- The 3S-2024 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 the commanding officers on watch. For HUS this means cruise leader/CO Kvadsheim or co-cruise leader/XO Lam.

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

Research has shown that naval sonar has little or no impact on fish populations (Sivle et al. 2014). However, in the area closest to a sonar source, it is still uncertain if some fish species might respond to sonar transmissions. Such short-duration 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 therefore established to avoid negative impact on fishery. Such safety distances will vary with the transmitted source level, duty cycle and speed of the source (Sivle et al. 2014). 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.

The study species are two cetaceans previously shown to avoid the sonar source and cease foraging during exposure, and either to rapidly resume foraging (humpback whales; Sivle et al. 2016) or to have more prolonged responses (killer whales; Miller et al. 2014). Thus, sonar transmissions in an area can result in avoidance responses in marine mammals (e.g. Miller et al. 2014), and they might leave the area at least during the sonar operations (Kuningas et al. 2013). The threshold for avoidance will vary between different species (Harris et al. 2015) and it will also vary within a species depending on the behavioral context of the animals (e.g. are they feeding, migrating, socializing or breeding) (Sivle et al. 2015). Commercial activity related to marine mammals (whaling and whale watching), can therefore be negatively affected by naval sonar activity in the same area.

There is no commercial whaling going on in the operation area at this time of year. Whale watching are also unlikely in the off-shore areas, but if we operate in the more in-shore areas of Kvænangen we might encounter commercial whale watching operators bringing tourists out to watch our study species. We will primarily operate in the in-shore areas when the weather is too bad to work off-shore, and under such conditions whale watching boats might not be out. If there is whale watching activity going on, we will not conduct full duration exposure experiments in-shore until we have tested to which extent our experiments might lead to avoidance of the exposed area by whales over an extended period. In any case we will try to avoid doing behavioural studies in areas with dense vessel traffic close to the focal whales, because of the risk that this might compromises the controlled sonar exposure experiments.

Risk mitigation measures

- Prior to the operation we will contact the whale watching companies operating in the area and fishery organisations to inform them about our planned activity.
- During active transmissions by the Socrates source, a safety distance (sonar shut down range) of 500m from fishing vessels actively engaged in fishing will be maintained.
- During the operation we will monitor where the whale watching vessels primarily operate and as much as possible stay away from their core area.
- To minimize risk of accumulated effects of active sonar transmissions will not be conducting experiments closer than 20 nmi of where HUS conducted previous exposures experiment within 48 hours. This is also important to avoid habituation or sensitization of the experimental animals.

Responsibility
Management of risk of impact on commercial activities is the ultimate responsibility of FFI operating the research vessel HUS. On a daily basis the responsibility to manage this risk lay with the CO on HUS Petter Kvadsheim and the XO in his absence (Lam).

4. Risk of losing or damaging expensive equipment (Tags, Socrates and Delphinus)

During the operation the SOCRATES source 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. Risk of damage to this system includes risk of hitting the sea floor, risk of cavitation during high power transmission and risk of damage to the tow cable. A separate chapter of the cruise plan (Appendix B) contains specifications of the equipment as well as procedures for safe deployment, operation and recovery.

During operation we will deploy sophisticated digital tags (DTAG3 or Mixed DTAG^{++} to whales, expecting to recover them 20-40 hrs later. The intended use of the tags are specified in the 3S-2024 cruise plan. The tags are not commercially available and are especially made by University of Michigan and who makes then available to marine mammal research projects. If we lose tags, we lose data and other research groups might have to do with fewer tags. The current version of the tags have two transmitter types (VHF and Argos) enabling us to recover them using appropriate antennae systems and this reduces the risk significantly. The risk of losing tags are mitigated by careful testing beforehand, checking that batteries and sensor work as attended and double checking that the tags are programmed properly before deployment. Tags placement is also critical to optimize the chance that we can track the tag while on the whale.

Risk mitigation measures

- Risk mitigation measures for deployment, operation and recovery of the Socrates sonar source are specified in Appendix B of the 3S-2024 cruise plan.
- Procedures for deployment of tags are specified in the 3S-2024 cruise plan.

Responsibility
Management of risk of damaging Socrates 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 cruise leader Kvadsheim are responsible for assuring that the equipment is used in accordance with the instruction given by TNO (Appendix B). The responsibility of managing risk of tag loss lies with the PI prof Miller.

5. Risk to humans involved in the operation

Being on a ship at high sea constitute some elevated level of risk (e.g. tripping, falling over board, crushing hazard, being exposed to radar radiation etc). The research vessel HU Sverdrup II 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. Certain types of work operations, like working on tag boats, climbing in masts, or deployment and recovery of equipment from the aft deck require a work permit from the safety officer on the bridge. Before such a permit is issued a safety toolbox talk is required to clarify tasks, responsibilities, communication and necessary safety equipment for the people involved.

The ship will operate off-shore and getting acute medical care in an emergency will take longer than usual. During the 3S-2024 trial we will still operate within helicopter range for the search and rescue service. It is still considered critical that all personnel on board, including the science staff, are at good health and have basic first aid training before departure.

There is also a theoretical chance of fire or water intrusion making a full evacuation of the ship necessary. In such an emergency it is critical that everyone can take care of themselves as much as possible and therefore basic safety training with life rafts and survival suits are necessary. The scientific staff do not have formal safety roles on board, but it could take time before we get external help, and in emergencies we should be prepared to assist the ship's crew.

Risk mitigation measures

Table 2. Risk mitigation action plan for human risks during the 3S-2024 trial. Each theoretical incident is described with probability, consequence and necessary risk mitigation measures.

Incident	Probability	Consequence	Risk mitigation
Crushing hazard when working in tag boats or on aft deck with cranes	Very unlikely	Very serious	Safety toolbox talk before deployment of tag boats or heavy equipment from aft deck. Wear helmet and safety shoes in tag boats and on deck. Training of deployment and recovery of tag boats for tag boat crew.
Falling from heights during placements of antennae	Very unlikely	Very serious	Safety toolbox talk before any work >2m above the deck. Use safety harness when climbing
Medical emergencies far away from hospital could be life threatening	Very unlikely	Very serious	First aid training of crew Medical check before departure
Shipwrecking due to fire or sinking	Very unlikely	Very serious	Safety brief on board before departure, safety training course also for science crew before embarkment
Injury from projectile tagging systems	Very unlikely	Very serious	Projectiles and pneumatic tags (using ARTS system) are propelled with significant force and can cause serious injury. Ensure the weapon is primed/cocked and projectile loaded only when tagging effort is to commence. When loaded ensure the projectile is aimed outboard at all times and never sight across the deck of the vessel. If the projectile is not deployed it should be immediately removed from the weapon and the system made safe by releasing pressure from the chamber.
Man Over Board in cold arctic ocean could lead to hypothermia or drowning	Unlikely	Serious/Very serious	Use of personal flotation device when working on open aft deck. Use of floatation suit in tag boats. Safety toolbox talk and safety training of deployment and recovery of tag boats for tag boat crew. Tag boat driver must report in via

