Cetaceans and naval sonar
– the 3S-2009 cruise report

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Norsk sammendrag

Forsvaret har utrykt behov for å få kartlagt sjøpattedyrs følsomhet overfor sonarsignaler, også atferdsmessige påvirkninger. 3S-konsortiet, som for tiden består av fire partnere, FFI, Woods Hole Oceanographic Institution (USA), Sea Mammal Research Unit (UK) og TNO (Nederland), gjennomførte i mai-juni 2009 et forskningstokt i norske farvann for å undersøke hvordan spekkhogger, spermhval og grindhval påvirkes av ulike sonarsignaler. Målsetningen er å innlemme denne kunnskapen i retningslinjer for bruk av sonarer slik at man minimaliserer eventuelle negative påvirkninger på miljø. Forskningsgruppen besto av 29 forskere fra 9 ulike land.

Vi har satt ut 17 digitale sensorpakker (Dtags) på hval (spermhval, spekkhogger og grindhval). Disse har registrert dyrenes atferd i til sammen 176 timer. Vi har gjennomført 6 sonareksponeringseksperimenter ved bruk av Socrates sonarkilden som sendte ulike signalerformer i ulike frekvensbånd, og vi har gjennomført samme antall negative og positive kontrollforsøk, ved henholdsvis bruk av fartøy uten sonar og spilling av spekkhogger lyder. I tillegg har vi gjennomført et pilotforsøk for å studere effekten av ”forsiktig oppstart” (ramp-up), og vi har samlet inn normalatferdsdata på de tre målartene. Under gjennomføringen av disse eksperimentene ble det også foretatt systematiske registreringer av gruppeatferd, og vi studerte effekten av selve merkingen. Vi har også gjort betydelige fremskritt i utviklingen av mer effektive måter å merke hval på, både ved bruk av ARTS systemet som skyter merket på dyret og ved bruk av en veldig lang karbonfiber stang for merking av spermhval. I tillegg har vi kartlagt de akustiske transmisjonsforholdene i det miljøet vi har opererte i, og samlet inn data på passiv akustisk deteksjon og sporing av hval.

Gjennomføring av kontrollerte eksponeringsstudier på hval er kostbare og kompliserte operasjoner, som involverer tung logistikk inklusive to forskningsfartøy, bruk av meget sofistikerte sonarutstyr og innsamling av atferdsdata fra en art som stort sett er usynlig for det menneskelige øye. Dette er tredje gangen 3S-gruppen gjennomfører denne type tokt. Det totale resultatet fra dette internasjonale samarbeidet er 15 eksperimenter, hvorav de fleste innebærer gjentatte eksponeringer på tre arter av hval (spermhval, spekkhogger og grindhval). Dette innebærer en mangedobling av det totale datamengden som er tilgjengelig for å belyse spørsmålet om hvordan militære sonarer påvirker sjøpattedyrs atferd. Dersom vi adderer noe mer data på normalatferd, mener vi nå at vi basert på dette resultatet har et solid grunnlag for å si noe sikkert om hvordan de tre målartene påvirkes av ulike sonarsignaler. Denne kunnskapen bør brukes som grunnlag for vitenskapelige funderte retningslinjer for bruk av militære sonarer som bedre balanserer operative behov med miljøhensyn.

English summary

There is a pressing need to quantify the sensitivity of cetaceans to behavioral disturbance by naval sonar. The 3S group currently involving four main partners (FFI, TNO, SMRU and WHOI) conducted in May-June 2009 a research trial in Norwegian waters to investigate behavioral reactions of killer whales, pilot whales and sperm whales to Low Frequency Active Sonar (LFAS) and Mid Frequency Active Sonar (MFAS) signals, in order to establish safety limits for sonar operations. The research group consisted of 29 scientists from 9 different countries.

We have deployed 17 dtags to sperm whales, killer whales and pilot whales. These tags have recorded the behavior of the tagged animal for 176 hrs total. We have conducted 6 sonar exposure experiments using the Socrates sonar source transmitting signals in different frequency bands and waveforms and conducted the same number of negative and positive controls using vessel approaches without sonar transmission and playbacks of killer whale sounds, respectively. In addition we have conducted a pilot experiment on how to study effects of ramp up using a different exposure protocol, and collected baseline data on all three species. In carrying out these experiments we have also systematically collected focal follow and group behavioral data according to predefined protocols and we have collected data on the effects of tagging. We also achieved significant progress in developing new techniques for deployments of tags using both the remote launching system ARTS and a specially designed setup with a very long hand held pole for sperm whale tagging. In addition, we have collected data on the acoustic transmission conditions in the environment and collected data on passive acoustic detection and tracking of marine mammals from two towed arrays (Delphinus (TNO) and Beamer (SMRU).

Conducting behavioral response studies is an expensive and complicated operation involving heavy logistics, operation of sophisticated sonar equipment and collection of behavioral data of animals which are mostly invisible to humans. This is the third research cruise conducted by the 3S-team (triple S goes triple), and the total outcome of this international collaboration is 15 experiments, most of them involving multiple exposures, on three different species of cetaceans (sperm whales, long finned pilot whales and killer whales). This effort vastly increases the total amount of data available to address the question of behavioral effects of sonar on cetaceans. With the addition of some data on baseline behavior, we now believe we have a solid data set to address the questions of how our target species are affected by different sonar signals. This information should be used to make science based mitigation procedures which can better balance operational requirements and unintended environmental consequences of sonar use.

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Preface

When humans set out to sea to study marine mammals, they soon realize that they are a simple form of life. Studying the behavior of animals which lives in an environment which turns you into a blind, death and cold cripple, requires methods and technology that is far from trivial. In May-June 2009 a dedicated group of scientist representing 9 different countries and 4 different research establishments set out to study how high power naval sonars affect marine life. These sonars constitute a potential risk to the marine environment and the idea of the 3S-2009 mission was to contribute to the establishment of scientifically based guidelines for naval sonar operations.

In a complicated mission like the 3S every participant has a role they need to fill. If someone does not perform properly, it all fails. I.e. there are many heroes in our team. The sonar operator who first detected a faint whistle or click and turned the vessel around, the visual observer who first spotted the animals, the tag boat driver and the tagger who through thorough coordination get the tag on the animal. All the people who through their skills and dedication work around the clock, because so does the sun, to collect the information we need, not to mention the crew of the research ships who bring us out there and safely home.

This report summarizes the achievements from the 3S-09 trial, and presents some preliminary results. However, all the collected data are still being analysed, and thus the final scientific recommendations that are expected to be the outcome of the trial, will be published in a suitable format at a later occasion.

1 Introduction

There is a pressing need to quantify the sensitivity of cetaceans to behavioral disturbance by naval sonar, and to determine how potential behavioral changes may affect biologically significant activities. Behavioral responses to sonar are thought to be a factor in stranding events, and perceived effects can cause conflict with nature tour operators and environmental groups. This study will produce quantitative information on how cetaceans react to sonar and relevant control sounds.

Data on the responsiveness of cetaceans to mid-frequency sonar signals are lacking, with only a few species having been studied in relation to a few types of sonar. This research effort seeks to quantify the risk of behavioral change as a consequence of sonar exposure, to discover what factors affect the probability of behavioral effects (e.g. received level at the animal, distance of the source, sound propagation conditions, frequency or amplitude of the sonar signal, behavioral state of the animal) and to understand what are the consequences for the animals and for human users of marine resources (such as tour operators). Our experimental approach gives us the ability to study the causal relationship between sonar exposure and behavioral responses, and the factors that determine behavioral responses.

This report summarizes the achievements, activities and data collection of an international research cruise in Norwegian waters in May-June 2009. This is the third research cruise conducted by the 3S-team (triple S goes triple). Previous achievements are partly reported in Kvadsheim *et al.* 2007.

1.1 Cruise objectives

Investigate behavioral reactions of killer whales, pilot whales and sperm whales to Low Frequency Active Sonar (LFAS) and Mid Frequency Active Sonar (MFAS) signals, in order to establish safety limits for sonar operations.

1.2 Cruise tasks

1.2.1 Primary tasks

1. Tag killer whales, pilot whales and sperm whales with DTAG recording behavior, and thereafter carry out controlled exposure experiments (CEE) where the tagged animals are exposed to LFAS-, MFAS sonar signals and control experiment without any active transmission.
2. Test new techniques for deployment of DTAGs

1.2.2 Secondary tasks

3. Carry out control experiments were tagged animals are exposed to a playback of killer whale sounds.
4. Carry out pilot experiments where tagged animals are exposed to LFAS or MFAS up-sweep and down-sweep signals.
5. Do pilot studies on cetaceans to investigate the effectiveness of sonar ramp-up.
6. Collect group behavioral data to investigate the effect of tagging
7. Carry out pilot CEE experiments on new species (minke whales, bottlenose whales).
8. Retrieve information about the acoustic environment of the study area by CTD or XBT measurements, and do acoustic propagation modelling.
9. Tag animals and record natural undisturbed behavior.

Figure 1.1 3S-09 Participants: f.l. Jeroen Janmaat, René Dekeling, Mark van Spellen, Ana Catarina Alves, Ricardo Antunes, Annemieke Podt, Gunnar Rikardsen, Adri Gerk, Marijke Olivierse, Fleur Visser, Eva Hartvik, Sander van Ijsselmuide, Bart Voet, Rune Roland Hansen, Frans-Peter Lam, Paul White, Rob van Bemmelen, Allan Ligon, Tommy Sivertsen, Sanna Kuningas, Mark Hadley, Patrick Miller, Lars Kleivane, Paul Ensor and the cruise leader Petter Kvadsheim. (Alex Bocconcelli, Paul Wensveen, Pål Anton Nilsen, Thomas Sivertsen were not present when the picture was taken) (Photo: FFI, Leidulf).

1.3 Collaborating organisations

The 3S-2009 trial is a joint effort between:

• The Norwegian Defense Research Establishment (FFI)
• The Netherlands Organisation for Applied Scientific Research (TNO)
• Sea Mammal Research Unit (SMRU), Scotland
• Woods Hole Oceanographic Institution (WHOI), USA

1.4 Sponsors

The research project is sponsored by;

- The Royal Norwegian Navy and the Norwegian Ministry of Defense
- The Royal Netherlands Navy and the Dutch Ministry of Defense
- Office of Naval Research, USA
- World Wildlife Fund, Norway

1.5 Participants

The 3S-09 research team consisted of 29 scientist and engineers (fig 1.1) from 9 different countries (Norway, The Netherlands, USA, Portugal, UK, New Zealand, Denmark, Finland, Italy) representing the different research organisations involved. In addition the two research vessels had a regular crew of 7 and 4-5. The research group included people with background in biology, underwater acoustics, oceanography, electronics, mechanical engineering, environmental science and operational sonar use.

2 Overview of operation

The 3S-09 cruise took place along the coast of Northern Norway between 66° and 70° northern latitude between May 14 and June 11, 2009. Experiments were conducted using two ships, the R/V H.U. Sverdrup II (55 m) and the MS Strønstad (29 m). The Sverdrup is the main operation vessel from which the sonar source, Socrates (TNO) is deployed, as well as the Delphinus array (TNO) for passive acoustic monitoring. The Strønstad functions as the main animal tracking and observation vessel and is also equipped with a towed array, Beamer (SMRU). Table 2.1 summarizes the main activities during the trial and figure 2.1 shows the sailing track of Sverdrup.

This type of field work is weather dependent. We consider sea state 0-2 to be working conditions, whereas during sea state 3-4 the tagging and tracking become very difficult. At sea states above 5, we are non-operational. In the first of two legs of the trial we had extraordinarily good weather with workable weather every day. After the crew change mid way the weather became a highly limiting factor and we only had good workable conditions for three days. In total during the 29 day duration of the trial we had 12 days of good workable conditions, 8 days of border line (difficult working) conditions, 4 days of bad weather (non workable) conditions and we were docked for technical and logistical reasons for 5 days. Table 2.2 summarizes the weather situation during the trial.

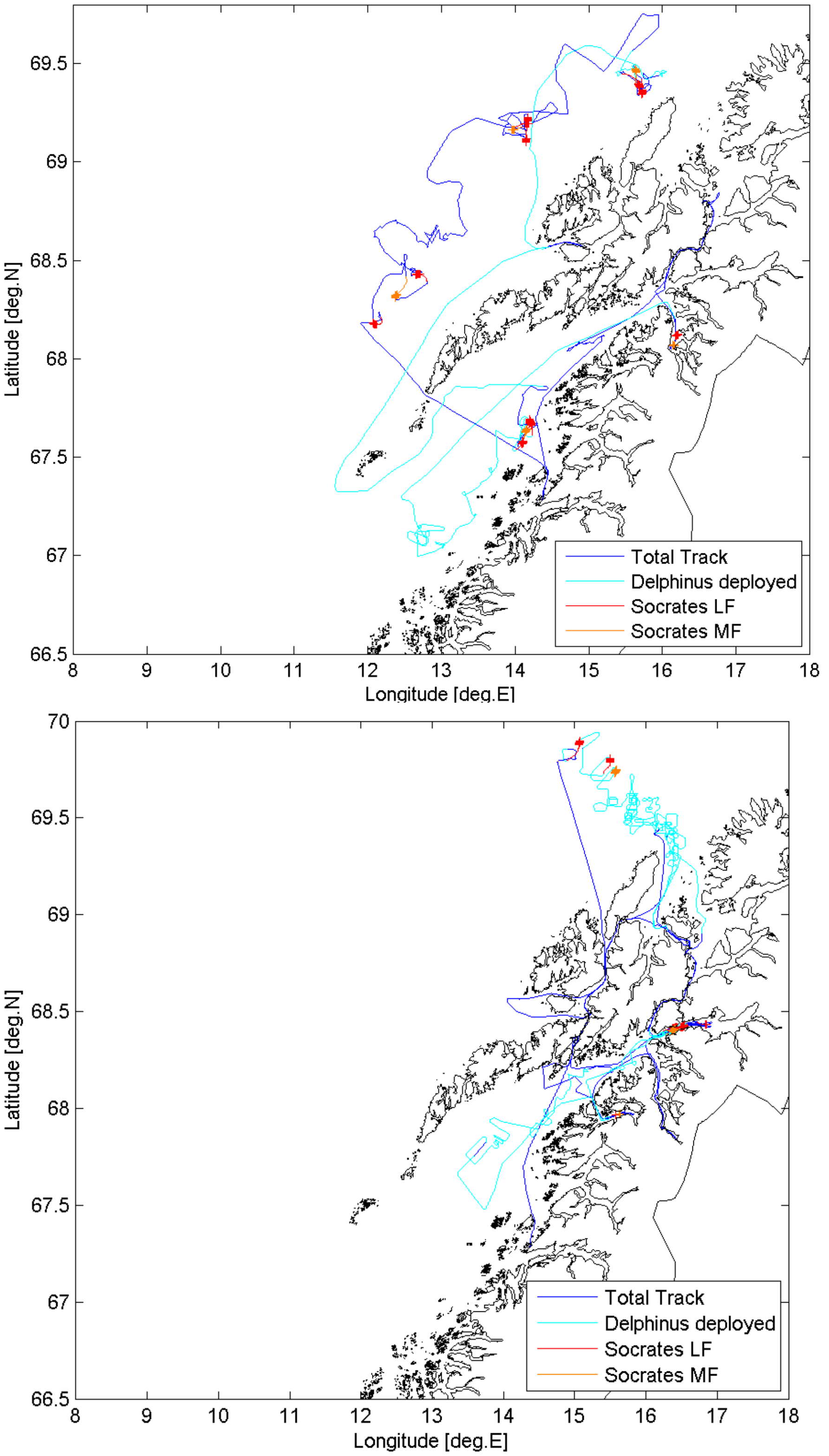

Figure 2.1 Sailed track (blue line) of HU Sverdrup II for leg 1 (upper) (May 14-27) and leg 2 (lower) (May 28-June11). Sonar transmissions of Socrates system are depicted in red (LFAS) and orange (MFAS). The cyan coloured part of the track (see legend) is where the Delphinus array is being towed, 208.6 hours in total. Daily tracks can be found in Appendix A.

Table 2.1. Sailing schedule and main activities during the trial (see appendix A for details).

Date	Area	Main Activities
May 14.	Harstad	Installation at shipyard
May 15.	Harstad	Installation at shipyard. Joint planning meeting with 3S09-team. Group training/planning sessions. Joint dinner.
May 16.	Tysfjord-Vestfjord	Sail off at 08:30. Transit to Tysfjord. Exercise of operation, calibration of Dtags. Searching for whales.
May 17.	Outer Vestfjord	Searching for whales. Tagging pilot whales. Baseline data collection.
May 18.	Outer Vestfjord	Pilot whales were tracked visually through the night. Tagging pilot whales. Conducted sonar exposure experiment and killer whale playback.
May 19.	Outer Vestfjord	Searching for whales.
May 20.	Vesterålsbankene, off shore	Short port call at Stokmarknes. Searching for whales. Tagging sperm whale. Conducted sonar exposure experiment and killer whale playback.
May 21.	Bleikdjupet	Searching for whales. Tagging sperm whale. Conducted sonar exposure experiment and killer whale playback.
May 22.	Vesterålsbankene, off shore	Search southwards of the shelf break for killer whales. Sperm whales observed almost continuously. Tag sperm whale and conduct sonar exposure experiment and killer whale playback.
May 23.	Vesterålsbankene, off shore	Searching for killer whales. Find scattered groups of killer whales on the shelf. One tag deployed but tag slides under the animals and gives no signals. Continuous attempts to deploy a second tag with pole were not successful. However, we manage to stay with the animals and recover the tag after 14 hrs.
May 24.	Vesterålsbankene, off shore	Tagging attempts on new group of killer whales. Two tags deployed. Sonar exposure experiment and killer whale playback conducted. Transit to Bodø to fix Delphinus.
May 25.	Bodø	Docked in Bodø all day to work on Delphinus. No working conditions anyway.
May 26.	Vestfjorden	Transit from Bodø to Skrova at night. Search westwards in very border line conditions. Find pilot whales moving east. Manage to tag a whale, despite the conditions. Collected 2.5 hrs of baseline data until the tag comes off. Transit to Harstad.
May 27.	Harstad	Crew change in Harstad
May 28.	Ofotfjord-Tysfjord	Transit from Harstad to Vestfjord. Exercised ramp-up protocol. Surveyed Ofotfjord and Tysfjord completely.
May 29.	Øksfjord/ Økssundet	Searching for whales. The “sound of silence experiment” with tagged Socrates. Transit to Svolvær because of storm.
May 30.	Svolvær-Harstad	Still bad weather. Transit from Svolvær to Harstad to pick up new Delphinus tow cables. Sightseeing in Trollfjord and fishing competition on the way.
May 31.	Harstad	Loading new tow cable for Delphinus. Installing and testing Delphinus.
June 1.	Andfjord Vågsfjord	Searching for whales, Found killer whales and sperm whales, but weather does not allow tagging attempts. Both ships return to Harstad for the night.
June 2.	Andfjord	Searching for whales trying to exploit an expected narrow window of good weather. Find sperm whales and track them acoustically and visually while we are waiting for the weather to improve enough to try tagging. Tag sperm whales in SS 4. The tag initially did not give any VHF signal and both ships therefore track sperm whales acoustically. After 4 hrs signals were picked up and the animal tracked until the tag released after 9 hrs. Transit back to Harstad.
June 3.	Harstad	Docked because of bad weather.
June 4.	Vestfjorden	Transit through Tjeldsundet. Searching for whales. Acceptable conditions but not good. Eventually we sight pilot whales but loose them.
June 5.	Vestfjorden/ Ofotfjorden	Both ships search eastwards in Vestfjorden. Find pilot whale and starts tagging attempts, but the animals were unusually difficult to tag. Eventually we deployed a tag and conducted under difficult weather conditions a sonar exposure experiment and a killer whale playback. The tag does not release and stayed on for 34 hrs.
June 6.	Ofotfjorden	Since the tag still sticks to the pilot whale, we decided to deploy a new tag and stay with them. One tag was deployed and pilot study using the ramp up protocol was conducted.
June 7.	Vestfjord-Andfjord	Transit to off shore area. Searching for whales. Find pilot whales, dolphins, sperm whales and killer whales outside Andenes and decide to start tagging the killer whales.
June 8.	Andenes	Tagging killer whales. After 18 hrs of more or less continuous attempts we give up and find a sperm whale instead. We tag it and start preparing for the experiments, but the tag releases itself after 3 hrs due to a malfunction.
June 9.	Blue Ocean off Andenes	Find a new sperm whale in Bleikdjupet and tag it. Conducted sonar exposure experiment and killer whale playback.
June 10.	Andenes-Bodø	Transit to Bodø, data management and start de- installation. Joint dinner and celebration.
June 11.	Bodø	De-installation, de-briefing,

Date	Area	Wind	Weather	Sea state
May 14.	Harstad	Docked (installation)	Docked (installation)	Docked (installation)
May 15.	Harstad	Docked (installation)	Docked (installation)	Docked (installation)
May 16.	Tysfjord-Vestfjord	Northeastern 3	Clear sky	1
May 17.	Outer Vestfjord	Eastern 1	Clear sky	0
May 18.	Outer Vestfjord	Southeastern 2	Clear sky	1
May 19.	Outer Vestfjord	Northeastern 2	Changing cloud cover	1
May 20.	Vesterålsbankene	Northwestern 2	Changing cloud cover	2
May 21.	Bleikdjupet	Western 0	Changing cloud cover	2
May 22.	Vesterålsbankene	Southeastern 1	Changing cloud cover	1
May 23.	Vesterålsbankene	Northeastern 3	Changing cloud cover	2
May 24.	Vesterålsbankene	Variable 1	Changing cloud cover	1
May 25.	Bodø	Docked (technical))	Docked (technical)	Docked (technical)
May 26.	Vestfjorden	Southwestern 7	Changing cloud cover	4
May 27.	Harstad	Docked (crew change)	Docked (crew change)	Docked (crew change)
May 28.	Ofotfjord-Tysfjord	Southwestern 5	Clouded	3
May 29.	Øksfjord/Økssundet	Southwestern 7	Rain	6
May 30.	Svolvær-Harstad	Southwestern 5	Clouded	2
May 31.	Harstad	Docked (weather)	Docked (weather)	Docked (weather)
June 1.	Andfjord/Vågsfjord	Western 4	Clouded	3
June 2.	Andfjord	Western 4	Fog	4
June 3.	Harstad	Docked (weather)	Docked (weather)	Docked (weather)
June 4.	Vestfjorden	Northeastern 6	Clear sky	3-4
June 5.	Vestfjorden/Ofotfjorden	Northern 5	Clouded	3
June 6.	Ofotfjorden	Eastern 2	Clouded	1
June 7.	Vestfjord-Andfjord	Northern 5	Changing cloud cover	4
June 8.	Andenes	Northern 1	Clear sky	1
June 9.	Off shore	Northeastern 3	Clear sky	3
June 10.	Andenes-Bodø	Northeastern 4	Clear sky	2
June 11.	Bodø	Docked (de-installation)	Docked (de-installation)	Docked (de-installation)

Table 2.2 The weather at noon (local time=UTC+2) recorded in the ships log. Wind force is given on the Beaufort scale.

3 Equipment and data collection

3.1 Summary of methodology

During the searching phase, observation teams on both ships conduct visual surveys and both towed hydrophone arrays are deployed to listen to cetacean sounds. All visual sightings are recorded in Logger, acoustic detections are recorded by specific software. Upon an acoustic detection of a target cetacean, the vessel is maneuvered in the direction of the animals, to obtain visual detection. Upon visual detection of a target cetacean species, the observation team on board Strønstad starts a track and observations of the group. During tracking, the travel path, as well as individual and group behavioral parameters are monitored at a rate of 1 record per ~1.5 minute. Following 30 minutes of baseline data collection (pre-tagging phase), one or both tag boats are launched from Sverdrup to commence tagging with Dtags using either a pole, or the ARTS system for deployment. The tagging phase ends when one or two tags have been deployed, or the decision is made to leave that group. The following phase, the experiment, consists of a block design including LFAS, MFAS, killer whale sounds and silent approaches, including pre- and post exposure intervals before and after each block. During the experiment, the Strønstad stays in good sighting range of the tagged animal for tracking, while the Sverdrup is positioned following a predetermined protocol for the transmission of sonar sounds to the tagged animal with Socrates, and maneuvers accordingly. During the tracking of sperm whales, the individuals are tracked acoustically during dives. Following the release of the tag(s), both ships return to searching phase and data checking/processing.

Please see the 3S-2009 Cruise Plan for a detailed description of methodology, protocols, research vessels, and equipment (Appendix C). Additional information on methodology and equipment is provided in the sections below.

3.2 Socrates sound source

During the controlled exposure experiments the multi purpose towed acoustic source, called Socrates II (Sonar CalibRAtion and TESting), was used and operated from the Sverdrup. Socrates II is a versatile source (see fig.3.1) that is developed by TNO for performing underwater acoustic research. At present the Socrates system is part of the prototype LFAS system being tested on board the multipurpose frigates of the Royal Netherlands Navy.

During exposure experiments two types of signals were used:
- LFAS (1-2 kHz hyperbolic up-sweep at 214 dB re 1µPa @ 1 m source level), and
- MFAS (6-7 kHz hyperbolic up-sweep at 199 dB re 1µPa @ 1 m source level).

Prior to full power transmission a ramp up procedure was used, starting at 152dB for LFAS and 158dB for MFAS, and increasing to full power within 10 min. The signal interval was 20s during both ramp up and full power transmission. The system also contains one hydrophone, depth, pitch, roll, and temperature sensor. All data from these sensors were recorded. See the 3S-2009 Cruise Plan (Appendix C) for details and operated towing characteristics. The Socrates operating software was available from a terminal on the bridge of Sverdrup, see fig.3.2.

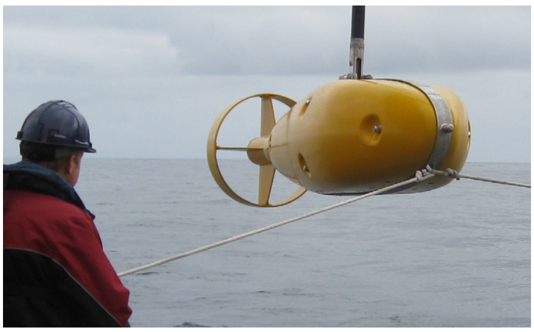

Figure 3.1 The Socrates fish as seen during deployment on the aft deck of Sverdrup (photo: Bart Voet).

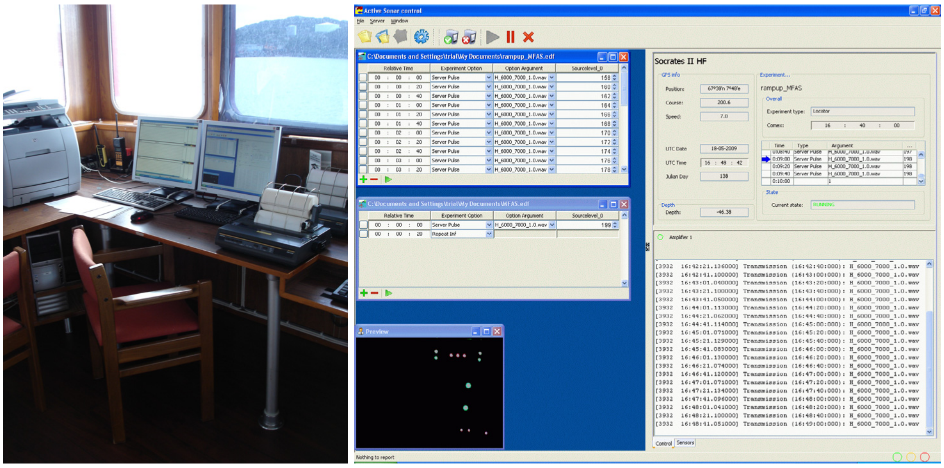

Figure 3.2 Set-up of operational terminal of Socrates on the bridge of Sverdrup (left) and the operating window of Socrates transmissions during MFAS ramp-up (right). Control lights on the amplifiers are monitored with a webcam in the lower left corner. (photo: Frans-Peter Lam)

3.3 Passive acoustics on Sverdrup – the Delphinus array (TNO)

During the 3S-2009 trial the Delphinus array was towed from Sverdrup whenever possible. A more detailed description of the system can be found in the cruise plan (Appendix C) and in Sheldon-Robert *et al.* (2008). The array has proven to be very helpful in the search phase for detecting target species (see section 4.3.3 for an example), as well as in other phases for tracking (diving sperm) whales. A brief description of the system and the way it was operated during 3S-2009 follows.

A sketch of the array configuration is presented in fig. 3.3. The array is operated with two different tow cables. With the longer tow cable (700m, until May 21st) all elements are used, while with the other tow cable (180m, after May 31st) only the centre 14 standard hydrophones were available. Data of the three high frequency elements were available with both tow cables.

An overview of the data processing of the Delphinus detector is presented in fig.3.4. Data of all hydrophones are stored in binary format in blocks of 4 seconds on computer hard disks (RAID system). These data-files are then used by a network link for subsequent processing. Whenever the data-processing stops, the recording of hydrophone data will continue. Data processing consists of beamforming (for data up to 12 kHz) and a transient detector. Five different sections of the signals up to 12 kHz can be discriminated, see right image of fig. 3.4. Note that the angle sensitivity can be increased by using different array shading of the beamforming algorithm. This is applied to the broadband waterfall display (see section 4.3.4 below).

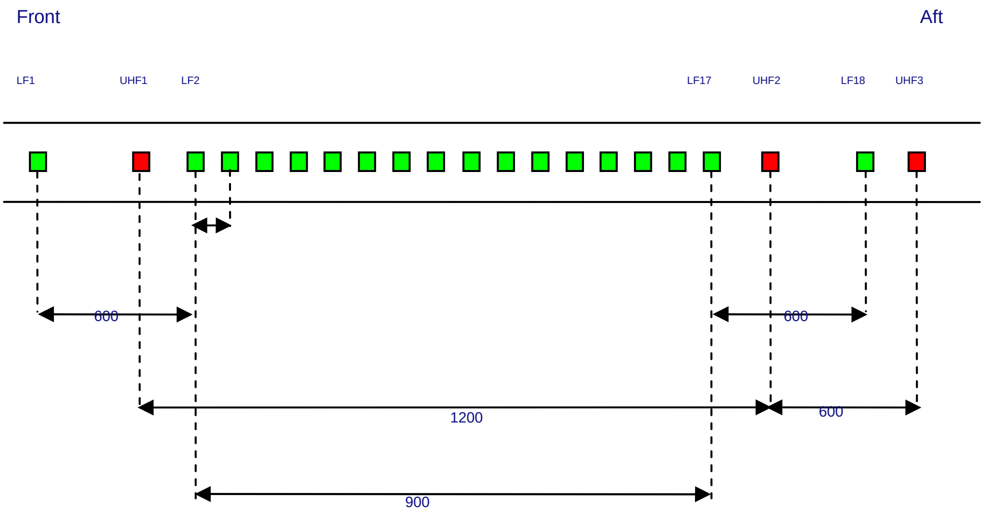

Figure 3.3 Sketch of array configuration of acoustic section of Delphinus system. The three (ultra) high frequency (UHF) hydrophones (up to 150 kHz) are shown in red. In green the 18 standard hydrophones are shown. With the shorter tow cable, used from May 31, only the middle 14 standard hydrophones are connected. Dimensions are given in mm.

Examples of the detection displays are given in fig.3.5, for the frequency band that is beamformed (up to 12 kHz, left image), and for the higher frequency band (up to 160 kHz, right image). The sonar operator can switch back and forth between these two displays. The (near) real-time audio stream was following this selection by broadcasting one of the five directional sounds received or the high frequent single (omni-directional) hydrophone. At the right of both displays the detected transient signals are shown relative to the selected threshold of the transient detector. Any detected transient signal was presented in a different display, where the signal was visualized by a spectrogram in a custom made "wav-player" for analysis. These detections were updated in (near) real-time, see section 4 for examples of this display.

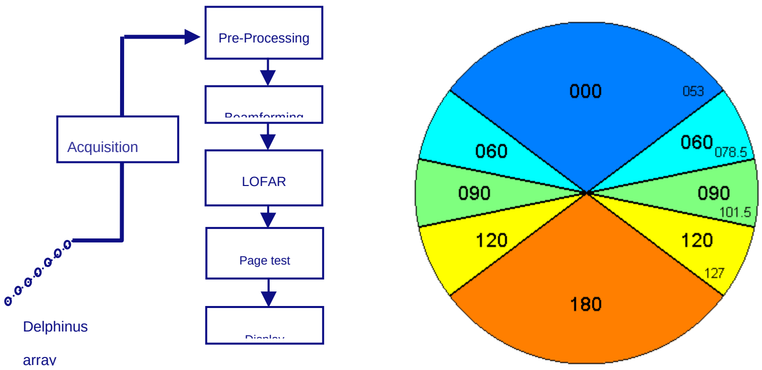

Figure 3.4 Left: sketch of the transient detector, as implemented in Delphinus dry-end, and available in real-time. Right: five discriminated sections of Delphinus with current standard beamformer (up to 12 kHz).

An overview of all displays available for the Delphinus sonar operator is presented in fig.3.6 (left image). Apart from the presentation of the acoustic data, as described above, also a GIS-display was available; in order to keep track of the ship's navigation. An example of this display is also presented in fig.3.6 (right image).

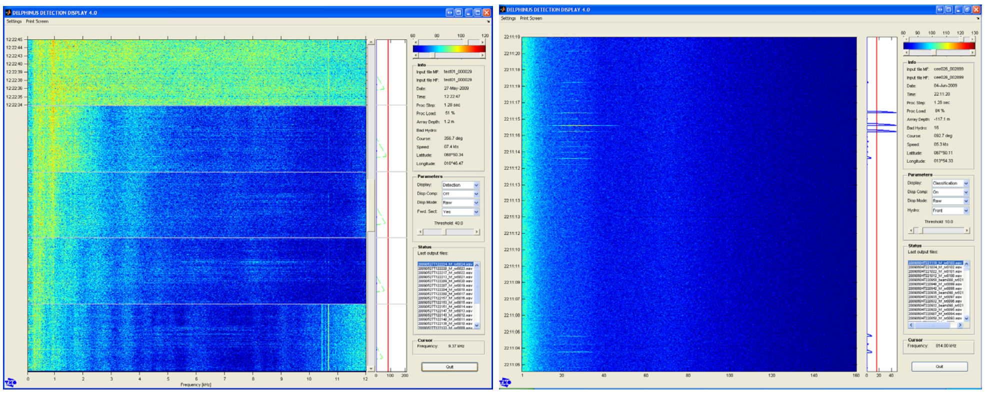

Figure 3.5 Left: Detection display of Delphinus, showing a waterfall display in five sections. Right: Detection display for the high frequency band, up to 150 kHz (single, hydrophone of choice). The example shows high frequency clicks of pilot whales close to the array in Ofotfjorden (04 June, 22:11 UTC).

Because Delphinus does not having a heading sensor, the orientation of the array is taken from the ship's heading. Lagging time of the array with respect to the vessel should be taken into account. A table with lagging times was used for this. The lagging time depends on the length of the tow cable and the speed of the vessel, and was typically between 30 and 120 seconds.

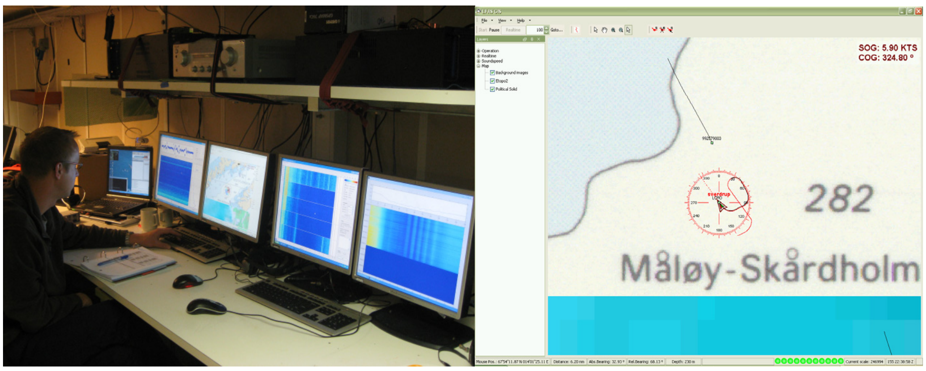

Figure 3.6 Left: Delphinus sonar displays as installed in the laboratory on board Sverdrup. From right to left: broadband waterfall/tracking display, detection display, GIS-display and "wav-player" for analysis of detected signals. The laptop at the far left was hosting file exchange and conference options with the radio-link with Strønstad (photo: Bart Voet). Right: Example of GIS display available next to sonar displays. This example shows the navigation after the tagging of pilot whales during borderline conditions (26 May) when Strønstad was underway for support of Sverdrup.

3.4 Passive acoustic on Strønstad - Beamer (SMRU)

The array used on the Strønstad array ("Beamer") was developed and built by Patrick Miller of SMRU. The 130m tow cable is Cortland Cable streamer cable with 18 twisted pairs, an outer Kevlar weave for towing, and external fairing threads to reduce tow noise. The active section consists of 16 Benthos AQ-2S hydrophones with custom 40dB pre-amplifiers located next to the hydrophone.

Signals from 12 channels of the array are routed into input channels of an Alesis HD24 digital recorder. The signals are sampled at 96kHz with 24-bit resolution. The Alesis recorder is powered using a low-noise Stabylex sine-wave inverter. Two channels are routed into a sound-card for real-time spectrogram visualization and click detection and bearing estimation using Pamguard software. The Beamer array and Alesis recording system was calibrated at TNO in 2008.

Recordings are created on the hard-disk as individual "songs". Songs are started once the decision is made to work with a group of animals, and continues until the tag is off or when the decision is made to leave the group. After about one hour, the current "song" is stopped and a new song started, so there is a short gap in recordings between "songs". We try to assure that all sonar transmissions for one exposure run are within a single "song".

3.5 Tagging sperm whales using long pole

Traditionally "big whales" such as sperm whales, humpback and right whales are tagged with a cantilivered long pole system. In this case it was not possible to use it on sperm whales because both tagboats had permanent structures on their bow. Therefore SMRU developed a unique long-pole tagging system. The system consists of 5 sections of 7ft (2.13m) length ultra light carbon fiber tubing joined for an overall total length of 10m (fig 3.7). A 90° robot was attached to the tagging end, with a custom spring insert to allow the tag to swivel more widely. On the other end, an approximately 8 kg counter-weight was attached so the pole could be balanced with the tag far forward. The system proved to be highly effective in low to moderate sea states.

Figure 3.7 Tagging sperm whales with 10 m long carbon fibre hand held pole with counter-weight from elevated platform of tag boat 2 (photo: Paul Ensor).

3.6 Directional hydrophone operated from tag boat

To increase the effectiveness of sperm whale tagging, SMRU created a directional hydrophone system (“Pickle”) consisting of a plate-shaped baffle with a hydrophone on either side. Each hydrophone was connected to one channel of a Micro-track recorder, and monitored using headphones. The tag boat used the system to fix the direction of, and subsequently approach, nearby clicking sperm whales so that the tag boat was close to the animal when it initially rose to the surface. This gained the tag boat sufficient time to approach the animals from behind at slow speed.

3.7 Visual observations – Group behavioral sampling

The behavioral parameters collected were: group size, calf presence, group spacing, surfacing synchrony, distance to the nearest other subgroup (all states) and surface display (events) (Visser *et al* 2009). These parameters were entered in Logger. Additionally, several behavioral parameters were collected on paper sheets, to allow for testing of these parameters (usefulness, ability to collect, necessity). These parameters were: group dive times, swimming mode, behavioral type, milling index, display events (other than collected in Logger) and group formation ‘lined up’ (Table 3.1).

During and following the first experiment, a pilot experiment collecting baseline data on pilot whales, the protocol for group behavioral sampling was tested, fine-tuned and adjusted. Two adjustments were made to the overall methodology, and one adjustment was made to Logger.

3.7.1 Definition of focal group

The focal (sub)-group was defined as ‘all individuals which interact socially and/or show coordinated activity in their behavior and are less than 15 body lengths apart. The focal subgroup is the smallest sample of individuals which can be regarded to form a distinct unit with the focal individual. The next level is the focal group, which can at times consist of several subgroups, one of them holding the focal individual.

Pilot whale groups especially are often observed to form several subgroups, repeatedly merging and unmerging during one experiment. When a group became divided into subgroups, we recorded ‘group divided in subgroups’ and determined whether the different subgroups should still be regarded as a single focal group, or whether the focal subgroup should be regarded as a distinct unit, and sampled ‘alone’. Group spacing was determined to be in subgroups, when a focal group was divided in several subgroups, which stayed within a distance of 200 m of each other. The size and group spacing of the focal subgroup was recorded at all times to ensure that data collection on the focal subgroup remained independent of the decision to record the focal group as a whole (subgroups), or to sample the focal subgroup alone.

Table 3.1 List and description of group behavioral parameters collected.

Parameter	**Description**	**Data collection**	**Values**	**Logger/ x|paper**
Group size	Number of animals in focal group	Low, best and high estimate of group size	Number	Logger
Calf presence	Presence of calves in focal group	Presence (1) or absence (0); number of calves recorded in *Comments*	Number	Logger
Group spacing	Number of body lengths between individuals in focal group	Sampled as one of 5 pre-determined categories. Very tight – Very loose	Coded entry for category, e.g. GS1	Logger
Surfacing synchrony	Proportion of individuals surfacing simultaneously	Sampled as one of 3 pre-determined categories. High – low.	Coded entry for category, e.g. Syn1.	Logger
Distance to nearest other subgroup	Distance between focal group and nearest other (sub)group in sight	Sampled as estimated distance in meters	Number	Logger
Display events	Surface display events in focal group, such as breaches	Count of the number of events between two data points, per event type	Number of events per event type, e.g. 3 loggings, 1 full breach	Logger
Group dive times	Start and end time of the period no individuals of the focal group are visible at the surface (group dive)	Record start time and end time of dive	Time entry	Paper
Swimming mode	Part of body visible during surfacing: fin only, fin + part of body, fin + head out	Sampled as one of 4 pre-determined categories	Coded entry for swimming mode, e.g. SW1	Paper
Behavioral type	Behavioral activity as is displayed at surface: resting, travelling, socializing, foraging, milling	Sampled as one of 5 pre-determined categories	Coded entry for behavioral type, e.g. R.	Paper
Milling index	Proportion of individuals of the focal group which surface in the same direction	Sampled as one of 3 pre-determined categories; no milling – milling	Coded entry for milling index, e.g. ‘0’ = all face same direction, ‘1’ = individuals facing various directions.	Paper
Group lined up	Group formation whereby all individuals surface lined up	Sampled as ‘lined up’ (1) or ‘not lined up’ (0).	Coded entry, 0 or 1.	Paper

3.7.2 Distance to nearest other subgroup

The distance to the nearest other subgroup was always recorded relative to the focal subgroup. If no other group or (sub)-group is in sight, we recorded ‘0’ for distance to nearest other subgroup. If it is uncertain whether other (sub)-groups are present in the vicinity, distance to nearest other subgroup was kept empty. In Logger, the sampling of distance to nearest other subgroup was changed from entering a pre-defined category, to entering a value for distance estimate (m).

Please see the 3S-2009 Cruise Plan (Appendix C) for a more detailed description of the group behavioral sampling methods.

4 Data collected

4.1 Overview of achievements

During the 3S-2009 research trial an enormous amount of data was collected. A complete data inventory is listed in Appendix B. The planned objectives and tasks of the trial are listed in section 1. The main project objective was met, and all primary tasks and almost all secondary tasks were achieved:

We have deployed a total 17 dtags to sperm whales, killer whales and pilot whales. These tags have recorded the behavior of the tagged animals for 176 hrs. We have conducted 6 sonar exposure experiments using different frequency bands and waveforms and conducted the same number of negative and positive controls using vessel approaches without sonar transmission and playbacks of killer whale sounds, respectively. In addition we have conducted a pilot experiment on how to study effects of ramp up using a different exposure protocol, and collected baseline data on all three species. In carrying out these experiments we have also collected focal follow and group behavioral data and data on the effects of tagging. We have come a long way in testing new techniques for deployments of dtags using both the remote launching system ARTS and a specially designed setup with a very long hand held pole for sperm whale tagging. We have also collected data on the acoustic transmission conditions of the environment and collected terabytes of data on passive acoustic detection and tracking of marine mammals from two towed arrays. The only secondary task we have not accomplished is to conduct pilot studies on tagging and sonar exposure of new species.

Table 4.1 summarizes the main data collecting events of the trial, and figure 4.2 shows the geographical positions of these events. In addition to these events, which involved tagging of animals and collection of marine mammal behavior observations, secondary data such as marine mammals sightings (fig. 4.1) and acoustic detections of marine mammals (section 4.3-4.4) were collected during the survey phases between each event.

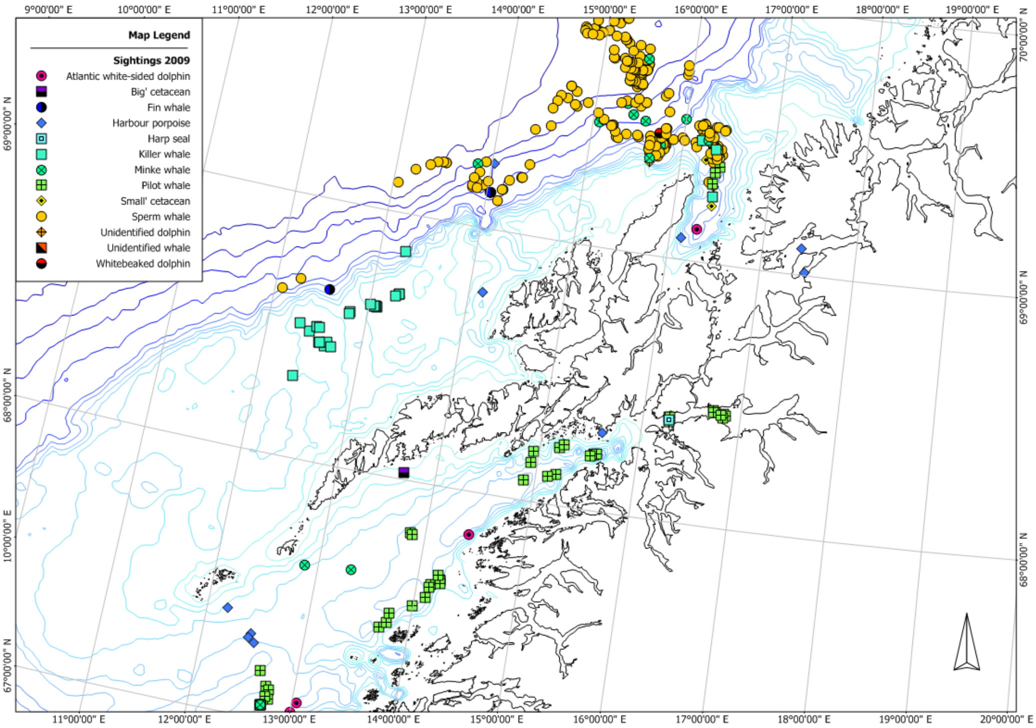

Figure 4.1 Marine mammal sightings from RV HU Sverdrup II and MS Strønstad during 3S-09.