			radio to "HU Sverdrup" to confirm communication lines every hour! MMOs should also report to the bridge over radio that they have safely arrived on station when they climb up to the MMO station in the dark.
Risk of exposure to radar radiation	Very unlikely	Serious/Very Serious	The ship are using powerful radars for navigation. Radar transmitters are placed on the bridge roof and on the top mast. The radars should be powered off before any personnel enters this area. First person to climb up to the MMO platform need to inform the navigator on watch before doing so, and everyone should check if the radars are running when they arriving on the MMO station.
Injury during pole tagging operations, being struck by the pole	Very unlikely	Serious	All personnel must be vigilant when the pole is assembled, and used on board.
Being struck by a drone during UAV launch and recovery	Very unlikely	Serious	The drone will be flown following an established protocol used successfully on previous field efforts. The pilot will check the weather prior to any flight and is responsible for establishing whether no fly zones exist in the survey area. The pilot will carry out a pre-flight assessment, complete and record preflight checks. Launch and recovery will follow procedures developed by research groups worldwide for the operation of drones from vessels. No stable landing pad requires launch and recovery by hand. Releaser/catcher is equipped with gauntlets and head/face protection, launch and recovery is effected slowly straight up and down on the go ahead from the skipper with all other personnel standing clear. All flights will be logged and any incidents reported to the relevant authority as appropriate.
Sea sickness in rough seas	Likely	Less serious	Sea sickness medication. Severe sea sickness over time could be a risk factor if it leads to lowered awareness. People with severe sea sickness should not be given risky work tasks.

For the 3S-2024 trial the following operations requires special attention:

- 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 4 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 "Health and safety requirements for guest personnel H U Sverdrup II.

Other relevant documents

- 3S-2024 cruise plan
- APPENDIX B - Specifications, deployment, operation and recovery of the SOCRATES sonar source
- NARA permit 23/110085
- Health and safety requirements for guest personnel H U Sverdrup II

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APPENDIX B

Specifications, deployment, operation and recovery of SOCRATES sonar source

In this appendix, technical details and sailing restrictions are presented for the SOCRATES system 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 damage to the tow cable to due excessive force.

Bottom Avoidance SOCRATES

During the trials the SOC3 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 SOC3 [m]	100	170	260	400	500	500	500(*)

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

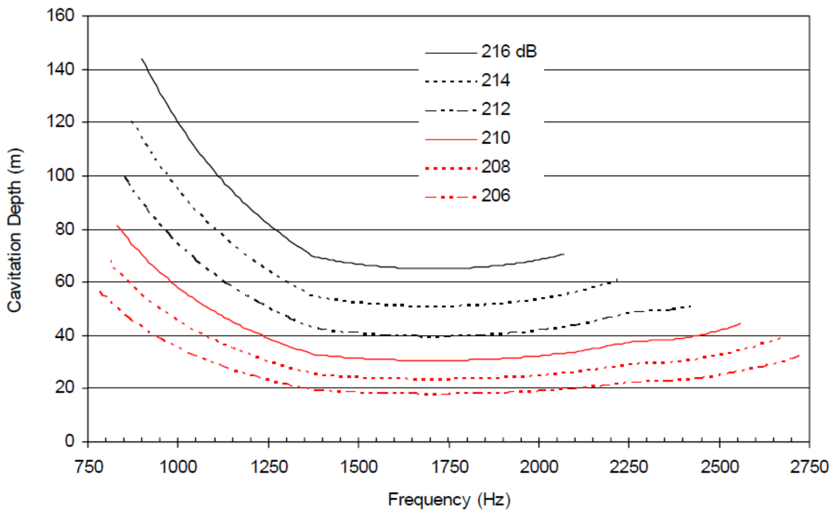
These values are based on the speed-depth diagrams at speed 3 kts with a safety margin of 20 m. When applied a minimum speed of 4 kts should be enforced.

Turn rate

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

Note that handling, like deploying and recovering SOC (see below), should take place during a straight course.

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 SOC3 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
SOC3 min depth [m]	100	90	80	70	60	50	40	30
SOC3 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
SOC3 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
SOC3 depth [m]	60	55	50	45	40	35	30	25
SOC3 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
SOC3 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	Killer whales and humpback whales
$LFAS_{shallow}$	1300-2000	HFM up-sweep	214	8	60	180	230	

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 will not use any acoustic array during the 3S-2024 trial and therefore not any dual tow.

Deployment and Recovery of systems

Sea state

The SOCRATES source 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

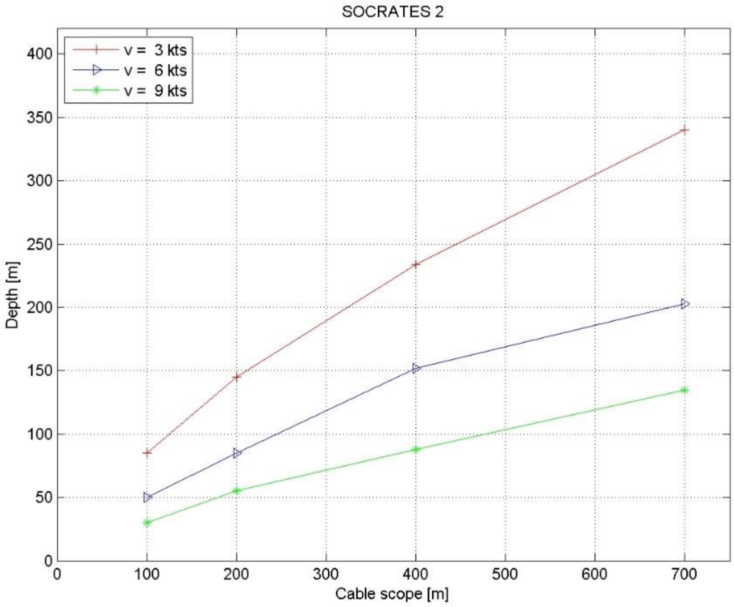
Deployment and recovery time for the SOCRATES to/from a cable scope of 100 m takes approximately 30 minutes and similar for the towed array. Stabilization time of towed body and towed array is about 5 minutes. During deployment and recovery, the tow ship speed is approximately 4 – 5 kts. When the handling 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.