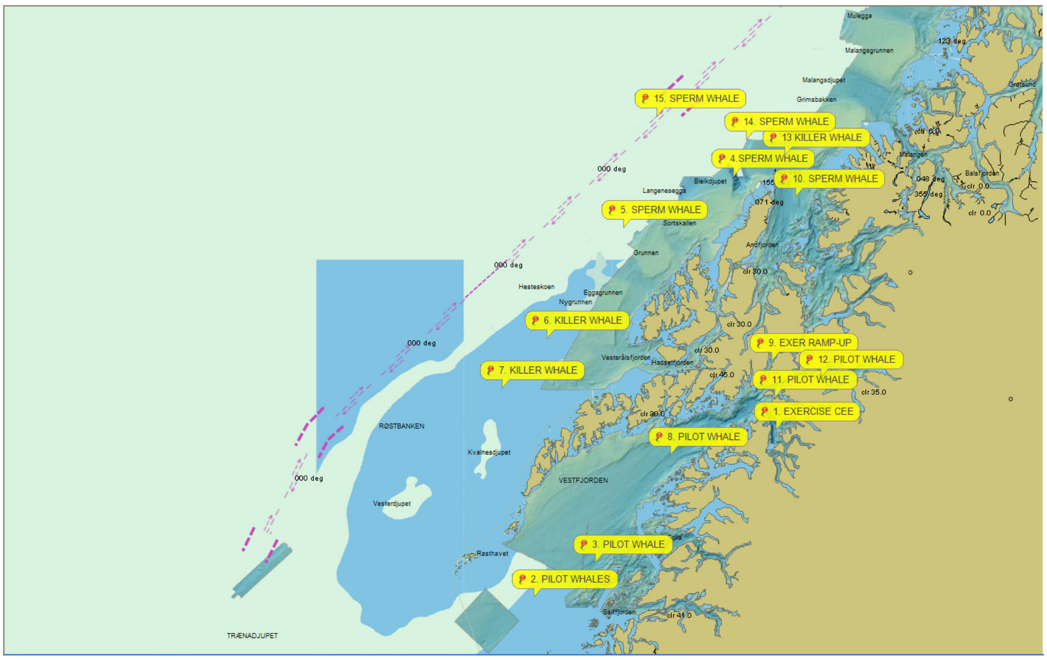

Figure 4.2 Geographical locations of main data collecting events. Sequential numbers of event refers to the description of the event in table 4.1.

Table 4.1 Main 3S data collecting events.

Event/ Species	**Date/ Area**	**Data collection**	**Comments**
1.Exercise CEE	May 16. Tysfjord	Exercise	Exercise regular CEE protocol with tagged buoy in Tysfjord. Calibrate Dtags.
2. Pilot whales	May 17. Vestfjord	Baseline	3dtags deployed, 25.5h of recording
3. Pilot whales	May 18. Vestfjord	Sonar exposure	2dtags deployed, 28.5h of recording. LFAS-MFAS-Silent-LFAS down sweep-orca-experiments.
4.Sperm whale	May 20. Bleikdjupet	Sonar exposure	1dtag deployed, 15.5h of recording. LFAS-MFAS-Silent-Orca-experiments.
5.Sperm whale	May 21. Off shore	Sonar exposure	1dtag deployed, 15h of recording. LFAS-MFAS-Silent-orca-LFAS down sweep-experiments.
6.Killer whales	May 23. Off shore	Baseline	1dtag deployed, 13h of recording.
7.Killer whales	May 24. Off shore	Sonar exposure	2dtags deployed, 24.5h of recording. LFAS-MFAS-orca-LFAS down sweep-experiments.
8.Pilot whales	May 26. Vestfjord	Sonar exposure	1dtag deployed, 2.5h of recording baseline behavior.
9.Exercise ramp-up	May 28. Ofotfjord	Exercise	Exercise ramp up protocol with tagged tag boat
10.Sperm whale	June 2. Andfjord	Baseline	1dtag deployed, 8.5h of recording of baseline data, but without visual tracking
11.Pilot whales	June 5. Ofotfjord	Sonar exposure	1dtag deployed, 18h of recording. LFAS-MFAS-Silent-Down sweep-Orca experiments.
12.Pilot whales	June 6. Ofotfjord	Sonar exposure	1dtag deployed, 8.5h of recording. Ramp up experiment.
13.Killer whales	June 8. Andenes	None	None, 18 hrs of non successful tagging attempts. Vocalization data recorded
14.Sperm whale	June 8. Andenes	Baseline	1dtag deployed, 2.5h of recording of baseline data.
15.Sperm whale	June 9. Blue ocean	Sonar exposure	1dtag deployed, 15h of recording. LFAS-MFAS-Orca and LFAS down sweep experiments.

4.2 BRS on cetaceans

Two types of experiments were conducted. The primary type was the standard MFAS-LFAS-Silent protocol, which included playback of natural O. orca sounds, and in 5/6 had an additional exposure to downsweep LFAS signals. The second type of experiment was a pilot study on the effectiveness of ramp-up as a mitigation protocol.

4.2.1 MFAS-LFAS-Silent protocol

The LFAS-MFAS-Silent experiments were conducted at a consistently excellent rate of quality. As can be seen in the figures below, the planned time intervals according to the protocol described in the cruise plan (appendix C) for pre-exposure, gaps between exposures and post-exposure were achieved in all cases (Fig. 4.3 – 4.8, note difference in vertical scale). Visual observations from Strønstad were consistently made on the subject animals, with no animals lost during the primary LFAS-MFAS-Silent experiments. Importantly, both silent approaches planned to be the first exposure were completed, though some silent approaches were skipped if they were not the first exposure type. Also, sounds of killer whales were played back at realistic source levels to all 6 of the subjects in the primary LFAS-MFAS-Silent design. Playback sounds were prepared from recordings of herring-feeding as well as mammal-eating killer whales, and these were played back in different combinations.

There were a few minor imperfections to some of the experiments, but none of these will pose significant issues to accomplishment of the study objectives.

In the second experiment, the source vessel was never able to cross a CPA to the tagged animal during the Silent approach, so it may not be usable. Also, tracking of the tagged sperm whale was lost subsequent to the killer whale sound playback, making it impossible to conduct the planned final Down-sweep exposure.

In the fourth experiment, the Silent exposure which had been planned as the third exposure was not accomplished due to logistical reasons. The animals were travelling too quickly away from the source boat for Sverdrup to make a good approach. Also, the Down-sweep exposure was started for a few pings, but then aborted in order to move to a more favourable position ahead of the animals. This may make it difficult to classify the period between the aborted transmissions and the eventual approach exposure. In the sixth experiment, no Silent exposure was conducted due to logistical reasons. The whale was travelling steadily north, and it was deemed impossible to accomplish all of the exposures with a good approach angle due to the need to pass the animal between each exposure. This is reflected in the dispersion between the transmissions. We therefore cancelled the silent exposure as it was not the first transmission type.

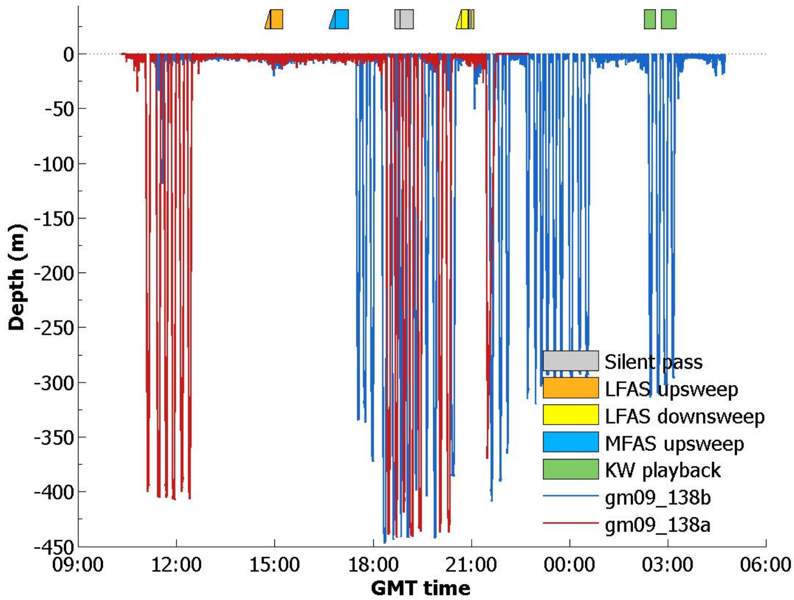

Figure 4.3 Dive profiles of two pilot whales in the first experiment. The shapes above the profile represent the exposure condition. Triangle-shapes are the ramp-up period. KW sounds were recorded from herring-feeding killer whales. During the LFAS downsweep experiment two emergency stops in sonar transmissions are visible. These were executed according to the predefined mitigation procedure of the experiments (see appendix C), because animals were in danger of appearing within the 50 m safety zone of the source.

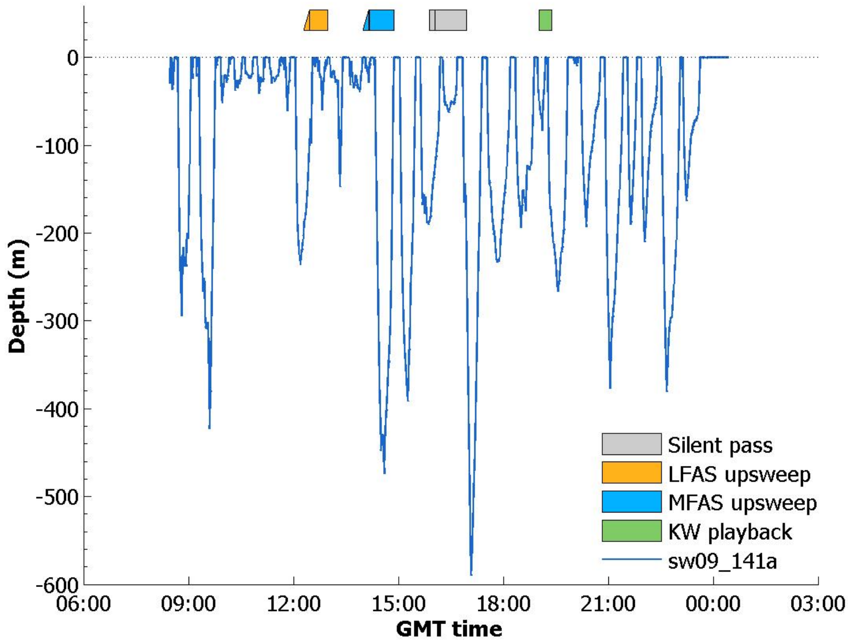

Figure 4.4 Dive profile of sperm whale in the second experiment. The shapes above the profile represent the exposure condition. Triangle-shapes are the ramp-up period. KW sounds played back were initially of herring-feeding killer whales, and then switched to sounds recorded from mammal-eating killer whales.

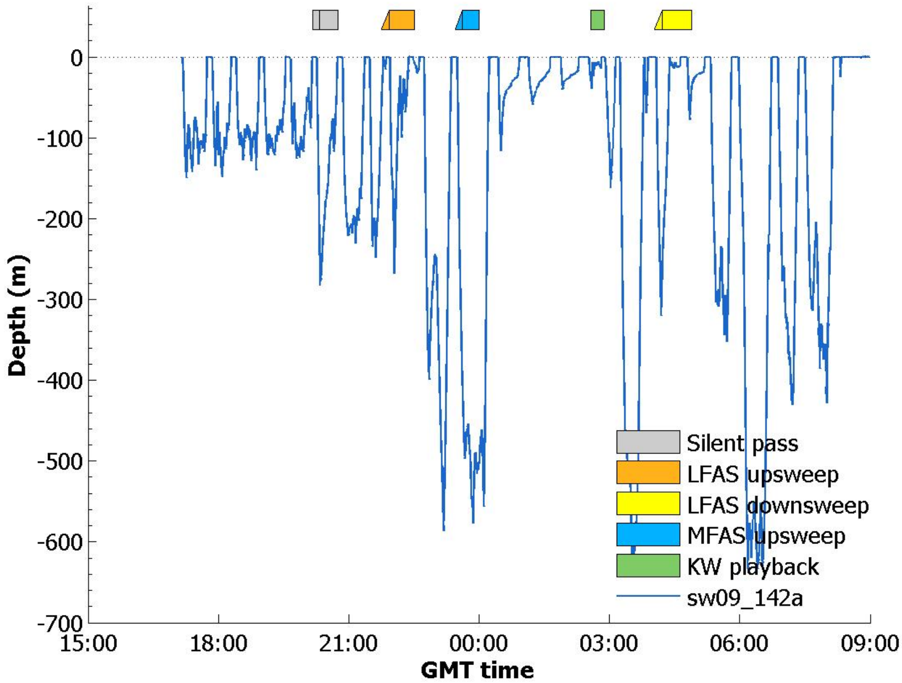

Figure 4.5 Dive profile of the sperm whale in the third experiment. The shapes above the profile represent the exposure condition. Triangle-shapes are the ramp-up period. KW sounds were recorded from mammal-eating killer whales.

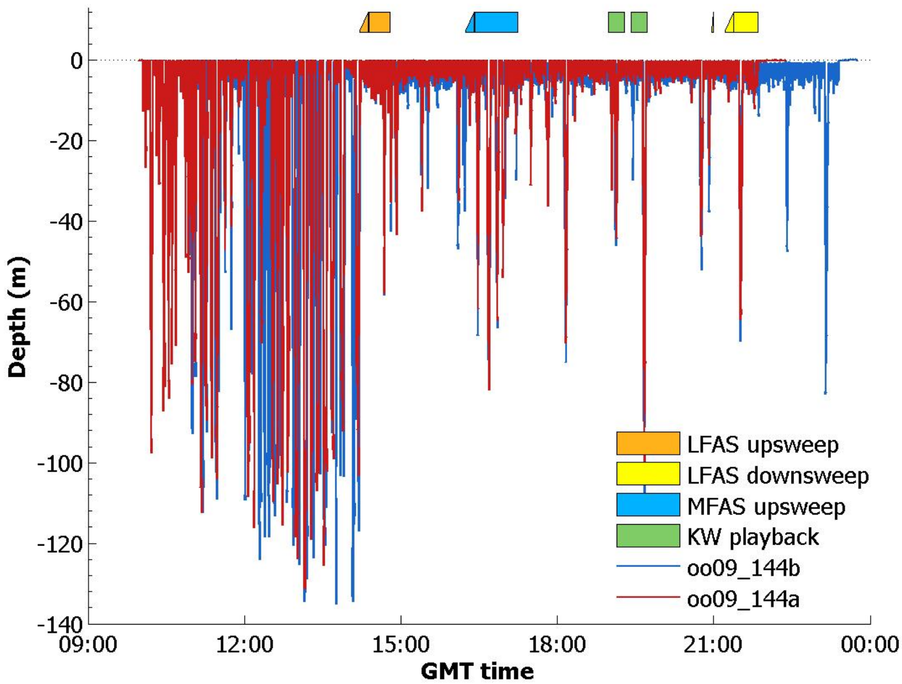

Figure 4.6 Dive profiles of two killer whales in the fourth experiment. The shapes above the profile represent the exposure condition. Triangle-shapes are the ramp-up period. KW sounds were recorded from herring-feeding killer whales.

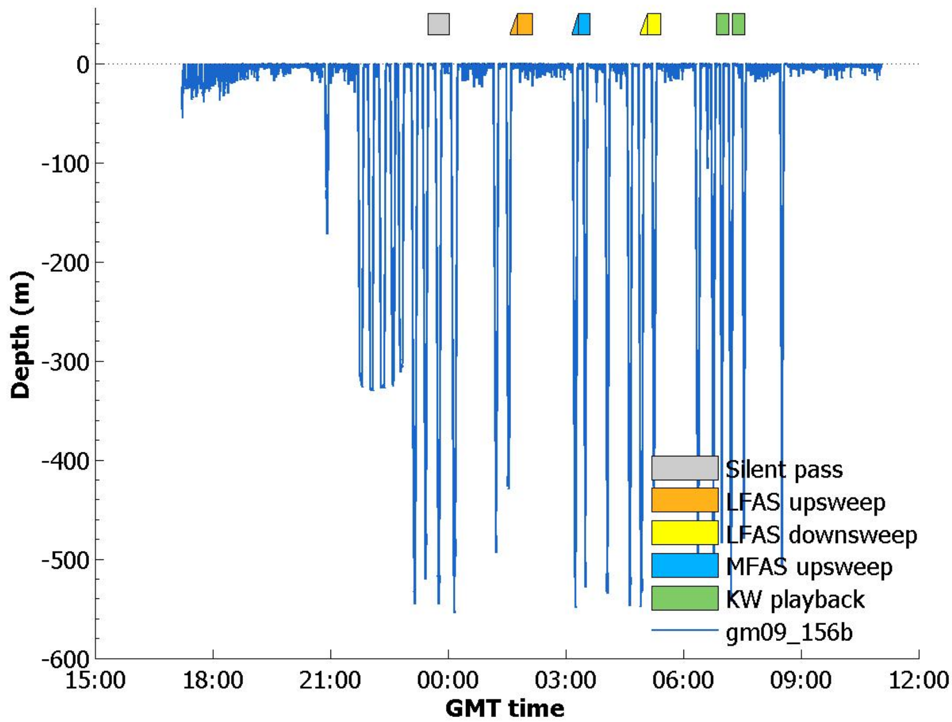

Figure 4.7 Dive profile of the pilot whale in the fifth experiment. The shapes above the profile represent the exposure condition. Triangle-shapes are the ramp-up period. KW sounds were recorded from herring-feeding killer whales.

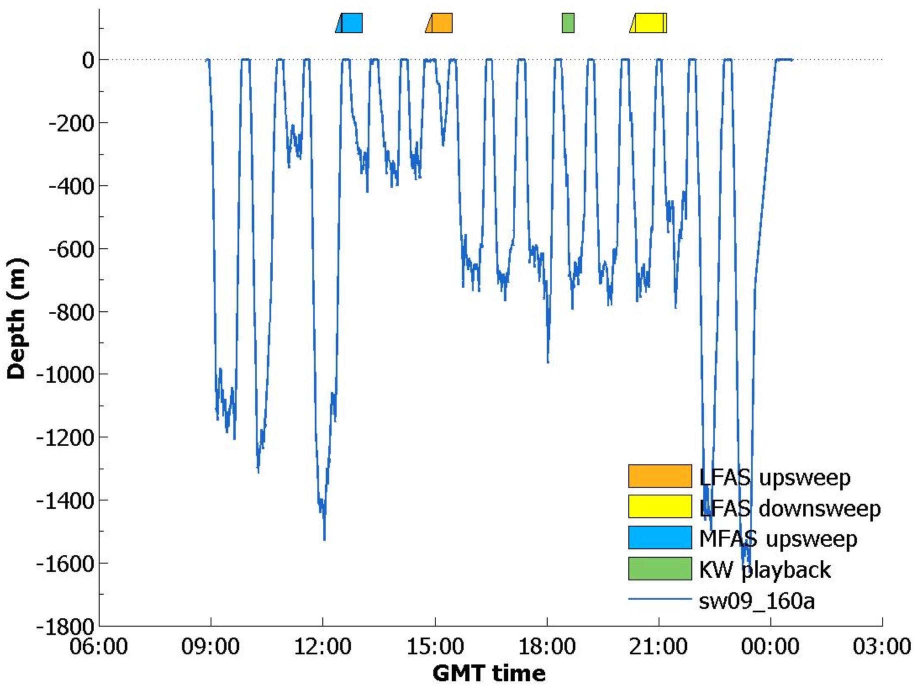

Figure 4.8 Dive profile of the sperm whale in the sixth experiment. The shapes above the profile represent the exposure condition. Triangle-shapes are the ramp-up period. KW sounds were recorded from mammal-eating killer whales.

4.3 Passive Acoustics – Delphinus

4.3.1 Effort

An overview of Delphinus operations for the entire trial can be found in fig. 2.1. Daily (towing) tracks can be found in Appendix A. A full list of towing times with run numbers is shown in Table 4.2. These run numbers correspond to the file names of the acoustic recordings. In total the Delphinus system was deployed for over 208 hours, providing 3.4 TByte of raw acoustic data. Due to leakage in the tow cable, the system was not available for the second part of leg 1, from May 21 to 26. During the second leg the system was operated with a different and shorter tow cable.

Table 4.2 Overview of the run numbers for towing times of the Delphinus system (table continues on next page).

Run number	Date 2009	Start time UTC	Stop time UTC	Duration hh:mm	Size [GB]	Mammals	Remarks
Cee001	16-05	17:09	19:18	02:09	31	None	Survey
Cee002	16-05	19:20	23:50	04:30	66	None	Survey
Cee003	17-05	00:33	11:02	10:29	154	Pilot whales	Survey
Cee004	17-05	11:03	22:46	11:43	169	Pilot whales	Survey
Cee005	17-05	23:04	05:46	06:42	97	Pilot whales	Survey
Cee006	18-05	05:46	10:45	04:59	72	Pilot whales	Survey
Cee007	18-05	11:17	21:12	09:55	143	Pilot whales	Exposure
Cee008	19-05	07:43	17:41	09:58	144	Pilot whales	Survey
Cee009	19-05	17:42	06:01	12:19	178	Distant sperm whales	Survey
Cee010	20-05	13:05	19:29	06:24	92	Sperm whales	Survey
Cee011	20-05	19:37	05:54	10:17	149	Sperm whales	Survey
Cee012	21-05	20:44	01:04	04:20	63	Sperm whales	Survey
Cee015	27-05	12:03	12:18	00:15	4	None	Test run repaired connector
Cee019	01-06	09:56	19:06	09:10	312	Sperm whales. Some porpoise clicks.	Survey Andfjorden
Cee020	02-06	05:50	07:08	01:18	19	Porpoise clicks	Recording stopped accidentally
Cee021	02-06	07:08	09:59	02:51	41	Porpoise clicks, sperm whale clicks	Cont'd Cee020
Cee022	02-06	10:00	22:38	12:38	182	Sperm whales	Cont'd Cee021, attempted exposure
Cee023	02-06	22:39	2:14	03:35	52	Sperm whales	Cont'd Cee022, exposure cancelled
Cee024	04-06	01:09	12:46	11:37	168	Some porpoise clicks	Survey Vestfjorden
Cee025	04-06	12:47	18:22	05:35	81	Some porpoise clicks	Survey Vestfjorden
Cee026	04-06	18:57	07:27	12:30	181	Pilot whales	Survey

							Vestfjorden
Cee027	05-06	07:30	13:52	06:22	92	Pilot whales	Survey Vestfjorden
Cee028	05-06	17:09	00:53	07:44	111	Pilot whales	Exposure
Cee029	06-06	00:53	06:12	05:19	77	Pilot whales	Exposure
Cee031	07-06	17:10	05:19	12:09	175	Porpoise clicks, sperm whale clicks, killer whale whistles	Survey Andfjorden
Cee032	08-06	05:20	19:31	14:11	205	Sperm whales	Survey Andfjorden
Cee033	08-06	19:32	22:49	03:17	47	Sperm whale clicks, some killer whale whistles	Survey Andfjorden
Cee034	08-06	22:51	12:00	13:09	190	Sperm whales	Survey Andfjorden
Cee035	09-06	12:00	17:46	05:46	83	Sperm whales	Survey Andfjorden
Cee036	09-06	17:53	22:09	04:16	62	Sperm whales	Survey Andfjorden
total				**208:37**	**3440**		

Table 4.2 Overview of the run numbers for towing times of the Delphinus system (table start on previous page).

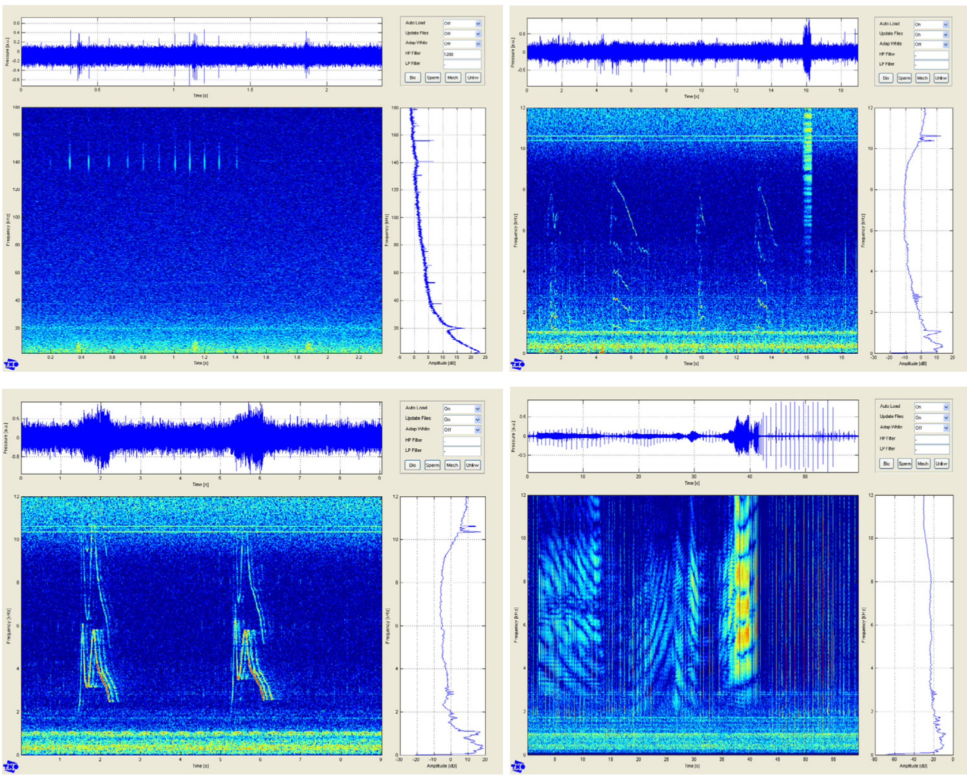

Figure 4.9 Examples of detections by Delphinus (wav-player/spectrogram images). Top left: HF porpoise clicks around 130 kHz; Top right: killer whale whistles; Bottom left: pilot whale whistles; Bottom right: sperm whale clicks and buzz.

4.3.2 Detection of mammal sounds

Table 4.3 provides an overview of all detections passing the threshold of the transient detector of the Delphinus system. As described in section 3, for each detected signal a wav-file is extracted from the processed data and recorded separately; see Fig. 4.9 for some examples. Appendix A provides images with an overview of the detections day by day. In classifying the detected transient signals, sperm whale detections are discriminated from other biological signals, due to the overload of sperm whale clicks near Andenes. Note that at some occasions, like for cee004, the relative amount of biological sounds is exceptionally high. In this case the ship was positioned close to the target species (pilot whales) for a longer time, partly awaiting the arrival of the observation ship.

4.3.3 Acoustic search/survey

During the search phases of the experiment the Delphinus array was towed by Sverdrup whenever possible, depending on the bathymetry of the operation area. Once biological transients (related to target species) were detected, the ship was navigated in the direction of the potential animals. Turns of the ship were needed in order to discriminate between signals coming from port or starboard. A good example of this manoeuvring is given in fig. 4.10, where pilot whales were detected at the opposite site of Vestfjorden, at a range of about 13 nautical miles. The detection of this group of pilot whales was several hours before the intended departure out of this area, and travelling west of Lofoten.

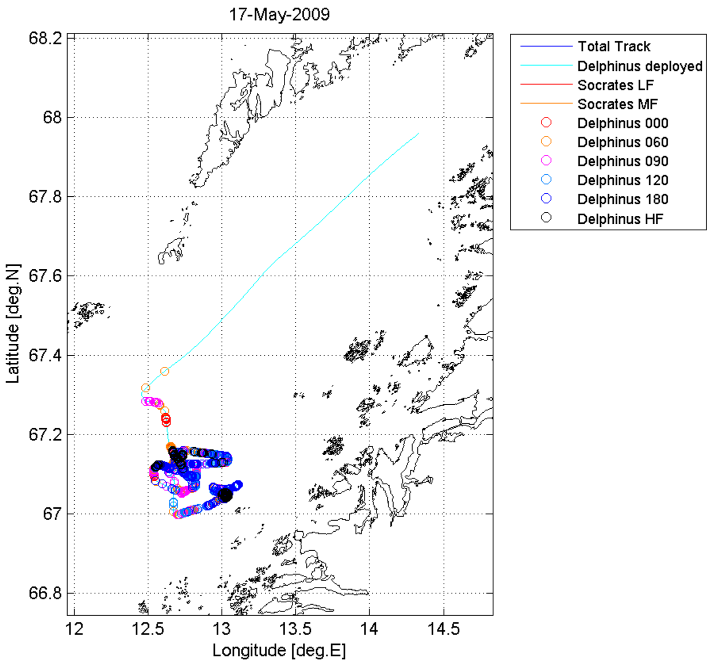

Figure 4.10 Example of navigating to detected pilot whales by Sverdrup on May 17th. The ship was sailing south when the whale vocalization was detected. The animals appeared to be at the opposite site of Vestfjorden, where tagging attempts got started.

Run number	Start date 2009	Start time UTC	End time UTC	#Bio detections	#sperm-whale	#other	#total detections
Cee001	16-05	17:09	19:18	0	0	50	50
Cee002	16-05	19:20	23:50	0	0	62	62
Cee003	17-05	00:33	11:02	247	2	274	523
Cee004	17-05	11:03	22:46	1152	0	206	1358
Cee005	17-05	23:04	05:46	845	0	266	1111
Cee006	18-05	05:46	10:45	357	0	122	479
Cee007	18-05	11:17	21:12	600	0	839	1439
Cee008	19-05	07:43	17:41	172	0	350	522
Cee009	19-05	17:42	06:01	0	12	570	582
Cee010	20-05	13:05	19:29	0	91	279	370
Cee011	20-05	19:37	05:54	66	1803	1218	3087
Cee012	21-05	20:44	01:04	4	521	863	1388
Cee015	27-05	12:03	12:18	0	0	0	0
Cee019	01-06	09:56	19:06	10	378	200	588
Cee020	02-06	05:50	07:08	1	0	30	31
Cee021	02-06	07:08	09:59	3	57	77	137
Cee022	02-06	10:00	22:38	0	1758	229	1987
Cee023	02-06	22:39	02:14	1	146	104	251
Cee024	04-06	01:09	12:46	2	0	163	165
Cee025	04-06	12:47	18:22	2	0	62	64
Cee026	04-06	18:57	07:27	212	0	698	910
Cee027	05-06	07:30	13:52	185	0	357	542
Cee028	05-06	17:09	00:53	155	0	408	563
Cee029	06-06	00:53	06:12	270	0	833	1103
Cee031	07-06	17:10	05:19	127	13	301	441
Cee032	08-06	05:20	19:31	7	451	278	736
Cee033	08-06	19:32	22:49	25	283	46	354
Cee034	08-06	22:51	12:00	0	2834	265	3099
Cee035*	09-06	12:00	17:46	0	1515	168	1683
Cee036*	09-06	17:53	22:09	0	770	86	856
Total				**4443**	**10634**	**9404**	**24481**

Table 4.3 Overview of Delphinus detections passing the threshold of the transient detector for all runs. Detected signals are grouped in sperm whale clicks, biological sounds (other than sperm whale clicks) and other transient signals. Other detections are mechanical and (a few) unknown sounds.
** Classification of runs 035 and 036 (June 09) not completed; numbers are estimated based on run 034.*

4.3.4 Acoustic Tracking

After target species have been detected and localised, the animals needed to be tracked either visually or acoustically. In some cases Sverdrup had to await the arrival of Strønstad, and acoustic tracking was applied. This was especially helpful for keeping track of diving sperm whales, which are easy to detect once they are under water and start clicking (loudly). An example of tracking an individual sperm whale is given in Fig. 4.11, where boxes around the tracked animal are being sailed. In the waterfall display the bearing of the animal can be seen, and geographic position of the animal can be estimated.

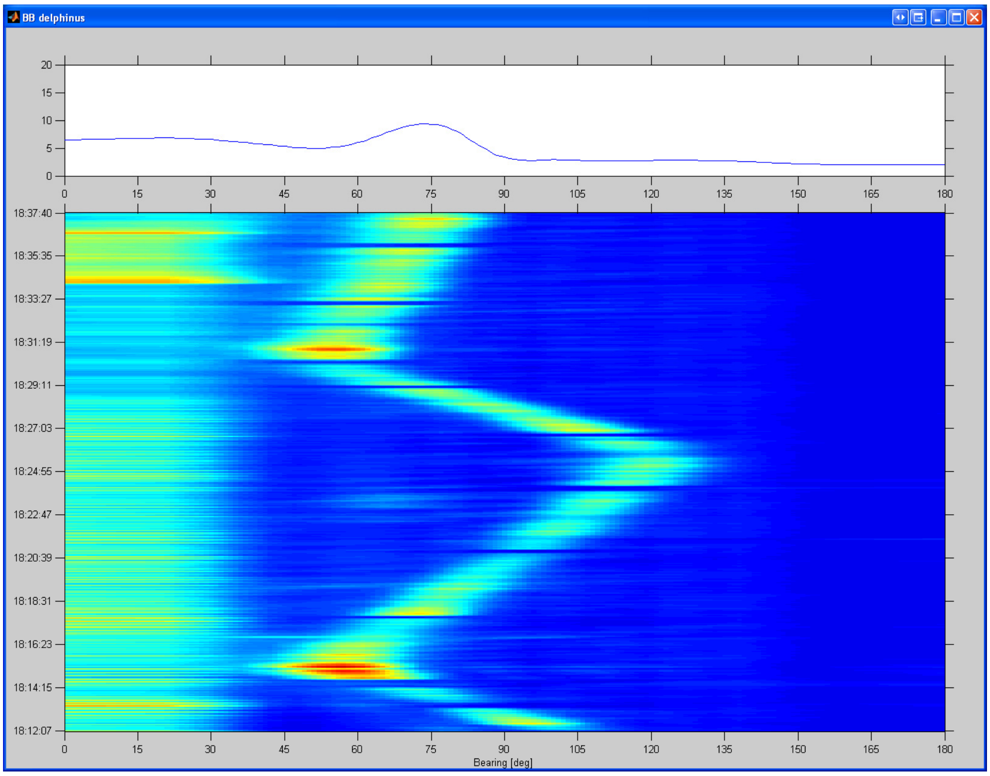

Figure 4.11 Example of the acoustic tracking of a sperm whale with the Delphinus system. A screen dump of the broad band tracking display, showing the tracking of individual sperm whale by sailing boxes on June 08, 18:38 UTC. The tracking display is a broadband waterfall display, visualizing the (auto-scaled) acoustic energy (between 5 and 11 kHz) against time and angle. Due to the adjusted array shading, the directional resolution of the display is improved compared to the standard beamformer with 5 different sections.

4.4 Passive acoustics - Beamer Array

4.4.1 Searching phase

The Beamer array on the Strønstad was effective for several different functions. The noise floor was generally dependent on vessel noise, and we worked with the ships crew to determine the optimal rpm/pitch combinations for minimum noise at different required speeds. Though it was not routinely used when searching for whales, it was important in this fashion to detect sperm whale clicks during the period when Delphinus was not working, and once to help us localize pilot whales in tandem with the Delphinus on Sverdrup.

4.4.2 Tracking

The Strønstad array is on the observation boat, which remains close to the tagged animal. This allows the acoustic observers on the Strønstad to reliably identify clicks from the tagged animal each time it dives. The real-time tracking capability of Beamer using Pamguard software was effective for sperm whales. This tracking ability was useful on several occasions to support the tag team, which linked the Beamer array angles to those heard on the Pickle directional hydrophone used on the tag boat. Beamer presents no restrictions for maneuvering the Strønstad, so regular tactical turns could be made to constantly resolve the left-right ambiguity while maintaining a target animal forward of Strønstad. Likewise, visual tracking was not constrained by turning restrictions. Once a tag was deployed on a sperm whale, the real-time tracking was very useful to stay close to the tagged whale between surfacing, reducing the risk of being too far away to detect VHF signals from the tag once the whale did come to the surface. Occasionally, however, tracking the tagged whale was difficult when many sperm whales were nearby. After a few cases of following the wrong animal, the acoustics team modified their protocol to also consider the previous movement path of the animal recorded and displayed real time in Logger software. Once they were uncertain which clicks were the tagged animal, they successfully used the previous trajectory of the whale to be close to its subsequent surfacing position.

4.4.3 Overview of recordings

Recordings on the calibrated Alesis 24 deck were successfully made throughout the trial. In only a few cases, songs were lost when the battery voltage dropped too low. In total, the Beamer PAM array made a total of 131.8 hours of recordings filling ~1.89 Terabytes of hard drive space.

Brand	Size	Date of first recording	Date of last recording	Hard-drive name
Western Digital	160 Gb	20/05/2009	21/05/2009	3S2009_01
Seagate	120 Gb	22/05/2009	23/05/2009	3S2009_02
Seagate	250 Gb	23/05/2005	24/05/2009	3S2009_03
Seagate	120 Gb	24/05/2009	24/05/2009	3S2009_04
Seagate	120 Gb	24/05/2009	02/06/2009	3S2009_05
Seagate	120 Gb	02/06/2009	05/06/2009	3S2009_06
Western Digital	250Gb	05/06/2009	06/06/2009	3S2009_08
Western Digital	250 Gb	06/06/2009	08/06/2009	3S2009_07
Western Digital	250Gb	08/06/2009	09/08/2009	3S2009_09
Western Digital	500Gb	09/06/2009	10/06/2009	3S2009_10

Table 4.4 Overview of recordings on the calibrated Alesis 24 deck.

4.5 Combined passive acoustics during sperm whale experiments

During exposure runs with sperm whales it is of crucial importance that the tagged animal is being tracked, so that the animal can be approached as desired following the exposure protocol (see cruise plan, appendix C). During deep dives visual tracking is not possible so that acoustic tracking is required. This was done mainly with the Strønstad array as explained above. In addition, some tracking could also be done with the Delphinus system on the source ship during the exposures. During 3S-09 we were not set up to combine the information from the two arrays in an efficient way to assist in conducting the exposure experiments. However, the last exposure experiment conducted during 3S-09 (June 09) on sperm whales showed the potential benefit of having the tracking information from both systems available during the approach:

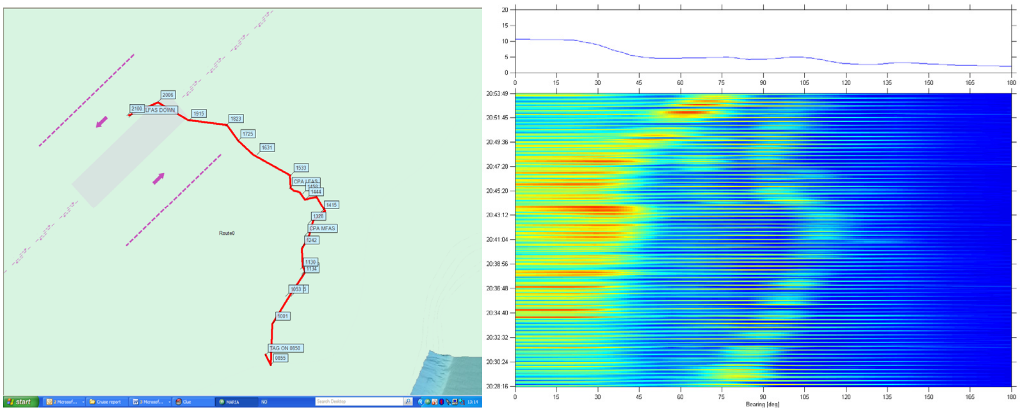

Figure 4.12 Left; display of visual track of sperm whale during exposure experiment on June 09 as seen on Sverdrup (source ship) but based on the tracking performed on Strønstad (observation ship). Right; acoustic tracking of sperm whale from source ship with Delphinus during exposure experiment on 09 June. Screendumps of broadband tracking display at UTC times 20:28-20:53. Image is distorted by the loud transmissions every 20 seconds.

In preparation for the approach the source ship was positioned about 4 nautical miles away from the estimated position of the animal based on the visual tracking information they receive from Strønstad (fig. 4.12 left). The initial course of the source ship (Sverdrup) upon start of transmission was determined based on a visual fix minutes before the commence of transmissions. However, the animal went into a long dive and did not re-appear at the surface until near the end of the experiment. The approach therefore had to be based on acoustic tracking using Delphinus. From the perspective of the operators of the passive acoustic array of the source ship, the approaching direction during the exposures is not favourable for tracking, having the whale in the forward beam. Moreover, the sonar display is distorted due to the loud transmissions close to the array. As shown in the example of Fig. 4.12 (right), the remaining tracking ability of the system was still supportive in executing the correct ship's navigation for the exposure run. In approaching the animal, around 20:40 the whale moved out of the (relatively wide) forward beam, possibly avoiding the approaching sonar source. At this point the animal is still more than 1000 m from the source ship and the exposure protocol states that the source ship should turn to continue to approach the animal. The problem the experiment coordinator on the source ship faced was that the single line hydrophone array does not tell him which way he should turn (port or starboard). Luckily the Strønstad was positioned on a 90° aspect relative to Sverdrup, and the operator of the Beamer array reported that the animal moved towards his forward beam. Thus, the left/right ambiguity was resolved and the Sverdrup did a correct starboard course correction, which moved the acoustic track back to the forward beam again around 20:45. A second animal caused a false alarm by coming out of the forward beam around 20:49, mimicking a pass over the animal around 20:50. This appeared not to be the tagged animal, that surfaced around 20:57 and being at CPA on 20:59 at 20 degrees starboard side, only 350m from the source ship.

4.6 Visual tracking

Visual tracking was successful in 3S-09. During the search phase, searching with naked eye and hand-held binoculars was augmented in the best weather conditions with big-eye binoculars on the Sverdrup.

The logger software is very efficient for data entry, with specific fields for species ID, range to animal, bearing to animal, and animal aspect relative to the direction of the boat. We also had specific fields to record behavior observations, weather conditions and effort. *Logger* stores the data in Microsoft Access tables, and creates a real-time display of the (re)-sighting position relative to the track of the observation vessel (Fig. 4.13). The real-time track is very valuable for checking in real-time that the information recorded is correct, and for maintaining the vessel in a good position to pick up the whale when it next surfaces.

	miles	**km**	**Time**
Total Track	1737.8	3218.5	346:27:20
Searching	1062.9	1968.4	155:10:47
Pre-tagging	10.6	19.7	03:53:01
Tagging	132.7	245.9	39:39:55
Tracking	500.6	927.2	141:48:03
Off Effort	19.9	36.8	04:10:05
Transit	11.1	20.5	01:45:09

Table 4.5 Visual effort table of the observation vessel Strønstad.

Total visual effort exceeded 346 hours, shown broken down in table 4.5. A total of 1481 resightings of tracked individuals were made

4.7 Group behavioral sampling

Group behavioral data was collected for pilot whales and killer whales, during pre-tagging phases, tagging phases and experiment phases, as well as during baseline experiments for both species, whenever the focal group consisted of more than one individual. A short pilot of group behavioral data was collected for sperm whales, when the focal animal was closely associated with 1 to 3 other whales. The group behavioral data was collected simultaneously with the tracking data, at the first surfacing following an interval of 1.5 minutes after the last surfacing.

As an overall result, the group behavioral protocol and methods, designed preceding the 3S 2009 cruise, worked well and needed only few adjustments. This was also true for the new format for data entry in Logger, which strongly facilitated the recording of the data and provided an immediate control of the data called by the behavioral observer. The addition of group behavioral data to the general protocol did not interfere with the tracking, or the collection of other data types.

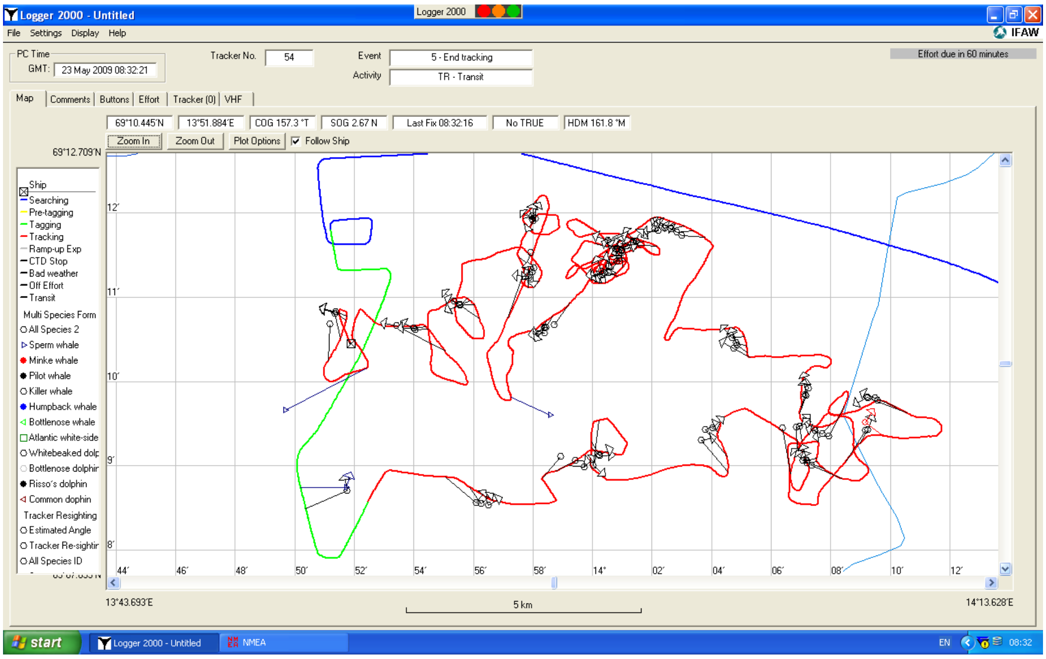

Figure 4.13 Screen print of Logger software display of the entire track of the sperm whale tagged on May 22. The line shows the Strønstad track, with blue representing the search phase, green the tagging phase, and red the tracking phase. The black circles are the whale location at the sighting, and the arrow displays the observed orientation of the whale at the surface.