Data Sheet

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

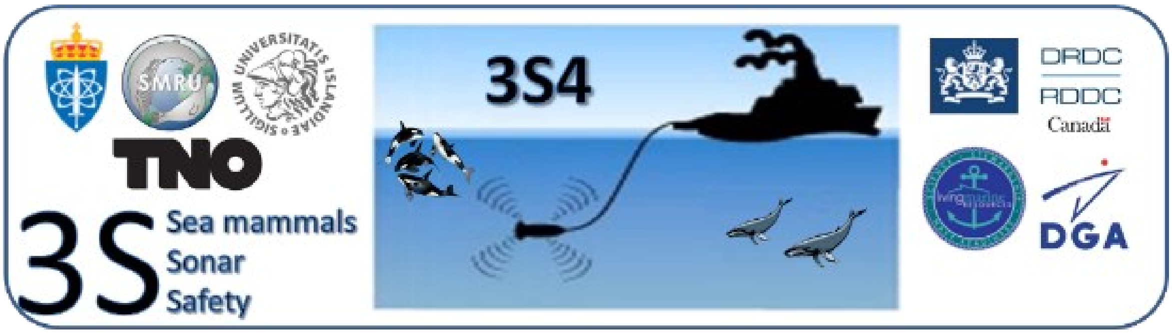
Item	**min**	**max**	**Remarks**
SOCRATES weight [kg (daN)]	430	750	Weight in water/air
SOCRATES tow length [m]	100	950	
Bottom Vertical Safety Separation [m]	20		
Upper Vertical Safety Separation [m]	15		When not transmitting
Upper Vertical Safety Separation [m]	40		When transmitting
Speed brackets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

Speed-Depth Graphs



D 3S-2024 Pilot study cruise report

Final Cruise report: 12 Feb, 2025



Cruise Report
3S-2024 - Iceland Pilot Study Trial

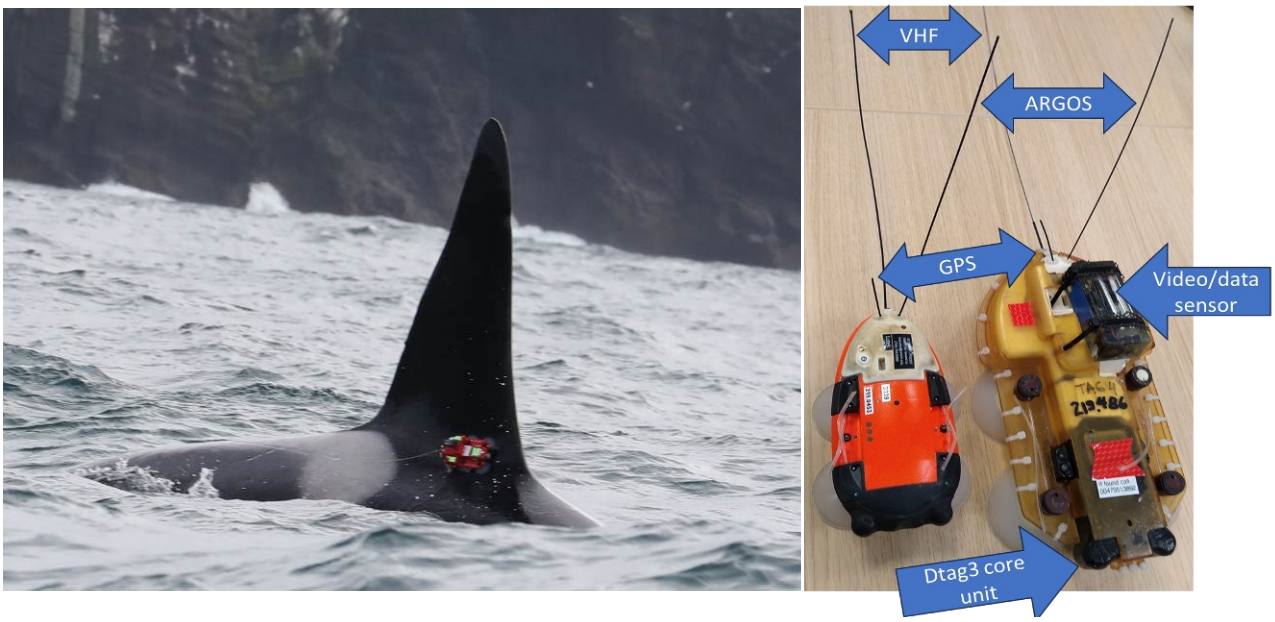


Figure 1: Left panel shows Mixed-DTAG++ deployment oo24_184b. This deployment stayed attached to the whale for 24 hrs, successfully recorded 102 GPS positions, and over 7hrs of video data. Photo by Giorgia Giovannini. Right panel shows the two tag types used in trial, integrated-DTAG on the left and Mixed-Dtag++ on the right. Note that the two tag types use the same LOTEK F6G134A FastGPS ARGOS system. The mixed-DTAG++ includes a DTAG3 core unit, and a Little Leonardo DVLW2000M130SW-4R video and data logger.

22 June -18 July, 2024

Patrick Miller, Cruise Leader; Filipa Samarra, Field Party Chief

Cruise Report prepared by:
Patrick Miller, Filipa Samarra

The 2024 Pilot Study trial in Iceland was funded by US LMR (project 57) and French DGA as part of the 3S research collaboration. Additional funding was provided by Rannís and the Earthwatch Institute. Fieldwork was conducted under a Marine and Freshwater Research Institute (Hafrannsóknastofnun) institutional permit, and research protocols were approved by the U of St Andrews Animal Welfare and Ethics Committee.

TRIAL OUTCOME –SUMMARY

Overall, the 3S-2024 pilot study cruise in Iceland (22 June – 18 July, 2024) was successful. As in 2021-2023, all facilities and equipment worked well. Though weather and whale conditions were not favourable, all primary tasks were addressed. From 27 total days of effort, 5 days were used for setup, breakdown and logistics. Of the remaining 22 days, we had workable weather on 11 days, 50% matching our expectation. Of the 11 days, tagging was attempted on 9 days and a total of 4 suction-cup tags (Mixed-Dtag++ or integrated DTAGs, Fig. 1) were attached on 3/9 tagging days. This was a higher rate of no-tag days than we experienced in previous years, due to the fact that the whales were more difficult to closely approach than normal. A total of 4 tags were deployed, 3 to killer whales, and 1 to a humpback whale. Mixed-Dtag deployments (N=3) on killer whales had good retention times, with an average duration of 22.8 hrs, and a maximum deployment duration of 24.9 hrs. The one integrated Dtag deployments on a humpback whales remained attached for 5.8 hrs.

As in previous efforts, ARGOS locations were successfully received while tags were attached to animals, and while floating after attachment (except one case mn24_176a when seaweed was attached to the ARGOS antenna causing the tag to float low in the water (Fig. 2). Video and data recordings using newly programmed Little Leonardo DVLW2000M130SW-4R video and data loggers were highly effective and 36-hr duration data (depth and acceleration) recordings were made consistently. The video recordings were high quality, revealing details of underwater behaviour, and video start times were as programmed (thanks to Little Leonardo for improving the software). However, due to a programming fault, the video recordings were not continuous.