4.7.1 Effort

In total 92.2 hours of group behavioral data was collected during 9 experiments, 5 on pilot whales, 3 on killer whales and 1 on sperm whales. The majority of effort was focused on the pilot whale (Table 4.6). For the pilot whale, group behavioral sampling was conducted during 3 complete experiments, involving a pre-tagging, tagging and tracking, of which one was a baseline experiment (no exposures). One experiment included a tagging and tracking phase only, due to pre-exposure to tagging effort of this group. One experiment on pilot whales was broken off during the pre-tagging phase, due to a sighting of killer whales (priority species at that moment). For killer whales, group behavioral sampling was conducted during 1 complete experiment, involving pre-tagging, tagging and tracking. Two experiments were conducted involving a tagging and tracking phase, one of which was a baseline experiment. During these experiments no pre-tagging was conducted due to practical and logistical limitations (rain, difficult tracking) or pre-exposure to tagging vessel presence. One pilot of group behavioral sampling was conducted on a group of 2-4 sperm whales, following tagging. For sperm whales, pre-tagging as well as tagging phases are difficult to sample, as it is difficult to be sure that the same animal is being tracked following a long dive. However, this can be supported with acoustic tracking of the sperm whale, which was done successfully during all sperm whale experiments. For sperm whales, surfacing synchrony was sampled differently, by the fluke times and surfacing times of individuals.

Phase	LF pilot whale	Killer whale	Sperm whale	Total Effort Phase
Pre-tagging	02:28 (4)	00:29 (1)		02:57 (5)
Tagging	11:00 (4)	13:24 (6)		24:24 (10)
Tracking	46:05 (8)	14:17 (4)	4:30 (1)	64:52 (13)
Total Effort Species	59:33 (16)	28:10 (11)	04:30 (1)	92:13 (28)

Table 4.6 Effort of group behavioral sampling per species for the different phases. Pre-tagging: all effort from first sighting until first tag boat is launched; Tagging: all effort with tag boats present; Tracking: all effort following a tagging phase. Effort given by total duration (hours) and by the number of time-series (in brackets).

4.7.2 Parameter selection

As a general impression during the experiments, the parameter selection for the group behavioral sampling, in combination with the tracking, was adequate to collect the behavioral data desired to track changes in surface behavior within and between phases of the experiment.

The complete set of parameters however, Logger and paper data, may generally be too demanding for one behavioral observer. As was provisioned, it is important to limit the number of parameters sampled, especially with short sampling intervals of tracking (<5 minutes). This is important both for the behavioral observer, as well as for the data recorder. Also, not all parameters can always be sampled as well as would be desired. Therefore, a selection is needed. Based on the experience and results of the 3S 2009 cruise, we will aim to set up a sampling priority table for parameter choice for behavioral response studies, based on species, measurability and other relevant factors. A first set-up was made in table 4.7.

The majority of parameters could be sampled well, and were given high priority for collection during group behavioral sampling. For group spacing, it is of high importance that the protocol for sampling of (sub)groups is well defined, and that data on group spacing and size is always collected for the focal subgroup. Surfacing synchrony is regarded an important behavioral parameter. However, while 'complete synchrony' and 'no synchrony' can be sampled well, it can be difficult to recognize intermediate states of synchrony. During the 3S 2009 cruise, one category of intermediate synchrony was sampled, and there is an overall concern that this may not have the level of precision desired to record changes in surfacing synchrony. This parameter may need video recordings for more precise sampling. Group dive times are regarded an important parameter, and can usually be measured well. Pilot whales especially, however, showed many group dives, with short surfacing intervals. In this case, it may be difficult to combine the collection of dive times with the collection of the other behavioral parameters.

Parameter	Species	Measurability	Priority	Comments
Group size	Gmel, Oo	Good	High	Takes some time to estimate
Calf presence	Gmel, Oo	Good	High	Presence as well as counts are reliable
Group spacing	Gmel, Oo	Good	High	Well measurable; protocol for subgroups should be well-defined
Surfacing synchrony	Gmel, Oo	Moderate	Moderate	Difficult to distinguish between intermediate states, may not be sufficiently discriminative
Distance to nearest other subgroup	Gmel, Oo	Good	High	Well measurable
Display events	Gmel, Oo	Good	High	Limit the selection of types to sample
Group dive times	Gmel, Oo	Moderate	?	Well measurable, but difficult if many dives; in combination with other parameters and high sampling rates
Swimming mode	Gmel, Oo	Good	Moderate	Important, but generally correlated to speed
Behavioral type	Gmel, Oo	Good	High	Record surface behavior, important to interpret changes in behavioral parameters
Milling index	Gmel, Oo	Good	High	Indication for synchrony, changes often show distinctive timing
Group lined up	Gmel, Oo	Good	Moderate?	Important, but often correlated to travel behavior

Table 4.7 Sampling table for group behavior parameters sampled during 3S 2009. Gmel: Long finned pilot whale; Oo: killer whale.

4.7.3 Preliminary results – descriptive summary

Behavioral changes observed frequently included changes in speed, direction, group spacing, dive times, behavioral type and/or milling index. For both pilot whales and killer whales changes in surface behavior were observed within and between the different phases. At first impression (while observing), behavioral responses varied between tagging phases and sonar exposure phases for both species. If so, this may be of importance in the interpretation of the response (if any) to the exposures, with one group of individuals reacting differently to different potential sources of disturbance.

The sampling rate was highly sufficient to record (changes in) group behavioral parameters. Shorter sampling rates as the one chosen here are not recommended for the collection of group behavioral data, as 1) the rate of change of group behavioral states is generally <1 per 1.5 minute and 2) the observer needs to be able to observe several surfacing to reliably assess group behavioral states. Under some circumstances, for example during long dives of the focal individual, it was not possible to record group behavioral parameters at the desired sampling rate. However, this was solved by the use of the paper forms next to the Logger software.

4.8 Tagging

During tagging operations, the two tag boats were generally operating alone with different sub-groups if both boats where launched. On just 2 occasions working with pilot whales and killer whales, tag-boat 1 and tag-boat 2 where cooperating during tagging approaches. However, no benefit from this additional effort was registered. A total of 17 Dtags were deployed, 10 by the pole, and 7 by the ARTS. See table 4.8 for an overview of all Dtag deployments, and figure 4.14 for comparison of tag duration using different tagging techniques. Figure 4.16 summarizes the performance of the new tagging system ARTS launching the DTAG.

4.8.1 Effort

We now seem to have good systems for deploying tags on the target species, and time to tag attachment is very reasonable. With the exception of two tagging approaches, one on pilot whales and one on killer whales, the time to deployment of DTAGs onto our three target species where within 2 hours after the launching of tag-boats. For those difficult cases, it has been due to weather or the behavior of the animals. We have pushed the tagging weather window by tagging a pilot whale in sea state 5 conditions and a sperm whale in high swell offshore; however those deployments were quite short and had bad VHF signals, respectively.

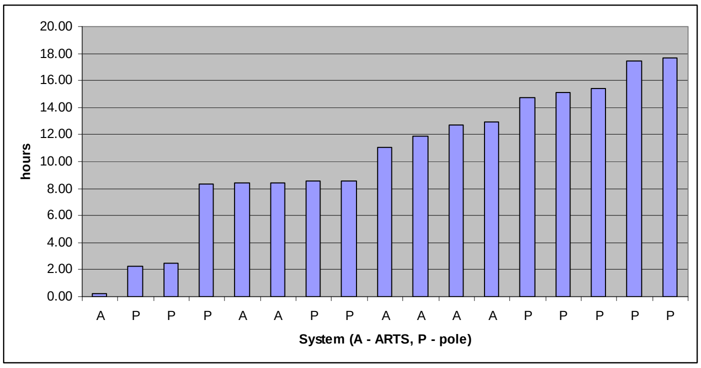

Figure 4.14 On-animal tag attachment duration for the ARTS and pole systems. Be aware that in most of the long duration deployments, the durations are limited by the programmed release time (see table 4.8 for details).

Species	Dataset/ Dtag#	Date – Local time	Deploy position	Duration (on animal)	System - boat (release, skin)	CEE/ Baseline
Pilot whale	gm137a 229	May 17th 14:52:40	67 04.921 12 46.003	8:35:00	Pole – TB1 (release, skin)	Baseline
Pilot whale	gm137b 220	May 17th 15:09:21	67 04.73 12 45.33	8:25:00	ARTS – TB2 (release, no skin)	Baseline
Pilot whale	gm137c 230	May 17th 15:52:05	67 05.339 12 44.600	8:23:00	Pole – TB1 (release, no skin)	Baseline
Pilot whale	gm138a 220	May 18th 12:17:57	67 27.09 13 45.78	11:02:00	ARTS – TB2 (slipped, no skin)	CEE
Pilot whale	gm138b 227	May 18th 13:19:18	67 29.388 13 46.978	17:26:00	Pole – TB1 (release failed, skin in cup and external)	CEE
Sperm whale	sw141a 229	May 21st 10:27:59	69 24.176 15 49.036	15:23:00	Pole – TB2 (release, no skin)	CEE
Sperm whale	sw142a 229	May 22nd 19:10:30	69 08.75 13 52.160	15:08:00	Pole – TB2 (release, skin)	CEE
Killer whale	oo143a 220	May 23rd 19:37:05	68 37.060 13 06.476	12:54:00	ARTS – TB2 (slipped, no skin)	Baseline
Killer whale	oo144a 229	May 24th 11:58:53	68 26.733 12 37.044	11:52:00	ARTS – TB2 (slipped, no skin)	CEE
Killer whale	oo144b 230	May 24th 11:58:53	68 27.259 12 38.506	12:43:00	ARTS – TB2 (release, no skin)	CEE
Pilot whale	gm146a 220	May 26th 09:49:40	68 04.864 14 53.123	2:14:00	Pole – TB2 (slipped, no skin)	Baseline
Sperm whale	sw153a 220	June 02 19:52:16	69 28.519 16 18.123	8:36:00	Pole – TB2 (release, no skin) no beeps at start	Baseline
Pilot whale	gm156a 220	June 05 14:47:32	68 13.71 15 14.10	00:12:00	ARTS – TB2 (slipped, skin)	Baseline
Pilot whale	gm156b 229	June 05 19:12:24	68 13.044 15 35.016	17:51:00	Pole – TB1 (release failed, no skin)	CEE
Pilot whale	gm157a 220	June 06 17:40:48	68 26.434 16 36.264	8:24:00	ARTS – TB2 (release, no skin) tag damaged	CEE ramp up
Sperm whale	sw159a 220	June 08 22:46:56	69 32.536 16 48.947	2:30:00	Pole – TB2 (release, no skin) Tag failed (leak)	CEE
Sperm whale	sw160a 230	June 09 10:51:01	69 34.559 15 20.402	14:45:00	Pole – TB2 (release, no skin)	CEE
5 sperm 3 killer 9 pilot	17	12 different days		176:01:12	7 ARTS, 10 pole 4 TB 1, 13 TB 2 10 to release 5 skin samples	6 l-m-s 1 ramp 7 Total

Table 4.8 Summary of all Dtag deployments during 3S-2009.

4.8.2 Pole tagging

For sperm whale tagging, the combination of the directional hydrophone ("Pickle") and the long pole was highly effective in most cases. Four of the five tags were deployed on the first approach, and the other on the second approach. We did fail to retag one individual which was alone in the area, but that was due to its behavior, not the system used. Tag-boat 1 was highly effective for tagging pilot whales using the normal hand pole.

4.8.3 ARTS tagging

The ARTS system was tested at sea during 3S-09 on pilot whales, sperm whales, and killer whales. It has proven to be a very valuable delivery system for the Dtag, especially for fast moving animals such as killer whales, which are usually approached at speeds of 6 knots or more. It needs some improvements to be used effectively in "rough" weather conditions, as the tag placement on the animal is critical (for radio tracking), and it is difficult to achieve such precision with the current ARTS system.

Figure 4.15 Tag boat 2 with elevated platform for use with the ARTS (top, photo Paul Ensor), and incoming dtag with ARTS carrier about to touch down on a killer whale (lower left, photo Sanna Kuningas) and a pilot whale (lower right, Sanna Kuningas). The pilot whale was already tagged, but the shooter could not see the tag from his position (picture is taken from other tag boat).

A new tag-boat (tag boat 2) with a designed platform elevated in the front (figure 4.15) was a major improvement for the tagging operation. In general during approaches of pilot whales and killer whales the ARTS was the principal tagging method used from this tag boat, while during sperm whale approaches an extended long pole was the principal tag deployment technique during 3S-09. Improved results with the ARTS system is particularly due to the new launching platform combined with detailed changes to the tag carrier and the DTAG robot (weight and an impact absorption stem). After some rebound deployments using the ARTS system at 8 bars, the standard operational pressure was set to 7 bars. However, the accuracy of the ARTS system launching the DTAG might improve considerably if the system could be operated within the maximum pressure according to the protocol. Launching the existing DTAG at 8 bar resulted in a number of rebounding of the tag. Also, the experiences we had using 7 bar pressure during rough seas question the stability of the ARTS system during windy conditions, and therefore require further development of the launching system.

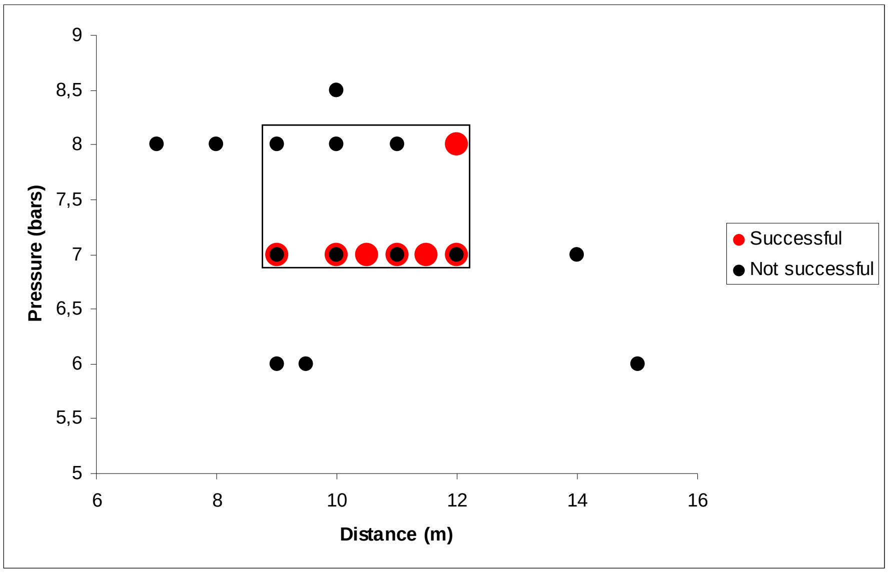

Figure 4.16   Performance of the ARTS system at different ranges to target and different barrel pressures. Most successful launchings of the DTAG during 3S-09 where between 9-12m with 7-8 bar pressure. If the pressure is too high or the distance to short, the tag tends to bounce off the target animal, and if the distance is too long or the pressure too low, the result is often a miss.

4.9 Photo ID

Intensive photo-ID efforts were made from the tag-boats and the Strønstad when the whales were close enough. A total of 6840 photographs were taken from the primary photo-ID cameras. The tagged whale was always photo-identified. The primary objective of photo id data collection is to indentify if any animal or group of animals are exposed repeatedly. However, photo-identification of the tagged whale proved useful for in-the-field analysis of what was going on with the tag:

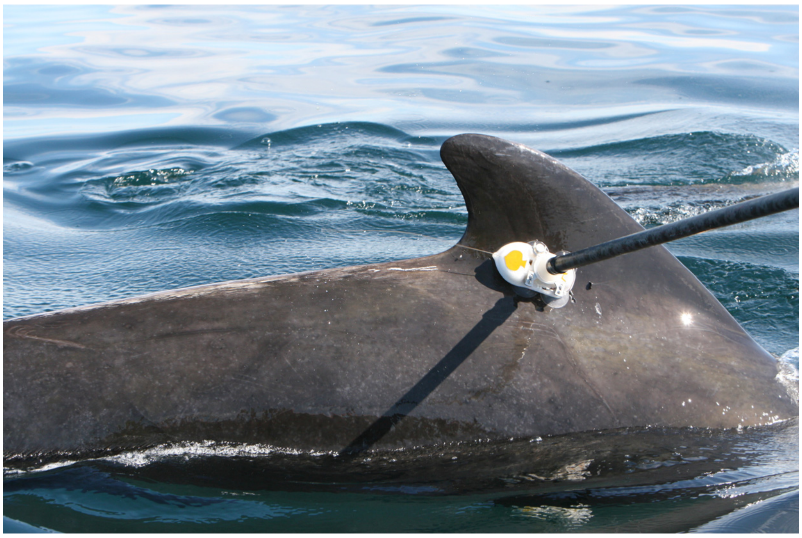

Figure 4.17 Identification photograph of tagged pilot whale tagged on May 17th (gm137a) taken during tag deployment (photo: Sanna Kuningas).

In the final sperm whale experiment, time was running out, so the tag needed to be recovered efficiently. Subject sperm whale sw160a was photo-id'd upon tagging (Figure 4.18 left), and followed successfully for the entire experiment. Some minutes after the scheduled release time, the acoustic tracking team predicted the tagged whale was coming to the surface 45° to starboard. In fact, a whale did surface in precisely that location, but no beeps were heard from the tag. We positioned ourselves for a 2nd photo-id shot when the whale dove (Figure 4.18 right). Inspection of the two photographs was accomplished on-board within minutes, showing a clear match. This enabled us to predict that the tag was off, and that we should leave one of the two vessels at the location of the previous dive. In fact, the tag did float to the surface from 800m depth, which took 30 minutes. The tag was then efficiently recovered and the data secured.

Figure 4.18 Identification fluke shot of sperm whale tagged on June 09th immediately after tag-attachment (left), and just after the tag had detached at depth (right). (Photo: Ricardo Antunes and Allan Ligon).

Another example of photo ID as a tool and benefit during difficult tracking conditions was during the tracking of tagged killer whale oo134a on 23 May. The tag slid on the animal and we had less and less VHF beeps from the tag. Two sub-groups of killer whales merged and divide during the 13 hour of tracking before the tag released, and due to photo ID we were confident of tracking the right animal. About 9 hours after tag attachments and 4 hours before we could safely recover the tag, we confirmed this by sighting the tag and taking a photograph.

Figure 4.19 Identification shot of killer whale tagged May 23th immediately after tag-attachment (left), 2 hours- (middle) and 9 hours (right) after tag-attachment (photo: Paul Ensor).

4.10 CTD measurements and transmission loss modelling

After every sonar exposure experiment, CTD profiles were taken from Sverdrup using SAIV SD-200 CTD-profiler in the transmission path of the experiment. A total of 18 sound speed profiles were collected. The number of profiles taken in relation to each experiment varied from 1-5 depending on the expected complexity of the oceanographic conditions (near shore areas, depth current etc). The standard procedure was to do a profile in the position of the closest point of approach of the tagged animal from each run. In addition to CTD's, 13 temperature profiles were taken using Sippican 77 XBTs. The XBT was partly taken during the sonar experiment runs and partly during survey phases to estimate marine mammal detection range of the acoustic arrays.

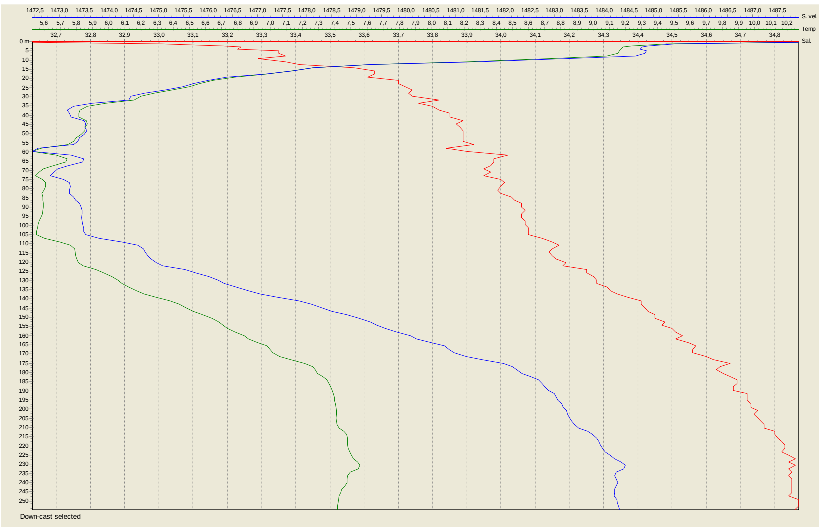

Figure 4.20 CTD (station HUS05) from LFAS exposure experiment on pilot whales May 18th. Red line is salinity, green line is temperature and blue line is sound speed. The fresh and warm water at the surface, and the layer of cold water under the surface layer creates a sound speed minimum at 40-100m depth. The sonar source was towed within this layer at 45m during the experiment.

During the sonar experiments the acoustic tag (Dtag) makes it possible to measure the received level on the tagged animal. The CTD's are used as input in propagation loss models to describe the acoustic surroundings of the animal. This will in turn be used in analysis of horizontal as well as vertical avoidance strategies of the exposed animals. Figure 4.20 shows an example of a CTD-profile of a pilot whale experiment, and figure 4.21 shows the corresponding estimated sound propagation using the acoustic model LYBIN developed by the Royal Norwegian Navy and FFI. In this example there is a sound channel at the depth of the source (45 m) which creates a sound shadow area close to the surface. Figure 4.3. shows that the animals mainly stay in this vertical shadow at the surface during the exposures.

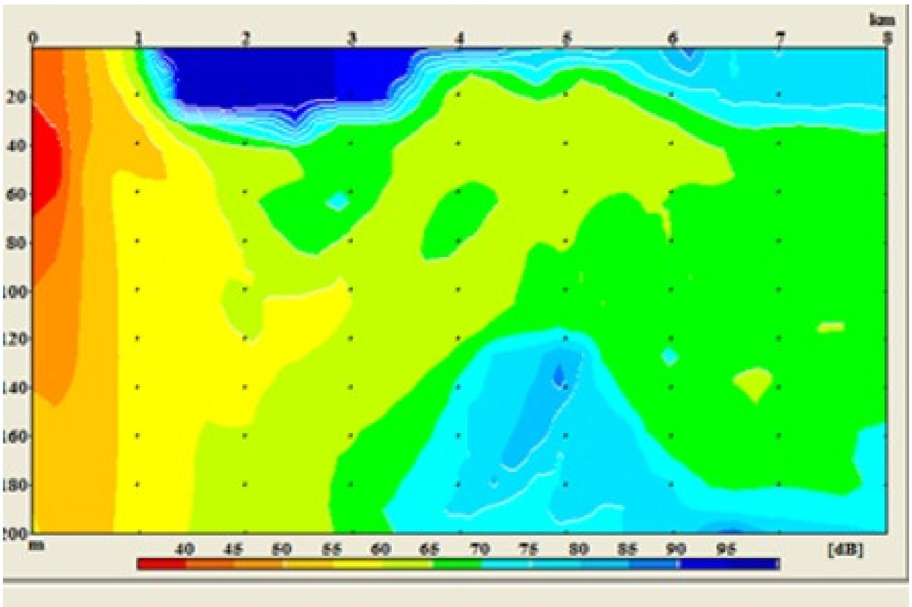

Figure 4.21 Transmission loss estimate from the acoustic model LYBIN using CTD HUS05. The source depth is in the sound channel from 40-100m, thus the sound mainly propagates in this channel. This creates a sound shadow near the surface.