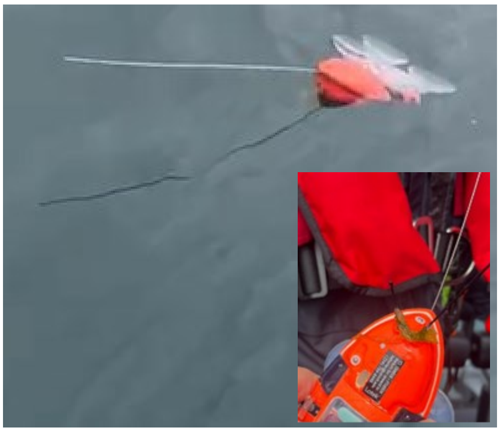


Figure 2. Integrated Dtag floating after deployment mn24_176a. Note the floating angle was such that the ARGOS antennae did not rise above the surface. This was due to some seaweed had become attached to the GPS and ARGOS antennae (inset box). The bad flotation angle explained the relatively low rate of ARGOS positions received (0.37/hr – Table I) when the tag was floating. Photo by Giorgia Giovannini.

Though our data sample was small, we addressed all of the primary objectives. Conditions were too rough to track any tagged whales using the Goniometer system. Instead, a boat-boat tracking test was accomplished, which successfully demonstrated the continued effectiveness of the automatic GPS-ARGOS tracking system, as well as the new PamGuard software for integrated visual and GPS tracking (named 'PamGonio'). A substantial degree of training was accomplished with ARTS tagging (Wensveen and Miller), tag technician (Sato and Giovannini) and photo-id (Hayward) – in preparation for the 3S4-2024 sonar trial in Norway. Most secondary objectives were achieved, but conditions did not allow for drone flights.

<u>Conclusions and Recommendations for the 3S4 sonar-effects study</u>

The results of the 2024 Pilot Study were consistent with those of previous years (2021-2023), and reinforce the recommendations made for 3S4-2023. The Mixed-Dtag++ is highly effective for 3S4, with long attachment durations and 36hr backup sensor sampling (increased from 24hr) with the Little Leonardo video units. An ARTS deployment of a Mixed-Dtag++

was successful, with an effective deployment duration, no notable tag damage, and successful data recording (Table I). However, a Dummy Dtag broke apart during ARTS testing. ARTS tagging can be part of the tag deployment mix in 3S4-2024, though there remains concern that launching using ARTS can damage the Mixed-Dtag. The goniometer automatic GPS tracking system worked very well as it did in 2023.

We attempted to deploy a new version Mixed-Dtag++ with a Dtag4 core unit. That system does not have a release device, so would have been a good test for even longer deployment durations than that achieved. Unfortunately, we were not successful in deploying that version of the Mixed-Dtag++ as whales could not be approached closely enough for pole tagging. The tag could be an option for use in the 3S4-2024 trial, if logistics permit deployment of a tag without a release device.

OPERATION AREA

The operation area was waters near the island of Heimaey in the Westmann Islands, Iceland.

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

Primary tasks:

1. deploy GPS-ARGOS linked Mixed-Dtag++ (with Dtag3 and Dtag4 core units) and integrated-Dtag3 on target species, to quantify and compare key performance indicators (automatic tracking effectiveness, suction cup retention duration and stability, ARGOS to aid recovery, video-data logger effectiveness). Tags will be deployed using hand-poles or ARTS to compare functionality as a function of deployment method. When weather forecasts allow, no release time will be set, to test maximum obtainable deployment durations. The killer whale (Orcinus orca) is the primary species, but long-finned pilot (Globicephala melas) and humpback (Megaptera novaeangliae) whales may also be tagged.

Outcome: Four suction cup deployments were made, totalling 74.3hrs of on-animal data (Table I). All four deployments had effective placements with acceptable GPS and ARGOS uplink performance. The pole deployments on killer whales had ideal orientations and remained attached until the programmed release time. The ARTS deployment on a killer whale was launched at 9.2-9.4 bars and attached at 12-15m distance. It attached sideways, and detached several hours before the programmed release time, but the 19.8 hr attachment duration is an acceptable duration for 3S4 exposures. The Little Leonardo video units worked well with improved software enabling 36hrs of backup data and improved functionality of delay to start video recording. The integrated Dtag deployment on a humpback (mn24_186a) was much shorter in duration, and had less frequent ARGOS updates when floating, which was due to algae attached to the antennae (Fig. 1).

A Mixed-Dtag++ replacing the Dtag3 core unit with a Dtag4 core unit was built and successfully float tested. However, it was never deployed upon a whale. It does not include a release device, and was not trialled for deployment with the ARTS system.

Primary task 2. train additional staff in tag technician and tagging roles

Outcome: Intensive training was accomplished. George Sato and Giorgia Giovannini trained as tag technicians; George Sato trained as a pole tagger; Paul Wensveen and Patrick Miller trained as ARTS taggers, and Ellen Hayward trained for photo-id. All now have sufficient skills to carry out those roles during the 3S4-2024 sonar trial.

Primary task 3. track tagged whales with the automatic GPS-ARGOS tracking system using a goniometer antenna, alongside visual tracking of position and behaviour.

Outcome: This task was not accomplished with tagged whales as weather conditions were too rough to use the tracking vessel MV Friðrik Jesson when tags were deployed on whales. Instead, several hours of boat-boat testing was carried out with a GPS-ARGOS tag transmitting on the tagboat transmitted while being tracked visually by an observer on the MV Friðrik Jesson. The result shows the effectiveness of adding the automatic GPS positions to the traditional Logger track created using visual tracking (Fig. 3). This new publicly available Pamguard software will be highly effective at making this method more widely usable by the research community.

<u>Secondary tasks</u>:
4. Collect photogrammetry and behavioural recordings using drones.
Outcome - no drone flights were possible due to poor weather conditions

5. Collect sightings and photographs of target species and other cetaceans encountered.
Outcome – large sighting and photo-id datasets were collected.

6. Collect echosounder survey data of herring in the study area, using a SIMRAD EK-80 echosounder system.
Outcome –transect lines were carried out by a separate vessel on 6, 8, 9, and 10 July. None of the echosounder survey dates overlapped periods when we had a tag deployed on a whale.

7.   Collect biopsy samples of whales in the study area
Outcome – a total of 8 biopsy samples were collected during the field effort.

CHRONOLOGICAL OUTCOME

22 June:	Travel to Iceland. Miller, Sato, Hayward, Giovannini. Arrived to Heimaey OK, moved into housing. Shipment hadn't arrived yet.
23 June:	Began preparing tags, and team training led by Hayward.
24 June:	Weather is not workable, high winds. CARNET documents for the shipment are missing.
25 June:	Weather is not workable, high winds. Hayward continued training. Two mixed-Dtag++ with D3 core unit have been fully built up and float tested.
26 June:	Weather is not workable, high winds. Car seemed to have a dead battery so needed to be jump-started, but then worked OK throughout.
27 June:	Weather is not workable, high winds. Continued training and setup
28 June:	Weather is not workable, very high winds. Shipment arrived all OK.
29 June:	Weather is not workable, very high winds. Rest day.
30 June:	Weather is not workable, very high winds. Continued training and setup
01 July:	Weather still not workable, very high winds. Set up Fridrik and did car tests. Conducted VHF tests with all tags. All tests successful.

02 July:	Weather was a bit rough, but improving so we went out to try to tag. deployed two tags oo24_184a and oo24184b. Excellent placements, but tracking wasn't possible as conditions were too rough to track.
03 July:	Weather worsened overnight, too rough to attempt Gonio tracking from Fridrik. recovered both tags deployed the previous day.
04 July:	Weather OK. tagged a humpback whale with integrated Dtag. It was doing sideways surface lunges. Very easy to approach.
05 July:	Last ARGOS position at midnight near the island. Weather is workable. Recovered humpback tag. It had seaweed on the ARGOS antenna causing it to float underwater, explaining the lack of ARGOS to aid recovery. Attempted tagging ~4hrs with killer whales using Dtag4-Mixed-DTAG++. No luck. George had excellent tagging training.
06 July:	Patrick trained George in tagging. George had one attempt on the smaller humpback we previously tagged, but tag did not attach to the whale.
07 July:	Paul trained George in tagging with cantilever weight. No attempts.
08 July:	George tagging with Paul doing Biopsy. 4 biopsies collected, but no tag attempts.
09 July:	George rest day. Whales found near Surtsey. Ellen fully handled photo-id successfully, training complete. VERY difficult to get close enough to tag or attempt biopsy with any whale. No attempts
10 July:	George tagging with Paul doing Biopsy. Whales found closer to Heimaey, not at Surtsey as they have been for several days. No tags on though whales were close many times.
11 July:	Weather not workable, very high winds. Rest day.
12 July:	Weather not workable, very high winds. Office day.
13 July:	Weather is not workable, very high winds. Prepared ARTS tagging equipment
14 July:	Weather is not workable, high winds. Paul and Patrick practice sessions on the Golli using ARTS Dummy Dtag broke during ARTS practice.
15 July:	Weather better. Paul tagged a male oo24_197a with ARTS! 2 beeps per surfacing.
16 July:	Went out with Fridrik for tracking. Conducted boat boat-boat tracking and using the PamGuard software which was highly successful. Many good tracks generated sufficient for demonstration of functionality. The weather was too rough to attempt whale tracking. Tag was off when we returned after boat-boat tests, so tag was recovered successfully using Fridrik in rather rough conditions. ARGOS positions and Goniomteter greatly aided recovery, with 2 GPS locations received when we got close to the tag.
17 July:	Weather is still too windy – sea state 4, and wind predicted to increase. Tagging cancelled so field operations are complete. Organized datasets and prepared shipments. Dismantled Fridrik.
18 July:	Ellen travels to Airport on bus. Shipment prepared by end of day.
19 July:	Ellen departs Iceland. George, Giorgia, Patrick travel to airport.
20 July:	George and Patrick fly to Scotland, Giorgia to Italy.

SUCTION CUP TAG DEPLOYMENTS

Tagging was conducted off the RHIB "Golli" using a 5m hand pole with a straight orientation of the tag relative to the pole, or with the ARTS tagging system. As detailed in Table I below, a total of 3 deployments were made with the Mixed-Dtag++ (1 using ARTS) and 1 deployment was made with an integrated-DTAG. Of the 4 tag attachments, no behavioural response to tagging were noted for 2 cases (including the ARTS attachment), while a minor response (level 1), such as a body flinch or tail slap was observed for 2 cases.

GPS LOGGING, GPS-ARGOS, and ARGOS-ONLY LOCATIONS

Performance of the LOTEK GPS receiver and ARGOS transmitter systems was similar to that of the 2021-23 baseline trials, with locations logged regularly for tag placements that weren't low on the body. We carefully quantified the rate of location information received while tags were attached to the animals, and during the floating period before recovery (Table II). Performance was highly acceptable, except for the floating period of deployment mn24_186a which was affected by seaweed attached to the ARGOS antenna (Fig 2, above).

GPS-GONIOMETER TRACKING

Whale-boat tracking with the Goniometer was not possible due to adverse weather conditions. However, we successfully conducted boat-boat tests collected and displaying real-time GPS (+ visual) tracking data within a newly developed Pamguard module (Fig. 3).   This test was perfectly successful, demonstrating this publicly-available interface for use with the real-time GPS tracking system.

Figure 3.   Combined visual and GPS track recorded and visualized in Pamguard software. Visual sightings are shown as blue circles offset from the MV Friðrik Jesson sailing track. Red squares show automatic GPS positions obtained with the LOTEK realtime software.

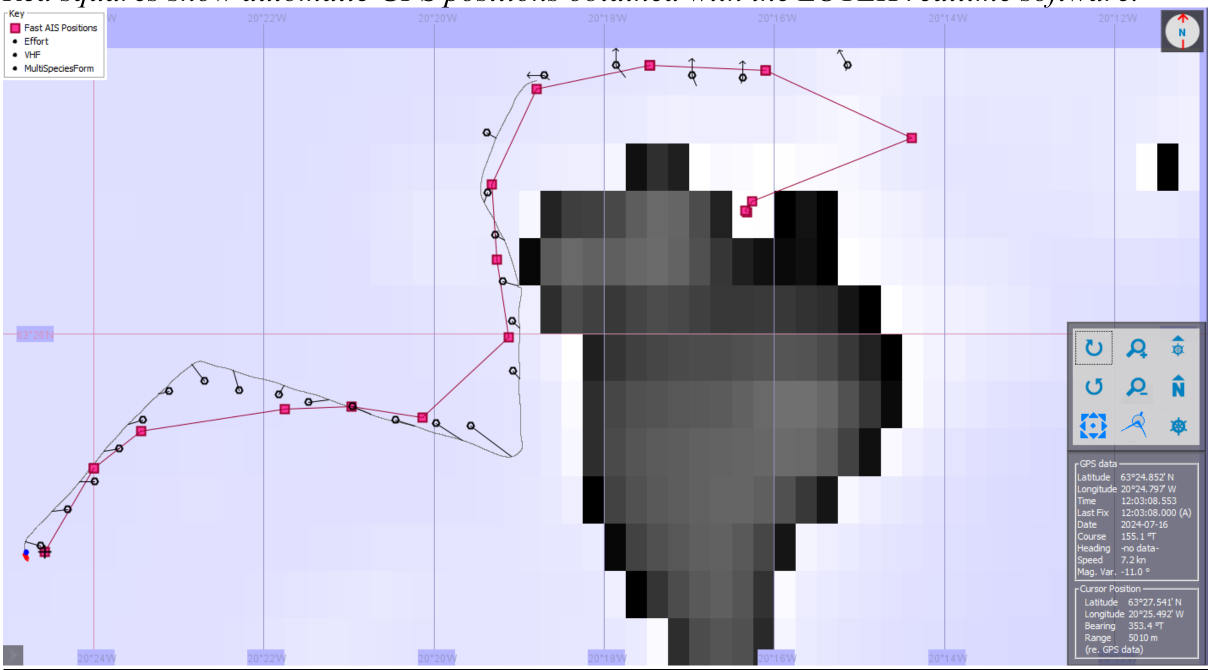


Table 1. Details of Dtag deployments during the Iceland 2024 pilot study trial.