4.11 Experimental design and pilot test to study effectiveness of Ramp up

One of the tasks of the trial was to do pilot experiments to establish an effective and feasible protocol to study the effectiveness of ramp up in mitigating impacts to marine mammals. A suggested protocol is described in the cruise plan (Appendix C) and on June 06^{th} we decided to tag a pilot whale in a group which had been subject to the regular exposure protocol the day before. An animal in this group was already tagged as the tag deployed the day before did not release until the next day. The suggested protocol implied that the tracking boat should track the focal group containing the tagged animal as normal, while the source ship should move in and move in parallel with the animals between the source ship and tracking ship at a distance of 300-500 m from the source ship when transmission starts. Course and speed of the animal and both ships should be steady, and as soon as transmission starts the source ship will no longer change their course or speed. The idea was that any change in distance from animal to source should be caused by the animals change in course and speed. This way we could compare the total exposure level on the animal during ramp up compared to initial full power transmission.

During the ramp up experiments we conducted three approaches, trying to follow the original protocol. A silent approach with the source in the water but without transmitting, a 10 min ramp up from 152-214 dB with 2 min of full power transmission, and finally an approach with 12 min of full power transmission. All experiments started when the source ship was 300-500m from the animals moving in parallel at the travel speed of the animals (2-3knots).

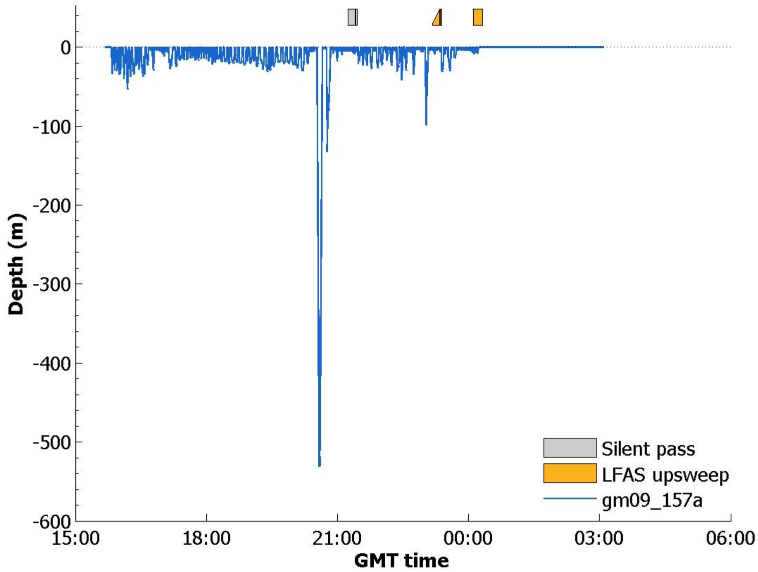

Figure 4.22 Dive profile of pilot whales in the ramp-up experiment. The shapes above the profile represent the exposure condition. Triangle-shapes are the ramp-up period.

We are very content that we got a chance to evaluate this protocol, as it proved to be very unwieldy and has helped us to develop a much more simple and elegant protocol. From the perspective of the tracking boat, the need for the source boat to be on one side of the whales often led to the observation boat being on a non-optimal side of the whale for tracking. One side is generally optimal depending on the sun's position, the side of the animal to which the tag is located, or both. Thus, the tracking boat's effectiveness was often compromised at the critical point when the source ship was approaching to start the ramp-up exposure. From the perspective of the source boat it turned out to be very difficult to move into position, and to keep a steady geometry between the source and the animal prior to exposure. The speed had to be very low in order to keep the geometry between animal and ship constant as a starting point. This slow approach has the disadvantage that the source ends up at 80-90m depth and when the animals are that close, they could easily be in an acoustic shadow zone. In addition, it might be argued that the operational relevance of such an approach is limited as naval ships rarely move at this speed. The most important grievance is that whereas we never see a strong reaction of pilot whales to the approaching source ship during the regular silent control run, the animals seemed more reactive to the situation of two ships being very close and moving slowly at their own speed. The animals exhibited rapid changes in direction which violates the requirement of a steady geometry between the source ship and the animal upon start of transmission. Even though we managed to execute three approaches (silent, ramp up and full power) in accordance with the protocol, it was very difficult, and we think it will be very difficult to reproduce experiments in a consistent way. Based on this analysis we choose to reject the current experimental design and have worked to develop a simpler and more elegant design.

5 Recommendations

This cruise report is published immediately after the cruise without any time for analysis of the collected data. Thus, it is too early to give scientific recommendations on the need for mitigation procedures during naval sonar exercises or future data needs based on the results from this trial. Such recommendations will be published in due time. The recommendations below are therefore focused on operational and methodological improvements to be considered for similar research trials in the future.

5.1 General

- Establish a more extensive command-and-control system to assist in the execution of the exposure experiments. This should include a data link where all relevant acoustic and visual information about the animals as well as the positions of the vessels and tag boats are visualized in one display.
- The ADF-box (Analog Direction Finder) indicates the direction to the VHF transmitter of the tag, and is a critical tool for following a focal tagged individual. We had several moments of deep concern when our ADF system was not working well. Though these proved to be easily fixed, the longer term problem exists that there is no manufacturer of the currently used ADF box. Therefore, we strongly recommend that users of this technology enable production of an ADF system that can be made available. Such a system could have substantial performance improvements over the current box, which is based on outdated analog technology.

5.2 Tagging

- Tag-boat 1 is very effective, but the lifting frame should be modified and low attachment point installed in its place. A driving consul should be installed which is high enough for the driver to be able to stand. This will vastly improve the visibility for the driver, which is a key factor for effective tagging.
- In some cases, the Dtag slipped low on the tagged animal, which made VHF tracking difficult. This risks the ability to accomplish an experiment, and increases risk of loss of the Dtag if the animals cannot be tracked using visual and acoustic methods and moves too far away for signal detection once the tag falls off. Therefore, it would be very helpful to develop a long-range VHF only tag. It should be robust, deployable using the ARTS system for long range, and have flotation for reuse. Cost should be low so they can be expendable if necessary.

5.2.1 ARTS development

- The major areas of improvement for the ARTS are flight stability, precision placement, DTag strengthening and last minute fine tuning of pressure regulation. For flight stability the arrow shaft can be built of much lighter carbon fiber tubing and the front end of the arrow can be re-designed to be more aerodynamic. A "float" section could be added in the front of the arrow, behind the robot, to allow for water surfing when the tag hits the water prematurely but still has enough inertia to place the tag on the animal.

- For more precise placement on the animal it is necessary to be able to absorb some of the initial impact on the side of the animal, which is the major reason for the tag skidding and sliding just after contact. This problem can be easily solved by adding springs on the robot arm. The springs will absorb some of the excess energy on impact and also improve the angle of attack of the Dtag on the animal. The robot should also be built in titanium rather than aluminum for better strength and durability. The forward counterweight on the robot should also be more flexible.
- The Dtag needs some reinforcement in the area where the suction cup stems are attached to the faring, and also the faring itself could be built of slightly thicker polyethylene, to ensure that the Dtag retains a sufficient buoyancy reserve.
- Sometimes the animal can very quickly approach the tagboat, and the tagger might have a preset launch pressure on the ARTS system which is too high for the closer position of the animal. In this case the Dtag will have too much energy on impact, causing skidding and sliding on the skin of the animal. This situation will likely result in a bounce-off or bad placement, making the tag very hard or impossible to radio/visual track. This problem will be partially solved by the modified robot with springs that will dampen the excess energy. An additional adjustment on the ARTS system that will quickly release one bar of pressure (or add, in case the targeted animal surfaces at a longer distance from the tagboat than estimated) would be very helpful.

5.3 Passive acoustic monitoring

- Data link of acoustic detections between the passive acoustic arrays on both ships.
- A "real world TMA" could be helpful. This means that the acoustic tracks are directly translated to a geographical location, and can be plotted on a navigation chart or any other GIS system. This can eliminate left-right ambiguity quicker, and will support the navigation during exposure experiments.
- The directional hydrophone ("Pickle") used off the tag boat was very effective for tracking sperm whales when underwater. A similar system that could be used for killer whales and pilot whales would improve the boat's ability to stay close when the animals are on a dive. The system should be very robust, towable to moderate speeds, and extremely simple to operate. We propose a spherical baffle shape containing 3 hydrophones, a strong metal mount from the front of the boat, and a simple switching box to headphones should be effective.

5.4 Group behavioral sampling

- Parameter selection is a very important preparation for group behavioral sampling, the number of parameters should be limited, but sufficient to record the changes in surface behavior observed. For the selection made for the 3S-2009 cruise, we recommend to interchange surface synchrony for milling index in Logger, and to add the parameter behavioral type to the data collection.

- The sampling rate for pilot whales, killer whales and sperm whales should not be higher than used in this study, or be lower than 1/5 minutes (outside of dives).
- *Logger* or similar software is a good and efficient method for behavioral data collection. The protocol combined with tracking ensures continued and structural collection of data. It is advisable to keep a paper record next to the *Logger*/software to be able record additional parameters, maintain some flexibility when needed and to keep an overview of behavioral activities taking place over the course of several hours. For example, for sperm whales, surfacing synchrony was sampled (on paper) by the fluke times of the different individuals, a function not built in *Logger*, as it was not expected to encounter sperm whale groups.
- The format of Logger could be simplified. At present, parameters are represented by boxes spaced at a certain distance, alternated with tick-boxes. It would facilitate data-logging if the parameters would be represented more in the format of a spreadsheet, whereby the data recorder has to make less use of the mouse or tab to switch between the different fields. Also it would give a better overview.

References

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Sheldon-Robert, M.K., S.P. Beerens, F.P.A. Lam (2008) *The Delphinus array for passive marine mammal detection.* Proceedings MAST conference, Cadiz.

Visser, F, P Miller, FP Lam, P Kvadsheim and P Tyack (2009). Group Behavioral Sampling Protocol in Behavioral Response Studies (in prep.)

Acknowledgement

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We are utterly thankful to all members of the 3S team, including collaborating partners and sponsors, who all contributed to our success. Special thanks to Peter Tyack (WHOI), Nina Nordlund (FFI) and Michael Ainslie (TNO), who were not on-board, but contributed significantly with advice and support in the planning and execution phase of the trial.
The Logger software was made freely available by the International Fund for Animal Welfare to support non-invasive conservation research.

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Appendix A Daily sailing tracks of Sverdrup (HUS), acoustic detections by Delphinus, and transmissions of Socrates during 3S-09

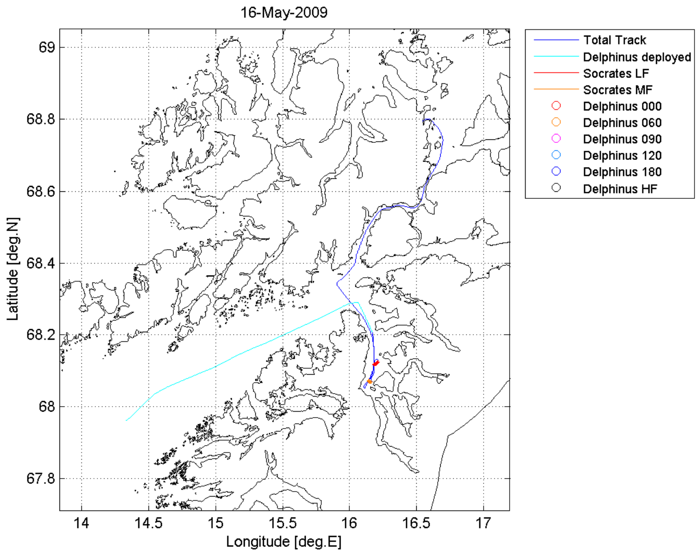

Figure 1: Sailed track of HUS for May 16; leaving Harstad and sailing south. Socrates transmissions are for exercise.

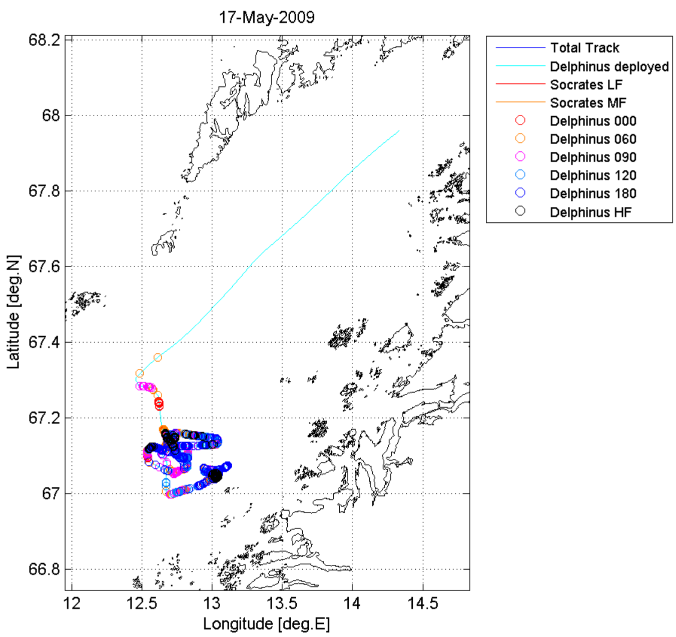

Figure 2: Delphinus detections of pilot whale vocalization along track of HUS on May 17. Tagging and baseline behavior.

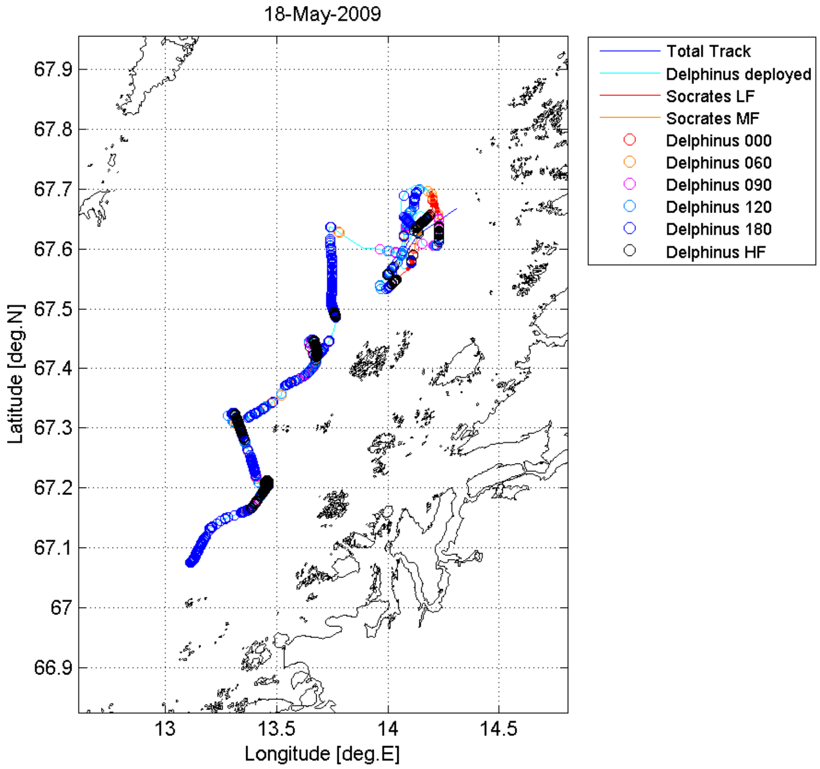

Figure 3: *Delphinus detections along track of HUS on May 18. Tracking, tagging and exposure runs with pilot whales.*

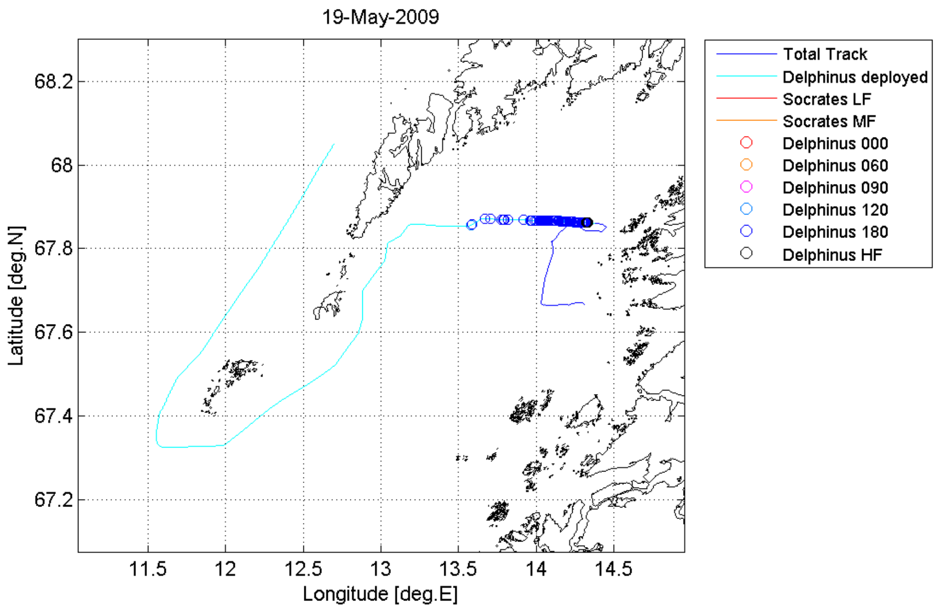

Figure 4: *Sailed track of HUS for May 19; leaving pilot whales area and Vestfjorden.*

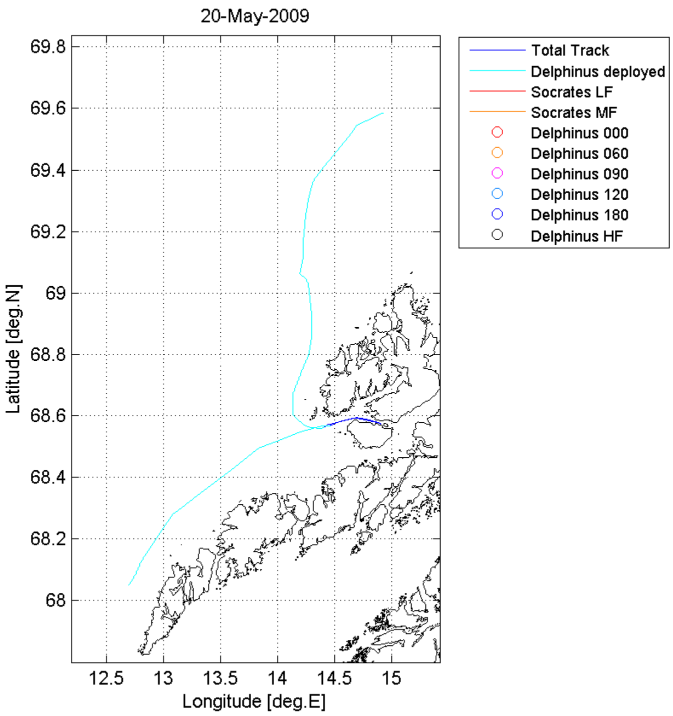

Figure 5: Sailed track of HUS for May 20, travelling north. During the day there was a short port call in Stokmarknes.

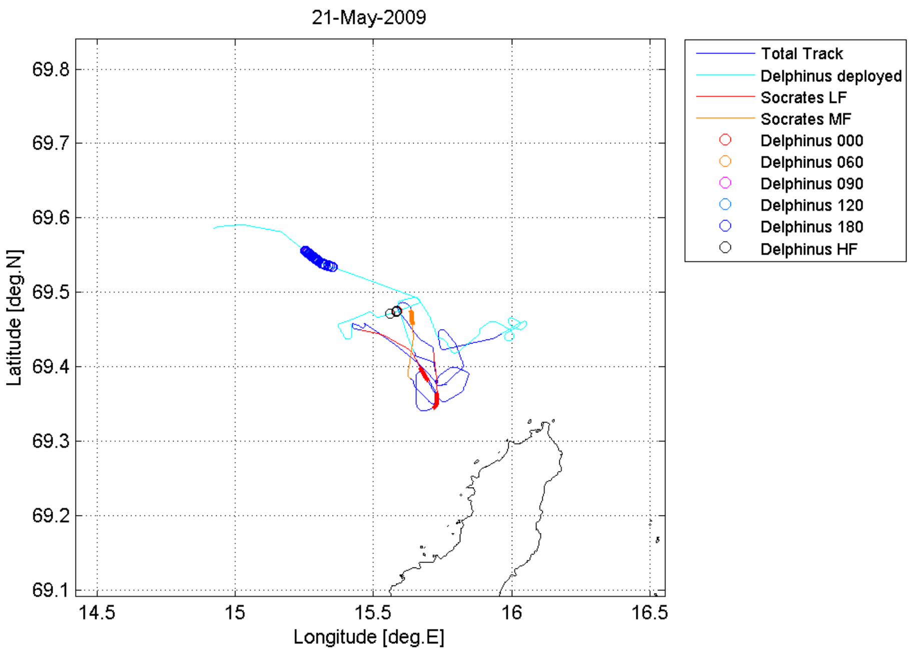

Figure 6: Sailed track of HUS for May 21. This was the last Delphinus operation with long tow cable (700m), until 05:54 UTC. Later this day the first CEE on a sperm whale took place.

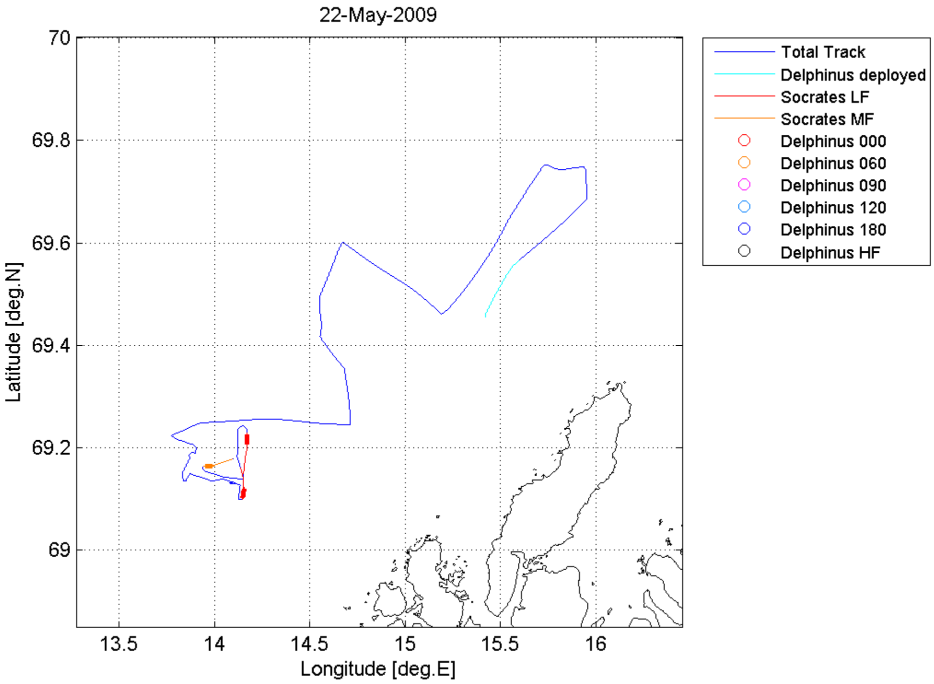

Figure 7: Sailed track of HUS for May 22, with 2nd CEE on sperm whales.