Date	Deployment ID/method	Tagon time and location	DTAG start time	Resp	Photo ID file/animal ID	Hrs on	Tag type (unit id)	FastGPS ID	Video Data	Why released	Comments
2.7.2024	oo24_184a Pole	16:25 UTC 63.41375 N 20.38918 W	02/07/2024 16:24:29 UTC	1	3T2A4310 (IS250 likely)	24.9	Mixed DTG++ Homer (C330)	183278	23006, 07:37:05 (17 files)	Seems to have released a bit late, releases burnt as programmed	Adult female travelling with Mulder
2.7.2024	oo24_184b Pole	16:50 UTC 63.4113 N 20.37868 W	02/07/2024 16:49:07 UTC	1	3T2A4456 (IS560)	23.8	Mixed DTG++ Elmo (C317)	161599	23007, 07:17:42 (17 files)	Released as programmed	Adult male travelling between feeding events
4.7.2024	mn24_186a Pole	14:16 UTC 63.47878 N 20.26195 W	04/07/2024 14:15:29 UTC	0	HYPM4391 (tag on) HYPM4394 (tag position)	5.8	Integrated DTag Orange (405)	198608	N/A	Released early	Only two suction cups stuck
15.7.2024	oo24_197a ARTS	13:43 UTC 63.29732 N 20.61495 W	15/07/2024 13:42:52 UTC	0	HYPM5912 (IS291)	19.8	Mixed DTG++ Elmo (C317)	161599	23007, 06:54:24 (18 files)	Released early	Sprouter male travelling in group of 5

Table II. Logger and remote GPS and ARGOS performance for each of the 4 deployments, while attached to each animal, and while floating after detaching from each whale.

			Logger GPS		Remote GPS		Remote ARGOS	
Individual ID	Status	Time (h)	# of positions	Rate (per hour)	# of positions	Rate (per hour)	# of positions	Rate (per hour)
oo24_184a (183278)	On animal	24.9	145	5.82	7	0.28	38	1.53
	Floating	0.67	5	7.46	0	0	1	1.49
oo24_184b (161599)	On animal	23.8	102	4.29	1	0.04	25	1.05
	Floating	0.98	10	10.2	0	0	2	2.04
mn24_186a (198608)	On animal	5.8	52	8.96	6	1.03	7	1.12
	Floating	16.06	9	0.56	0	0	6	0.37
oo24_197a (161599)	On animal	19.8	124	6.26	18	0.90	40	2.02
	Floating	6.87	57	8.29	1	0.15	11	1.60

Appendix: Pilot study cruise plan dated 29 May, 2024.

Cruise Plan

3S-2024 Pilot Study Trial

June 22 –July 19, 2024

Patrick Miller, Cruise Leader; Filipa Samarra, Field Party Chief

The 3S-2023 pilot study trial is primarily funded by the US Living Marine Resources (LMR) and French DGA, with additional support from RANNÍS and the Earthwatch Institute.

PROJECT OBJECTIVE

The 3S (Sea Mammals, Sonar, Safety) 2024 pilot study trial will focus on improving tagging systems and methods to be used in the 3S4 full scale behavioural response study (BRS) with killer and humpback whales. The first 3S4 trial was successfully conducted in Oct-Nov 2023, and methods developed in previous pilot studies based in Iceland were critical to the success of that trial. Several aspects of Mixed-Dtag++ performance are important for the 3S4 study, including: 1.) tag attachment using poles or ARTS launching systems, 2.) real-time location tracking of tagged individuals achieved with automatic relay of the tagged-whales' positions via the ARGOS satellite system and directly with a Goniometer antenna, 3.) duration of suction-cup attachments; 4.) effectiveness of the Little Leonardo video and data logger, 5.) ARGOS locations after tag detachment to support tag recovery, and 6.) capability to tag smaller body sized animals. Demonstrating these tag capabilities are the core objective of LMR project 57, which is sponsoring the field effort. As Dtag3 core units are being replaced by Dtag4 core units, so working with those new Dtag4 core units is a priority. Additional tag-technician, tagging, and photo-id staff are also needed for the next 3S4-2024 sonar trial.

CRUISE TASKS

The objectives of the 2024 pilot study are to continue to improve and demonstrate the capabilities of the Mixed-Dtag++ tag system, train tag-technician staff, and collect data to address baseline science objectives supporting the long-term research at the Iceland field site. The key identified areas are: 1) testing the automatic GPS tracking system alongside visual tracking using a new Pamguard module, 2) field testing delay timer settings for back-up video and data sensors produced by Little Leonardo, 3.) tagging whales using the ARTS launching system. The effort will provide valuable baseline knowledge, including inter-specific interactions, of the study species. 2024 pilot study outcomes will be communicated immediately after the trial, including recommendations for the 3S4-2024 sonar trial.

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 GPS-ARGOS linked Mixed-Dtag++ (with Dtag3 and Dtag4 core units) and integrated-Dtag3 on target species, to quantify and compare key performance indicators (automatic tracking effectiveness, suction cup retention duration and stability, ARGOS to aid recovery, video-data logger effectiveness). Tags will be deployed using hand-poles or ARTS to compare functionality as a function of deployment method. When weather forecasts allow, no release time will be set, to test maximum obtainable deployment durations. The killer whale (*Orcinus orca*) is the primary species, but long-finned pilot (*Globicephala melas*) and humpback (*Megaptera novaeangliae*) whales may also be tagged.

2. train additional staff in tag technician and tagging roles

3. track tagged whales with the automatic GPS-ARGOS tracking system using a goniometer antenna, alongside visual tracking of position and behaviour.

Secondary tasks:
4. Collect photogrammetry and behavioural recordings using drones.
5. Collect sightings and photographs of target species and other cetaceans encountered.
6. Collect echosounder survey data of herring in the study area, using a SIMRAD EK-80 echosounder system.
7. Collect biopsy samples of whales in the study area

MAIN LOGISTICAL COMPONENTS

MV Friðrik Jesson

Skipper: Sigurmunður Einarsson
Mobile phone: +354-864-4884
Real-time GPS-ARGOS (CLS goniometer antennae), VHF (DFHorten system) and visual tracking. ARTS tagging platform if needed. Rough weather tag recovery.
Length: 12m. Engine: Volvo 750 HP (diesel); 220V power Max/cruising speed: 17/13.0 knots

Vessel 2: Golli

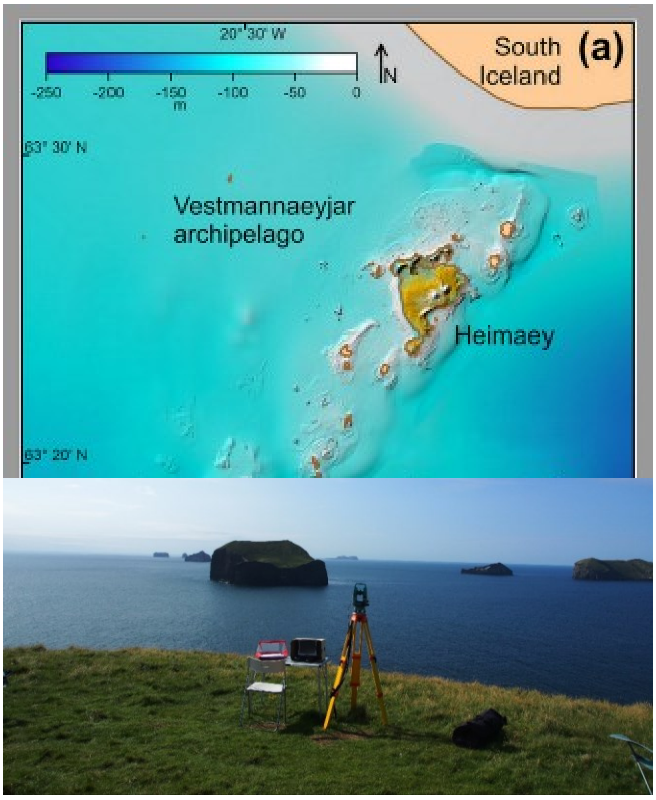
Customized techno marine RHIB (http://www.technomarine.pl/) with Suzuki 200 HP 4-stroke outboard motor. This second vessel will serve as the primary platform to search for and tag whales.

Mixed-Dtag++ and integrated-Dtag

3S-2024 pilot study efforts will focus on deploying and quantifying functionality of the Mixed-Dtag++ and integrated-Dtag, which is a suction-cup attached whale tag, attached using poles or ARTS launchers. Note the Mixed-Dtag++ uses Dtag2 suction cups, while smaller suction cups are used for the integrated-Dtag. Mixed-Dtag++ and integrated-Dtag will contain: Dtag3 or Dtag4 core unit (audio, depth, 3-axis accelerometer, 3-axis magnetometer, optional programmable release); LOTEK integrated GPS-ARGOS logger; VHF transmitter, flotation. A Little Leonardo video-data logger will be added to the Mixed-Dtag++ tags, but will not be part of the integrated Dtag.

OPERATION AREA

The operation area will be the waters of the Westmann Islands, in southern Iceland. The area is a long-term field site, with large numbers of killer whales and other species sighted during the summer months. A shore-based sighting station near the southern tip of the main island will be used to visually locate animals, and to assess weather conditions. A science team under management of F. Samarra will run visual effort from the shore station.



Left: Map of the Westmann Islands archipelago. Bottom panel: view from the land station looking southwest over the Westmann Islands.

TRIAL SCHEDULE

22 June: Miller, Hayward, Sato, Giovannini arrive Keflavik, pick up rental car and transit to Heimaey. First night of lodging on Heimaey.
23-24 June: Prepare tags and test goniometer reception and tracking systems.
25 June: Start of full operations working with whales.
26 June – 17 July: Regular operations.
17 July: Last possible day of full research operations. Tags recovered by end of day
18 July: Break down and pack equipment for shipment
19 July: Miller, Hayward, Sato, and Giovannini depart Westmann Islands, departing lodging. Return rental car. Stay in hotel near airport.
20 July: Miller, Hayward, Sato flight to Edinburgh. Giovannini return to Italy.

STUDY ANIMALS

The primary target species is killer whales, with secondary species long-finned, humpback, whales expected to be available for study. Individuals of these target species will be chosen opportunistically from animals found in the study site, ideally including a mix of body sizes.

SCIENCE CREW LIST / ROLES

NAME:	Primary Role	Secondary Role	Tertiary Role
Patrick Miller	Cruise leader	Tagger / Tag technician	Tracking
Filipa Samarra	Field party chief	Photo-id/biopsy	Land Station
Paul Wensveen	ARTS tagger	GPS-ARGOS tracking	Visual tracking
Ellen Hayward	Lead tag technician	Photo-id trainee	Goniometer tracking
George Sato	Tag technician trainee	Tagger trainee	Drone flyer
Giorgia Giovannini	Tag technician trainee	Photo-ID	Visual tracking, drone assist
Barbara Neubarth	Golli boat driver		
Chérine Baumgartner	Behaviour observer	Tracking observer	Land station
Anokhi Saha	Echosounder survey	Shore station	Visual tracking

DAILY WORK PLAN

A daily planning meeting with the Cruise Leader and Field Party Chief, at least, will be held each evening to determine the specific plan and team roles for the next 24 hours. Over the 24 days of possible at-sea operations (25 June - 17 July, inclusive), the Golli is budgeted for this project for 10 days, and Friðrik Jesson for 5 days. It is therefore expected that the Golli will operate on most good weather days. If weather is unusually good, we may add additional days of boat usage. The Friðrik Jesson will be used primarily to track tagged whales using the Goniometer system and visual tracking and behavioural observations. GPS-ARGOS-Goniometer tracking (led by Hayward) should always be carried out whenever the Friðrik Jesson goes to sea.

Vessels will work at sea for a maximum of 8 hours each day, with Friðrik Jesson and Golli returning to dock each night. The research team will be responsible for their own meals.

Recovery of any previously-deployed tags will be given top priority to assure safe recovery of the loggers and data contained therein.

Searching phase

The shore-station team will start by searching for whales at the start of each day. As much as possible, searching will be conducted first from the shore station and vessels will only be used once sightings of target species are confirmed, but Golli can also search independently. Shore teams will be trained in the use of VHF receivers to listen for tags and determine the direction to floating detached tags.

Before and during the search phase, at least 2 tags should be prepared so they are ready in ‘grab and go’ mode for use upon encountering animals. This is the key time period for training tag technician skills. A mix of Mixed-Dtag++ and integrated-Dtag deployments will be used to enable contrasts of performance. Details of release times will be agreed between the PI and Field Party Chief depending on weather forecasts and recovery vessel availability.

Tagging phase
Once a target species is encountered, we will observe and record the overall group characteristics and start taking identification photographs. If conditions allow, we will commence tagging effort. Tagging will be done from the Golli using poles or ARTS. 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. This is the key time period for training photo-id. Neonates cannot be tagged, but other animals will be tagged as possible.

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

0 No reaction: whale continued to show the same behaviour as before the tagging attempt;
1 Low-level reaction: whale modified its behavior slightly, e.g. dived rapidly or flinched;
2 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;
3 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 on the dorsal fin or high on the back in front of the dorsal fin. Tag attachments low on the body are not desirable as they preclude testing of the GPS-ARGOS system. Lead taggers Miller and Wensveen will train Sato on tagging procedures and techniques.