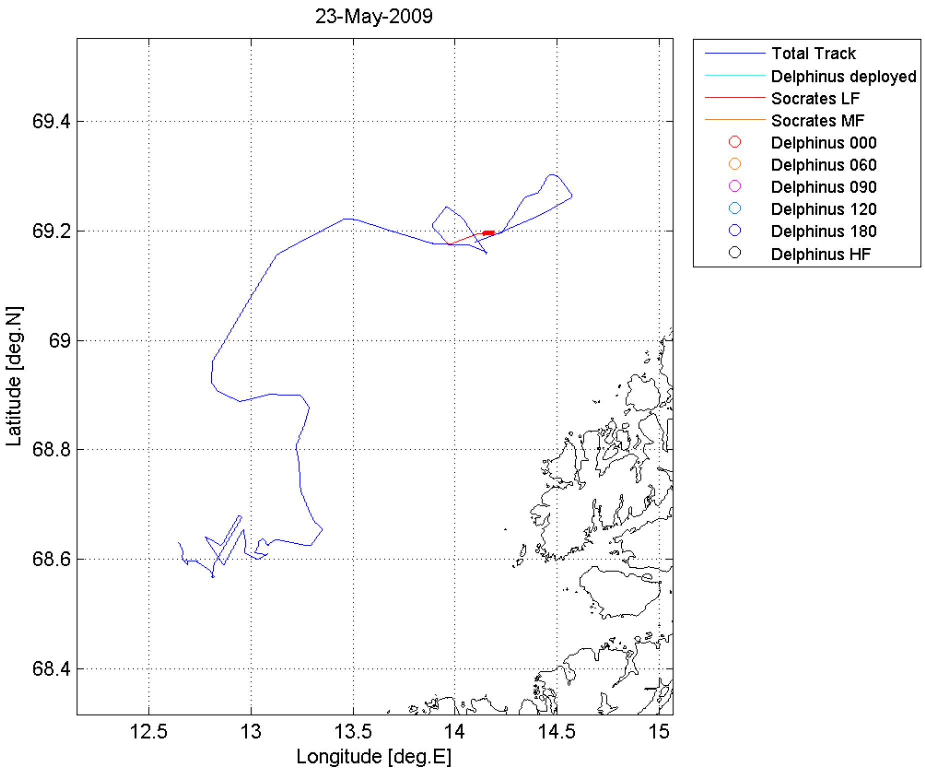

Figure 8: Sailed track of HUS for May 23, with last part of 2nd CEE on sperm whales and tagging attempts of Killer whales further south.

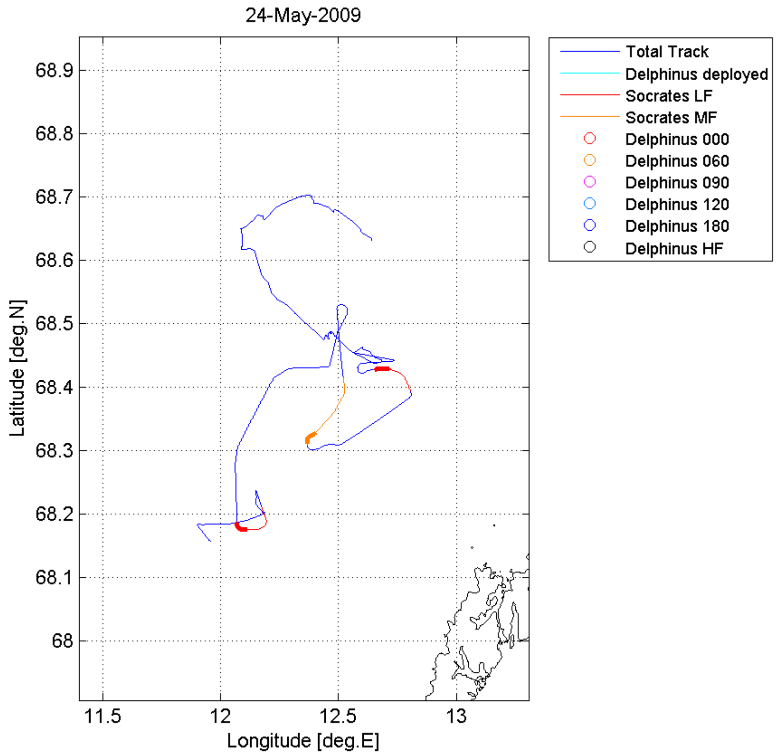

Figure 9: Sailed track of HUS for May 24, with CEE on Killer whales further south.

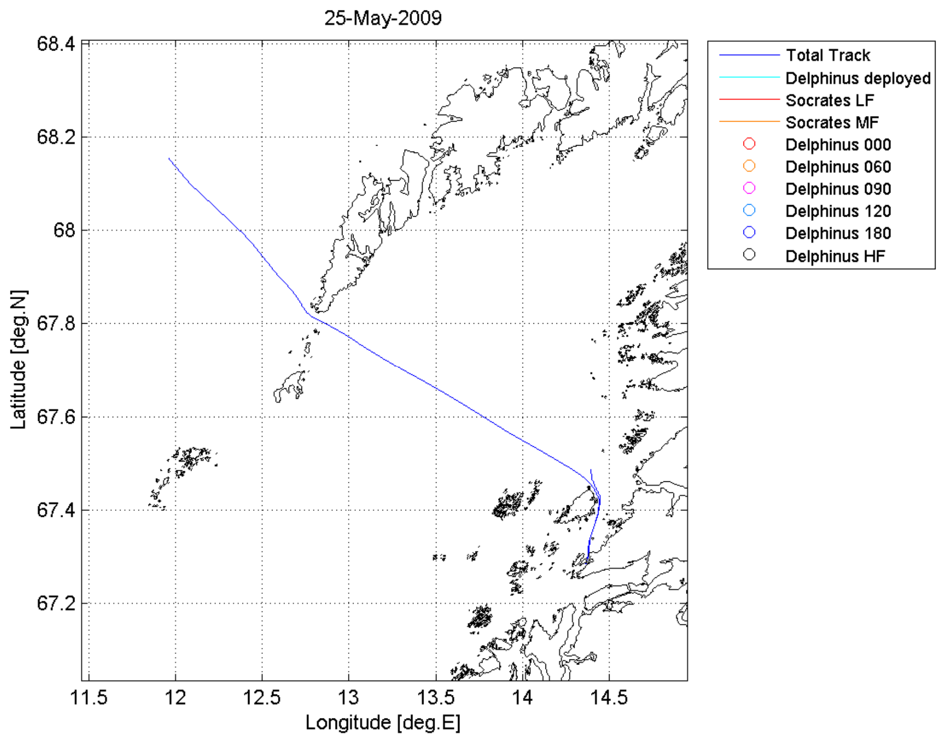

Figure 10: Sailed track of HUS for May 25 with port call in Bodø, and start of sailing north to Harstad.

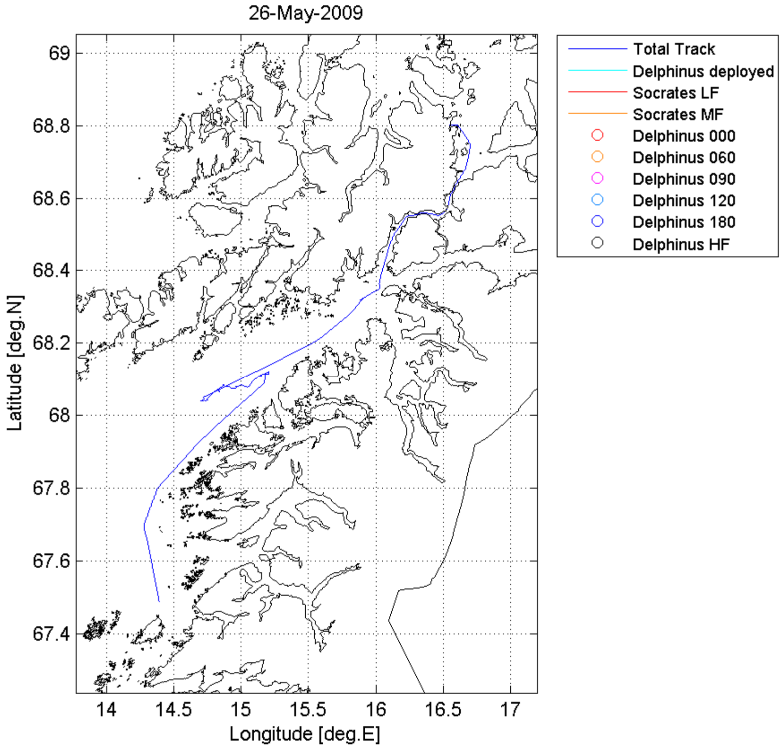

Figure 11: Sailed track of HUS for May 26: transit north to Harstad with tagging attempts of pilot whales underway.

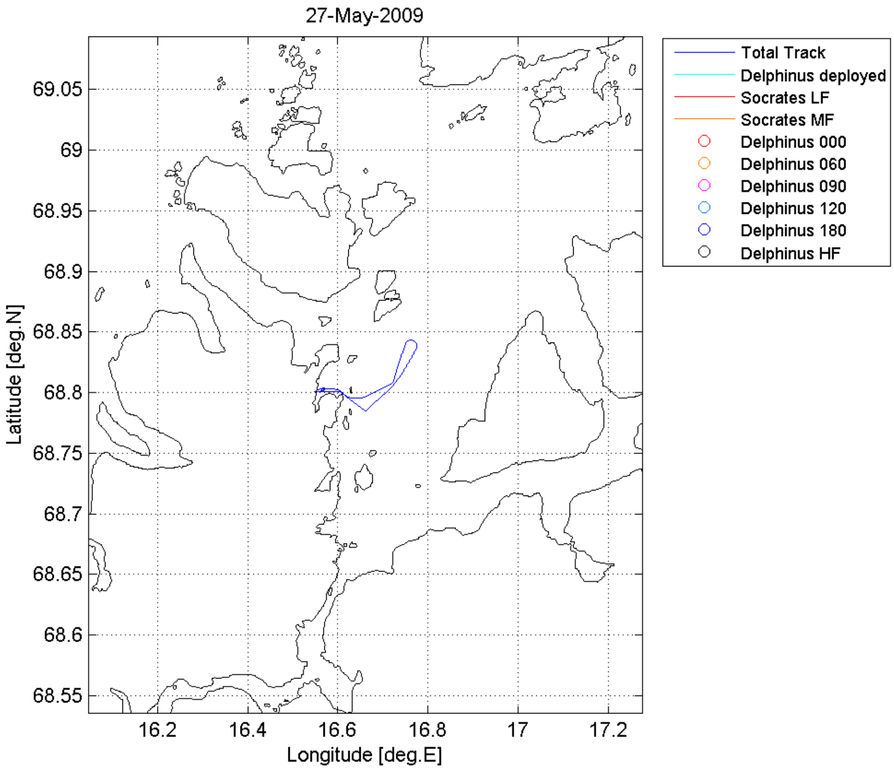

Figure 12: Sailed track of HUS for May 27 showing engineering test during port call in Harstad at day of crew change.

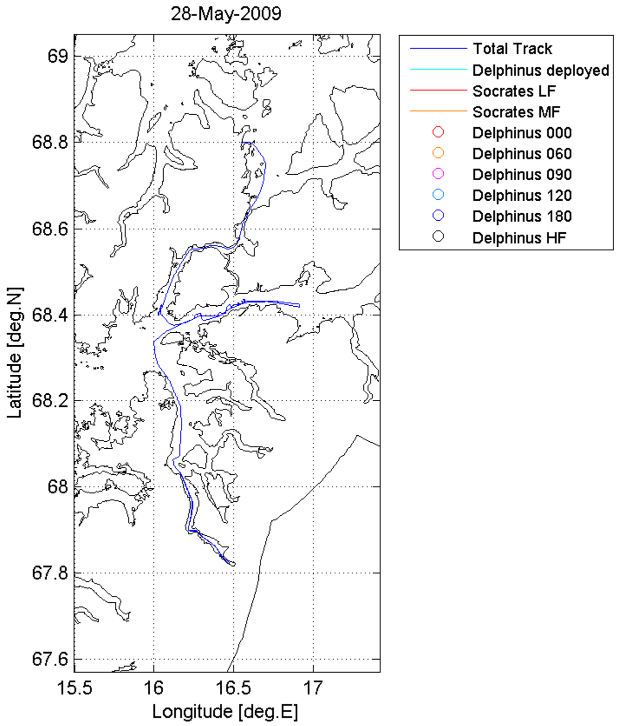

Figure 13: Sailed track of HUS for May 28; leaving Harstad after crew change, first test of ramp-up protocol and visual survey after final test (that failed) of repaired tow cable. During the survey SE the Swedish border was approached.

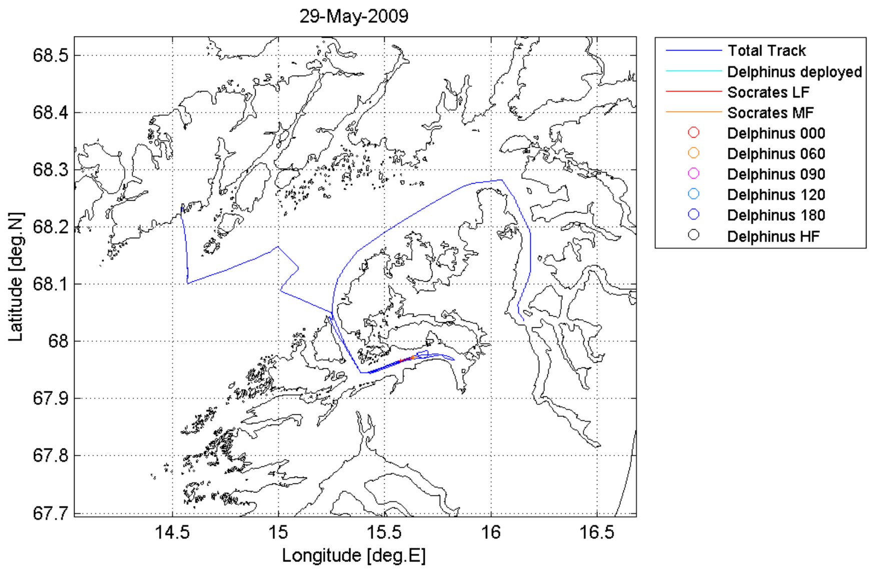

Figure 14: Sailed track of HUS for May 29 showing the completion of visual survey and testing the silence of silent transmission with tagged Socrates. After that Vestfjorden was crossed to join M/S Strønstad in Svolvær to shelter for bad weather.

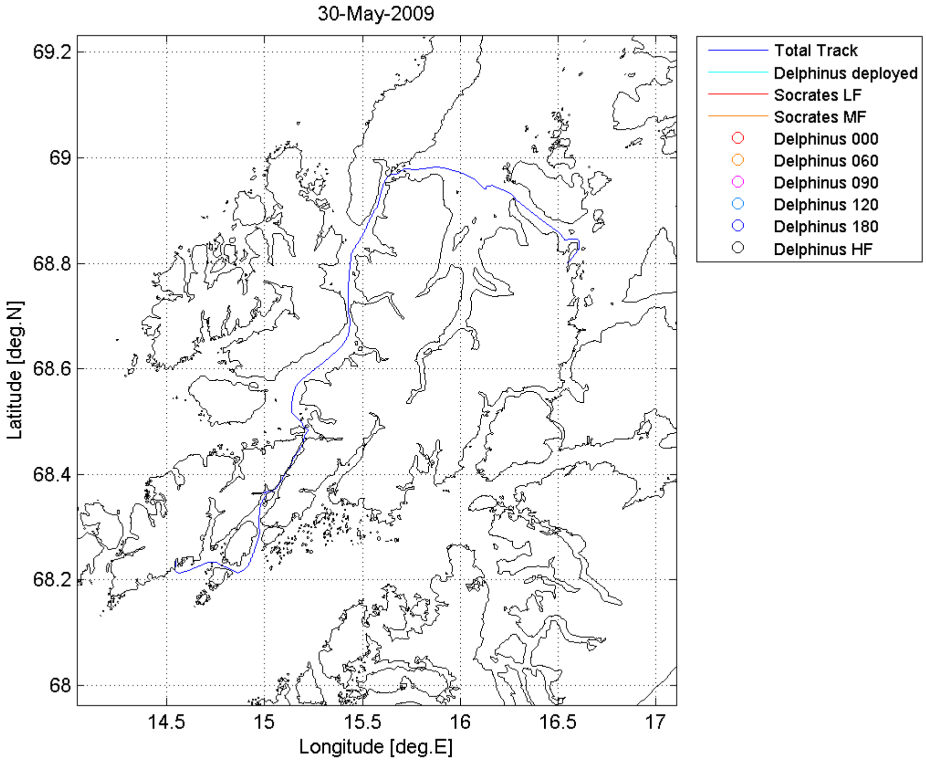

Figure 15: Sailed track of HUS for May 30 showing the transit from Svolvær to Harstad where the arrival of the other Delphinus tow cable was awaited.

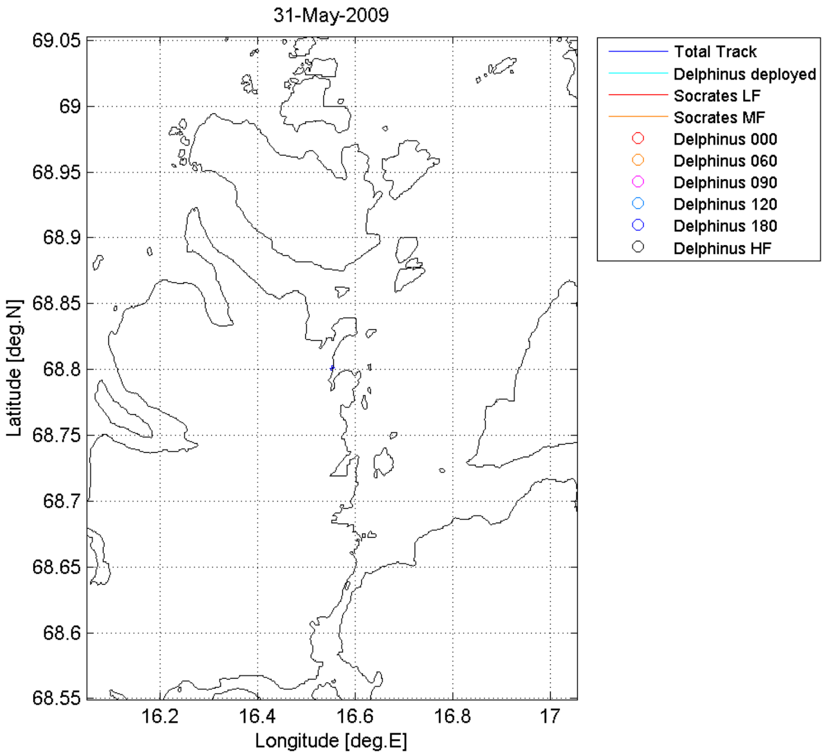

Figure 16: Sailed track of HUS for May 31. HUS did not leave Harstad to install the other Delphinus tow cable and to shelter for bad weather.

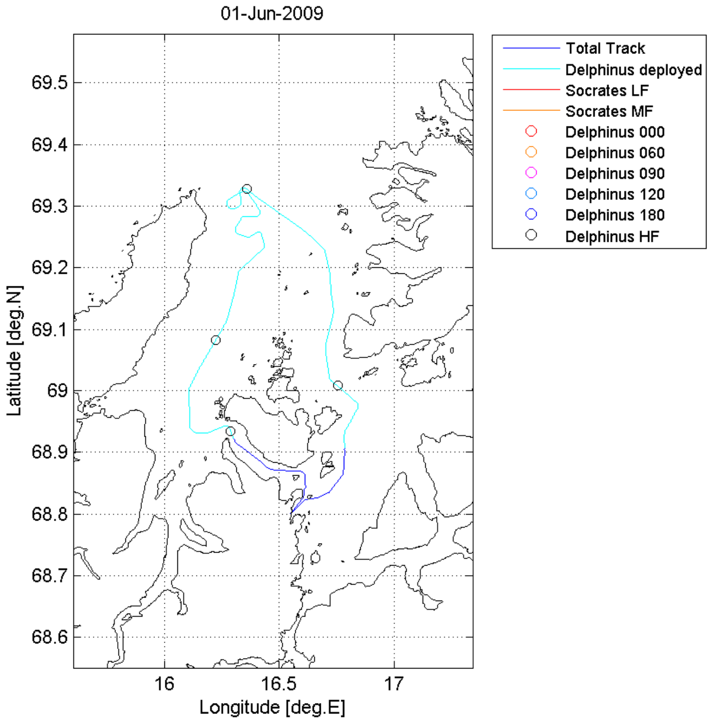

Figure 17: Sailed track of HUS for June 01. Surveying Andfjorden and Vågsfjorden clockwise during borderline weather conditions. The detections along the southernmost part of the track are probable porpoise clicks.

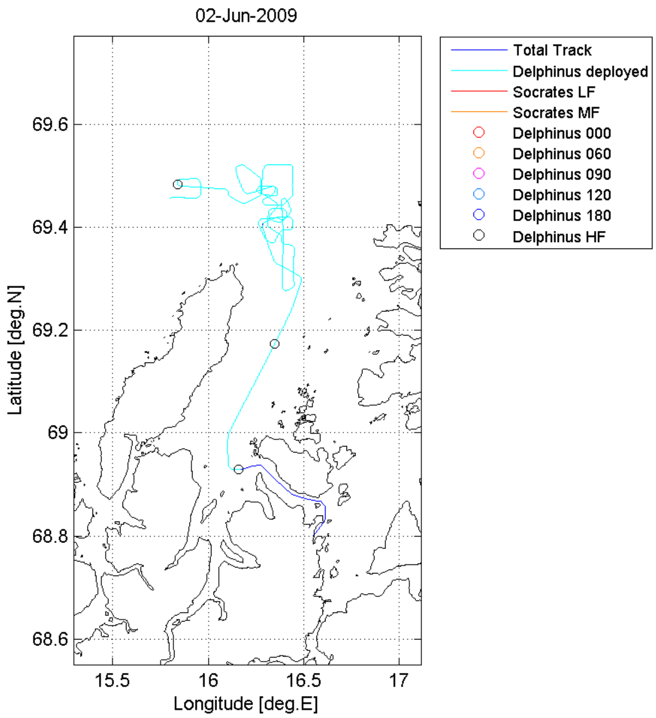

Figure 18: Sailed track of HUS for June 02 with tagging attempt of a sperm whale near Andenes. The detections along the southernmost part of the track are probable porpoise clicks.

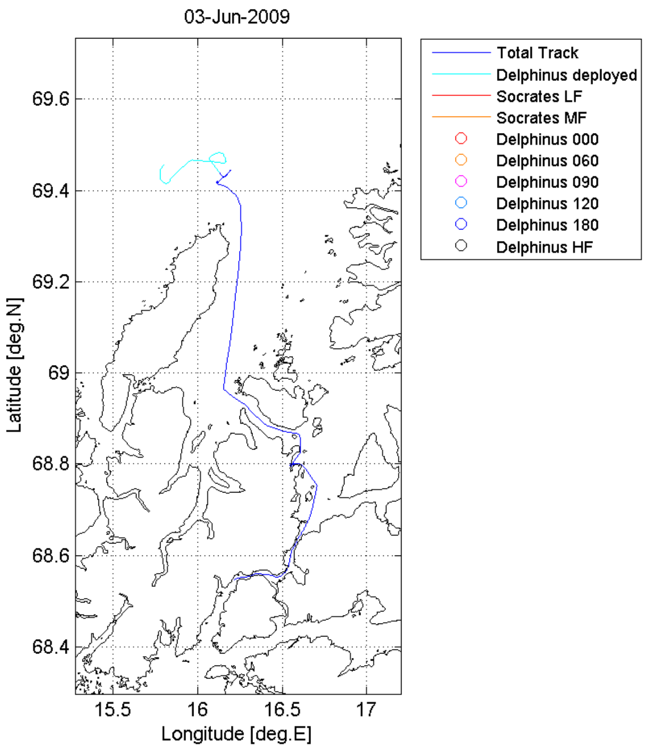

Figure 19: Sailed track of HUS for June 03 showing the tag retrieval near Andenes and transit back to Harstad.