Once a tagging attempt 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. Data sheets for each deployment should be completed promptly to assure that no information is lost. Good photographs of tag positions, and (when possible) body size of the tagged whale(s). This could include use of drones outfitted with LIDAR when conditions allow.

As much as possible during tagging efforts, the teams on the vessels should collect additional data for project goals, including visual notes of group behaviour and collection of fish prey samples. Once tagging effort is ceased, the tag boat can be used for secondary data collection, including identification photographs or biopsy samples.

Tracking and observation phase
Once a tag is deployed and VHF beeps are confirmed to be heard, a decision will be made to launch (or not) the Friðrik Jesson to track the tagged whale using the automatic GPS-ARGOS system, supported by VHF and visual tracking. GPS-ARGOS-Goniometer tracking (led by Hayward) should be carried out whenever the Friðrik Jesson goes to sea. The range of automatic GPS-ARGOS tracking will be tested only when Friðrik Jesson approaches or moves away from the tagged whale(s). It is therefore best that Golli return to dock to arrange staff for the Friðrik Jesson team.

The Friðrik Jesson should locate the tagged whale and conduct dedicated 1-hr duration sessions combining automatic GPS-ARGOS tracking and visual tracking in PamGuard. Behavioural observations should be made during the same time periods. Drone flights can also be made from Friðrik Jesson to obtain photogrammetry and behavioural recordings.

As tags will be programmed to detach late afternoon the day after tagging, we may also prioritize to locate whales tagged the previous day for tracking and behavioural observations.

Tag-recovery phases / data download and backup
ARGOS receptions should be checked to locate detached tags floating at sea. Detached tags will be recovered using the VHF signal 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 from Friðrik Jesson, which will be used in rough weather conditions. Suction cups should be inspected for any sloughed skin before commencing data download and battery charge.

VHF frequencies of the deployed tags should be routinely checked to listen in case they come off the whale. 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 up on at least two different hard drives before it is deleted from the recording device.

MANAGEMENT AND CHAIN OF COMMAND

Operational issues
As much as possible, decisions will be made by consensus between the Cruise Leader and Field Party Chief, after seeking advice from the rest of the team and the vessel skippers. Operational decisions such as sailing plan and crew dispositions are made by the Field Party Chief. Scientific decisions, e.g. which types of tags to deploy and tagging systems are made by the Cruise Leader.

Safety issues
The skippers of Friðrik Jesson and Golli will make the final decisions on safety issues. Always remember: 'Safety First'!

TRIAL RISK ASSESSMENT
The Friðrik Jesson 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 been obtained from the Marine and Freshwater Research Institute (Hafrannsóknastofnun), by Filipa Samarra.

ENVIRONMENTAL IMPACT AND RISK ASSESSMENT
Risk Inventory: The pilot trial will be conducted during June-July 2024. This is a time when many marine mammals are expected to be present in the study area, and other human users of

the area may be present. Echosounders will operate independently from any tagged whales, so the effect of those acoustic transmissions is expected to be negligible. Other environmental impacts of the trial will 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 Hafrannsóknastofnun, 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.

The active echosounder will operate independently of tagged whales, and will not intentionally be used closer than 1km from a tagged whale. Time periods when echosounders were within 5km of tagged whales will be checked following the cruise to determine received levels of the echosounder at each tagged whale.

Close approach by vessels for tagging and biopsy sampling:
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.

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

0 No reaction: whale continued to show the same behaviour as before the procedure;
1 Low-level reaction: whale modified its behavior slightly, e.g. dived rapidly or flinched;
2 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;
3 Strong reaction: whale modified its behavior in a succession of forceful activities, e.g. successive percussive behaviours (breaches, tail slaps).

If any animal in the group exhibits a strong reaction to a procedure, we will cease conducting that procedure, and cancel subsequent procedures in the study plan. For example, if a whale responds with a strong reaction during tagging, then no further tagging attempts, biopsy attempts, or drone flights will be conducted with that animal.

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.

TRAVEL AND ACCOMMODATION

The entire team will stay in Heimay, Westmann Islands in rented accommodation arranged by the Field Party Chief.

Travel will be either by car from Keflavik via ferry to Heimaey, or alternatively via bus and ferry. The team will have a rented vehicle available for moving equipment, shopping, and other movements on Heimaey.

EQUIPMENT PACKING FOR SHIPMENT AT THE END OF THE CRUISE

The bulk of research gear from St Andrews will be shipped under a CARNET, which will then be sent to Harstad, Norway for the 3S4 trial. The same items shipped via CARNET, must be shipped out of Iceland after the end of the trial.

SHIPPING ADDRESS TO WESTMANN ISLANDS:

University of Iceland c/o Filipa Samarra
Thekkingarsetur Vestmannaeyja
Aegisgata 2
IS-900 Vestmannaeyjar, Iceland

Phone number: (+354)5255302 / (+354)8528027
VAT number for University of Iceland: 19133

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

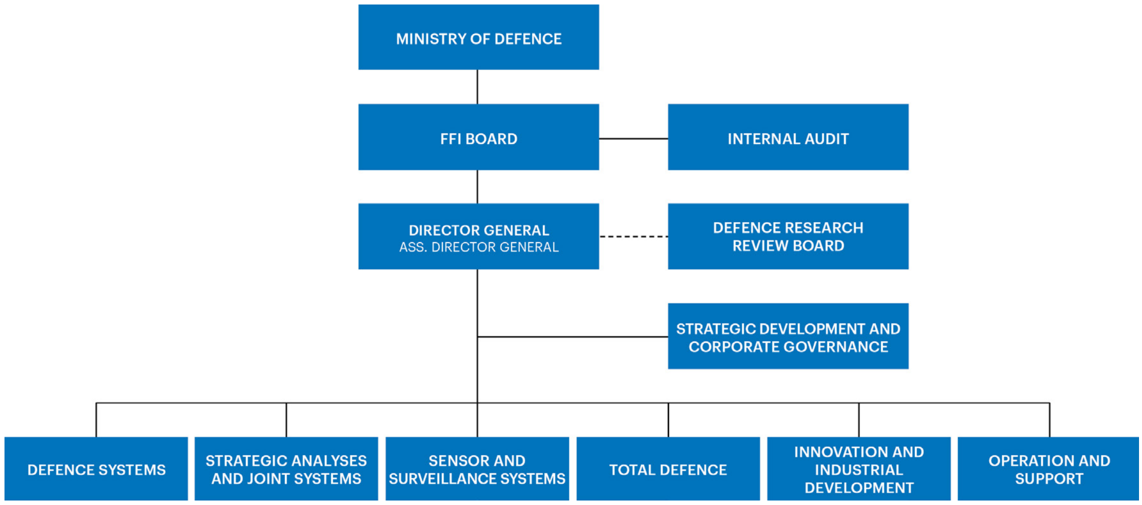
FFI is the prime institution responsible for defence related research in Norway. Its principal mission is to carry out research and development to meet the requirements of the Armed Forces. FFI has the role of chief adviser to the political and military leadership. In particular, the institute shall 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.



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