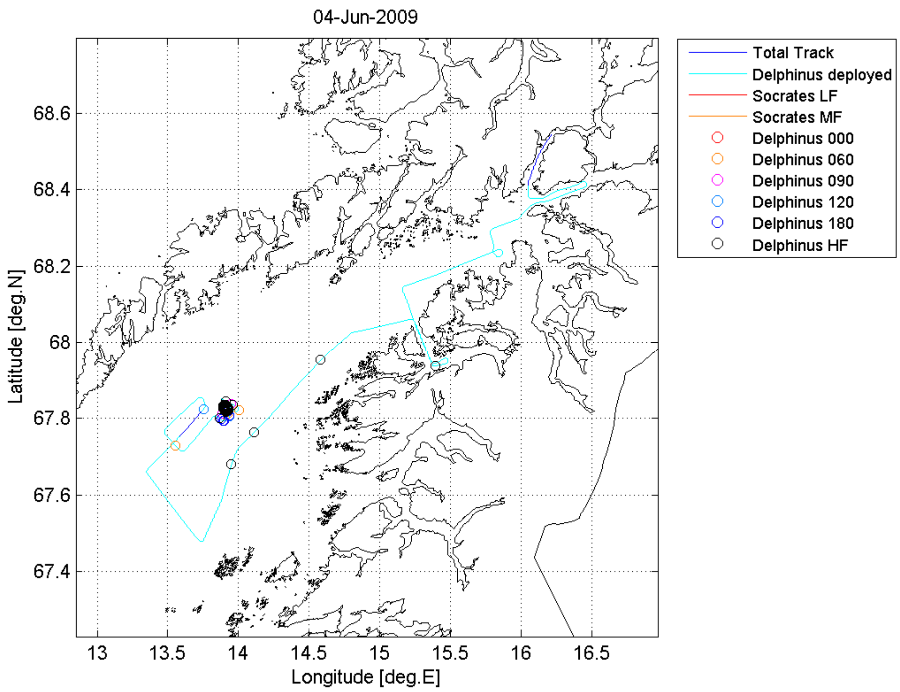

Figure 20: Sailed track of HUS for June 04, entering Vestfjorden for survey and detecting pilot whale vocalizations.

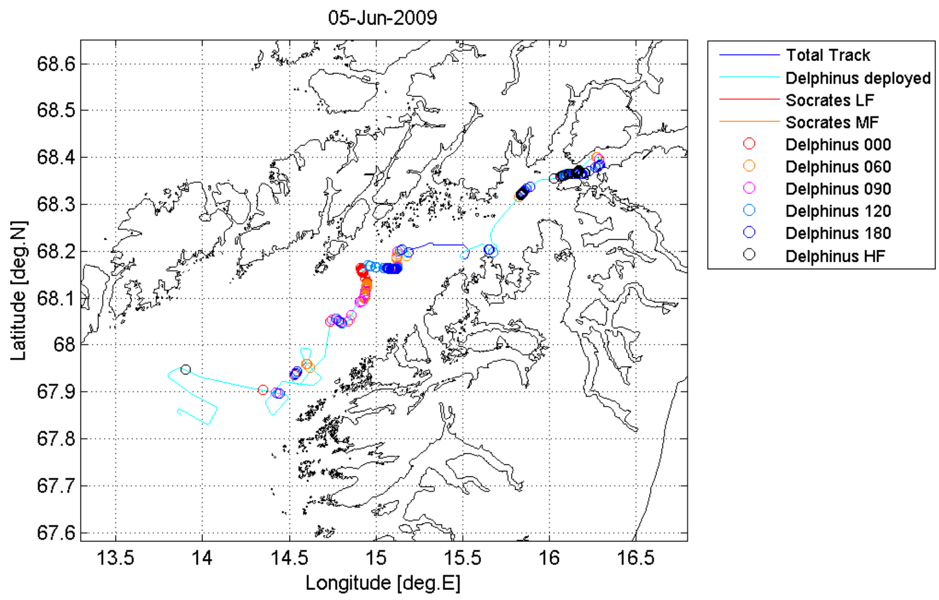

Figure 21: Sailed track of HUS for June 05 with more pilot whale detections and tagging attempts. The group with tagged animal was migrating NE into Ofotfjorden.

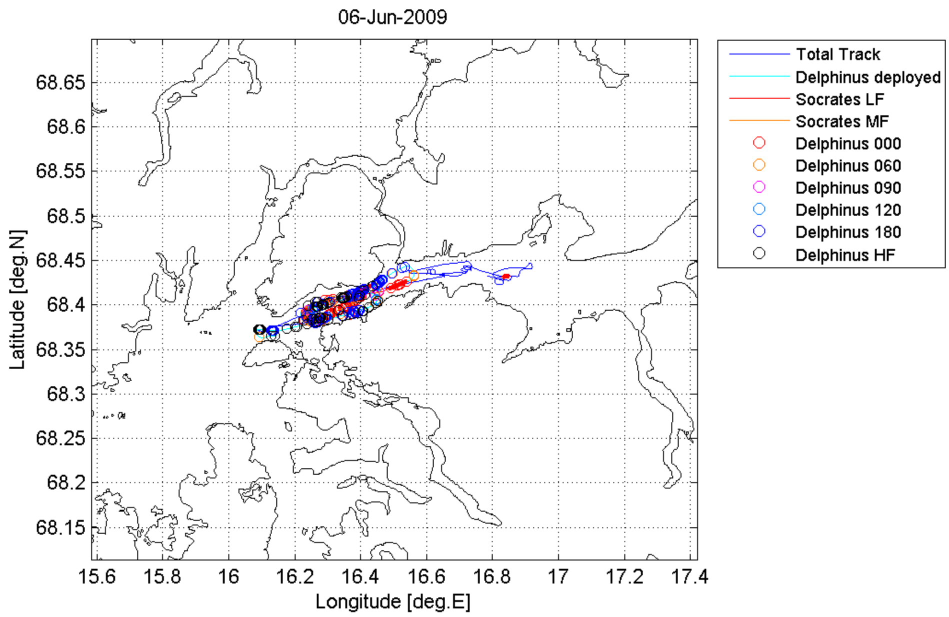

Figure 22: Sailed track of HUS for June 06 showing CEE on pilot whales in Ofotfjorden.

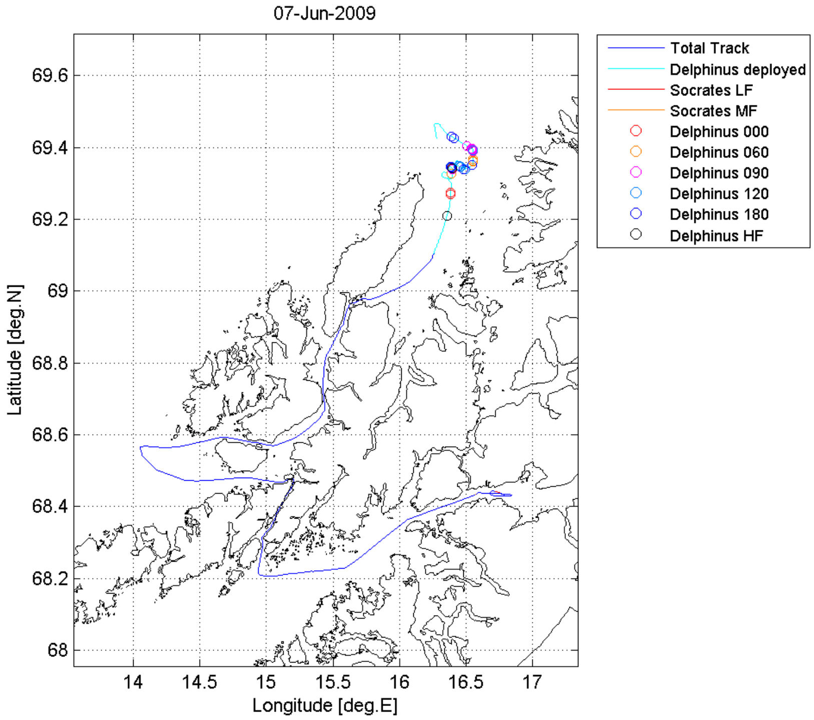

Figure 23: Sailed track of HUS for June 07; transit westward from Ofotfjorden to finally end up in Andenes area. Underway it appeared that weather conditions were not good enough to sail out west directly. Many species were found at northernmost part of Andfjorden: pilot/fin/killer/sperm whales at the same time at some moment.

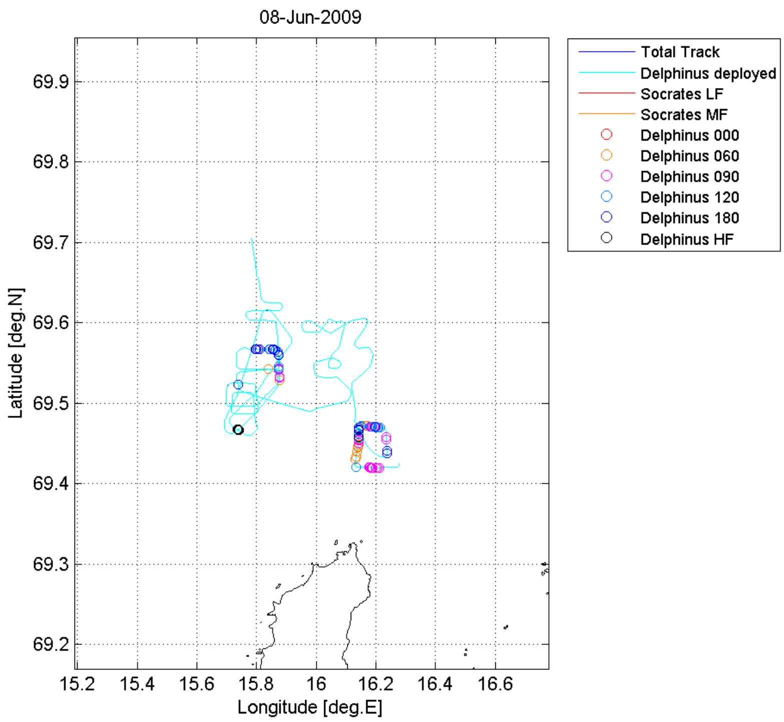

Figure 24: Sailed track of HUS for June 08 showing sperm whale tracking north of Andenes.

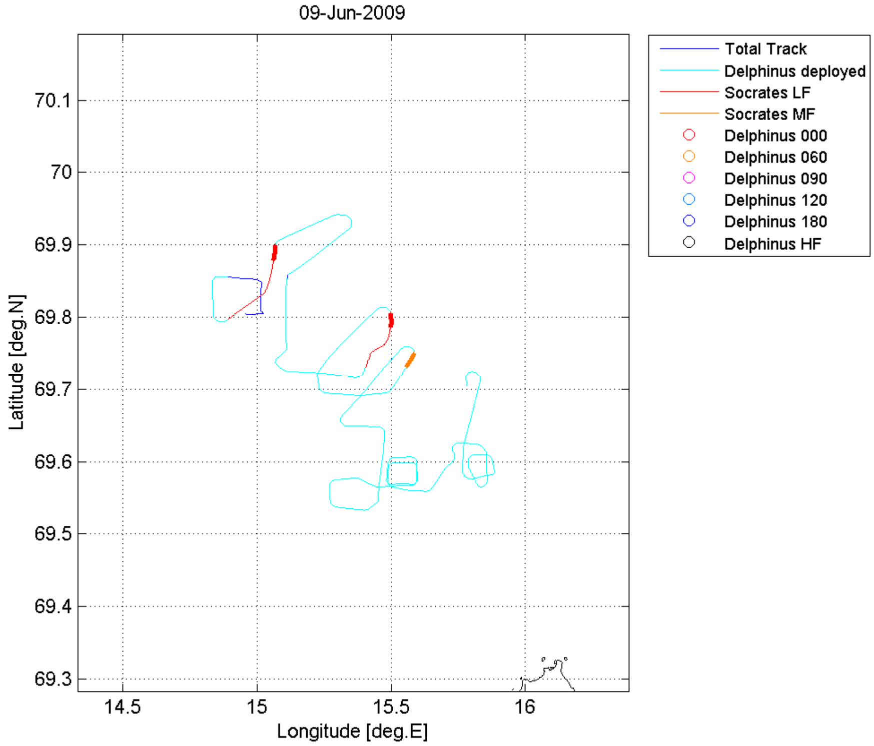

Figure 25: Sailed track of HUS for June 09 showing the navigation for pre-tagging tracking of individual sperm whales and transmissions for CEE on sperm whale. At the (very) end of the day the Delphinus array was recovered in order to take some CTD measurements.

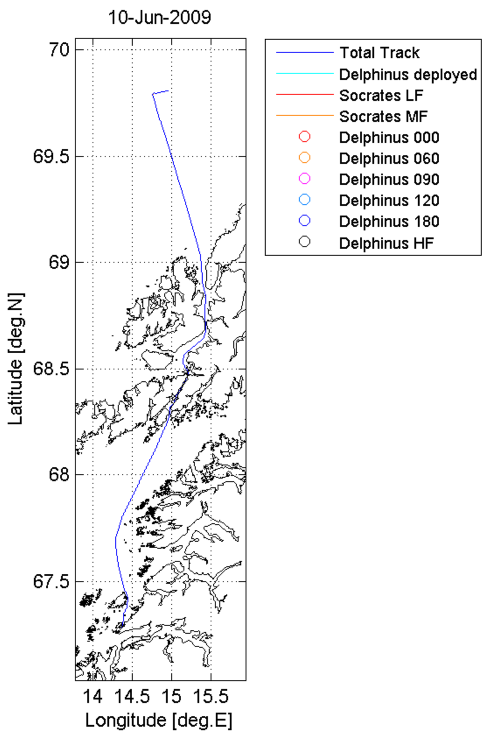

Figure 26: Sailed track of HUS for June 10, transit southward to Bodø.

Appendix B Data inventory

B.1 Data inventory FFI

Folder	Subfolders/files	Content	Data size
Daily work plans	1 .doc file for each day	Daily plans	10MB
Cruise leaders summary	1.doc file	Cruise leaders daily report	500kB
	1.doc file	Summary of events	
	1 .doc file	Weather report	
Cruise plenum meetings	.ppt files	Briefings by cruise leader	1MB
	1 .doc file	Notes from briefings	
CTD	.xls file	CTD log	11MB
	Raw data CTD files	Raw data CTD files (SD2) and software to read and convert files. (SD200W.exe)	
	CTD reports	CTD curves and maps of each experiments in .doc files	
	Lybin runs	Transmission loss model output in .doc files.	
HUS GPS AIS log	One text file for each day	Text files with GPS and AIS log from HUS.	200MB
3S event log	One text file for each experimental day	Text files with logs of events during experiments recorded from the bridge of source ship	100kB
3S cruise plan	3S cruise plan .doc and .pdf	Cruise plan	60MB
Pictures	Paul Ensor Lars Photos for Petter_Sanna		40MB
Videos	Lars (sperm whale tagging) Paul Ensor (pilotwhale tagging)		32MB
Tagging	.xls file of Running event	Tag Boat2 logg	2MB
	.xls file of ARTS log	Log of Tagging Attempts	
	Pdf of tag boat 2 Tagplatform	Drawings	

B.2 Data inventory TNO

Folder	Subfolders/files	Content	Data size
BB-tracks-screendumps	Leg 1; Leg 2 Images	Screenshots of broadband (BB) tracking display. Roughly every 25 minutes a screendump is generated, so that all tracks can be traced back.	44 MB
Delphinus_detections	File folders of cee001-cee036 Wav-files and images of spectogram. Word document with run numbers	All signals that passed the threshold of transient detector for Delphinus data. Selection of sounds in folder ”belle_wav”. Sounds are classified in 4 groups. June 9th not classified as of yet.	40 GB
Documents	Collection of text and xls docs, folders	Different documents, including digitized log-sheets and some array specifications	84 MB
GPS_log	Matlab and ascii docs	Position data of Sverdrup for entire trial. NMEA format (ascii) and matlab scripts to convert.	426 MB
Plot_tracks_leg1 Plot_tracks_leg2	Images of tracks Matlab software to generate tracks.	Track figures for 1st and 2nd leg. Images of all sailed tracks by H.U. Sverdrup II, with overview of tracks for both legs and tracks day by day. Systems deployed, SOC transmissions and bio/sperm detections are depicted.	106 MB 131 MB
Screendumps	Png files of screendumps	Examples of processing screens on board	19 MB
Socrates_logs	MFAS LFAS SLNT folder logs	Logs of all tranmissions Most data is hydrophone data that could removed.	17 GB
XBT	RDF files of XBT’s	13 temperature profiles	140 KB

B.3 Data inventory SMRU

Folder	Subfolders/files	Content	Data size
3S2009 Tag-data	One folder for each species, one for the calibration test from day 1, and one for refrigeration tests. Within each folder is a subfolder for each specific tag record	Dtag files	118 GB
3S_2009_natural sound playbacks	One subfolder containing the data for each natural sound playback. Another with the playback stimuli actuallused	Data and notes for natural sound playbacks Wav files	8.2 GB
Photos	Subfolders first for each leg Then sub-subfolder for camera used Then sub-sub-subfolder with date and photographer name	JPEG photographs of photo-id and tagging activities	27.2 GB
Stronstad_acoustics	none	Excel file with notes on songs recorded with Alesis Access database with acoustic notes	509 MB
3S-2009 LOGGER DATABASES	One subfolder has screen shots from Strønstad	Microsoft Access databases of visual fixes in Logger	118MB
Tag Boat GPS Data	Some raw unedited GPS tracks	Garmin software GPS data	640 KB

Appendix C 3S-2009 Cruise plan

3S-2009
Cruise Plan

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Project objective

Investigate behavioral reactions of several species of cetaceans to Low Frequency Active Sonar (LFAS) and Mid Frequency Active Sonar (MFAS) signals, in order to establish safety limits for sonar operations.

Cruise tasks

Primary tasks:

1. Tag killer whales, pilot whales and sperm whales with DTAG recording behavior, and thereafter carry out controlled exposure experiments (CEE) where the tagged animals are exposed to LFAS-, MFAS sonar signals and control experiment without any active transmission.
2. Test new techniques for deployment of DTAGs

Secondary tasks:

3. Carry out control experiments were tagged animals are exposed to a playback of killer whale sounds.
4. Carry out pilot experiments where tagged animals are exposed to LFAS or MFAS up-sweep and down-sweep signals.
5. Do pilot studies on cetaceans to investigate the effectiveness of sonar ramp-up.
6. Collect group behavioral data to investigate the effect of tagging
7. Carry out pilot CEE experiments on new species (minke whales, bottlenose whales).
8. Retrieve information about the acoustic environment of the study area by CTD or XBT measurements, and do acoustic propagation modeling.
9. Tag animals and record natural undisturbed behavior.

Collaborating organizations

The trial is a joint effort between:

- The Norwegian Defense Research Establishment (FFI), Norway
- The Royal Netherlands Navy (RNLN) and TNO, The Netherlands[*]
- Sea Mammal Research Unit (SMRU), Scotland
- Woods Hole Oceanographic Institution (WHOI), USA

[*] *The Netherlands Organisation for Applied Scientific Research (TNO) is through the NL MOD an indirect participating organization to this experiment. The performance of the tasks of NL MOD to this experiment will be carried out by TNO, as a contractor of NL MOD under the terms and conditions of the agreement with reference number 016.06.5105.02 (30 Oct.2007) (Internationale samenwerking Marine Mammal Protection Fase 2) between TNO and NL MOD.*

Sponsors

The research project is sponsored by;

- The Royal Norwegian Navy and the Norwegian Ministry of Defense
- The Royal Netherlands Navy and the Dutch Ministry of Defense
- Office of Naval Research, USA
- WWF, Norway

Sailing schedule

<u>May</u>

12. RV HU Sverdrup II (HUS) arrives Harstad at 0800. Installation of new MOB (tag boat 2) (hotel accommodation for everyone until May 14).
14. Start of 3S-09. MS Strønstad (MSS) arrives Harstad at 0800. Scientific crew embarks both ships. Installation of equipment start.
15. Continued installation. Joint planning meeting at 1030. Brief of crew at 1600. Joint dinner at 2000.
16. HUS and MSS starts transit to operation area at 1600.
    Inshore drill of operation and test of equipment.

17-26. Regular 3S-operation, no scheduled port calls.

27. MIDSAIL - HUS and MSS arrives Harstad at 0800 for crew change.
    Midsail meeting. Brief of new crew (hotel accommodation for off-going crew)
28. Transit back to operation area at 0800

28-31. Regular 3S-operation, no scheduled port calls.

<u>June</u>

01-09. Regular 3S-operation, no scheduled port calls.

10. HUS and MSS start transit to Bodø. Debrief.
11. HUS and MSS arrives Bodø at 0800. De-installation. Scientific crew disembark. MSS leaves Bodø at 1600 (hotel accommodation for scientific crew).
12. HUS leaves Bodø at 0200. Transit toBergenand Horten. Chief scientists and appointed personnel* stay on board to work on cruise report.
14. HUS arrives Bergen (at night).
15. HUS arrives Horten at 0800. Cruise report 90 % completed, end of 3S-09!

* Petter, Frans-Peter, Patrick, Lars, Fleur, Ana Catarina, Ricardo and Marijke

Main Logistical Components

R/V H.U. Sverdrup II (HUS)
Captain: Jonny Remøy/Bernt Skarsbø
Length: 180 feet
Max speed 13 knots
Crew: 7
Scientific crew: 14-15
Phone: +47 95138992 (Cruise leader)

Sverdrup will be outfitted with the Socrates source and operating software, Delphinus towed array system, ADS VHF tracking system, two tag boats with cradle for loading/off-loading. Fuel will be carried for the tag-boats. In addition Sverdrup will also carry a CTD probe.

Visual and acoustic search for marine mammals, VHF-tracking of tagged animals, operation of sonar source and preparation of the tags will be done from the Sverdrup. Sverdrup will also lodge 2/3 of the research team and be the command center for the operation.

MS Strønstad (MSS)
Captain: Jan-Gunnar Pedersen
Length: 94 feet
Max speed 10 knots
Crew: 5
Scientific crew: 7-8
Phone: +47 99431450

Strønstad will operate in close coordination with HUS. MSS will have a towed hydrophone array, ADS VHF tracking system, and CTD-probe.

Sverdrup and Strønstad also be outfitted with a radio link, for wireless network connection between them.

Visual and acoustic search for marine mammals, VHF and visual tracking of tagged animals, will be done from the Strønstad. In addition Strønstad will be the main observation vessel during exposure experiments on whales. Both tag boat teams will transfer to Strønstad during the observation- and experimental phase. Strønstad will lodge 1/3 of the research team.

Tagging boats

Both tag boats will be deployed from HUS, and thus both tag boat teams will be lodged on board HUS. Tag boat 1 is a four stroke outboard engine fibre glass work boat, and tag boat 2 is a water jet propulsion Man Over Board boat. Tag boat 1 is deployed using the ships derrick crane, and tag boat 2 is deployed using a dedicated davit. Tag boat 1 can be deployed and operate at sea conditions up to sea state 2, while tag boat two is a heavier more robust system which can be deployed and operated up to sea state 3. The tag boats will be launched when whales are sighted and weather permits tagging attempts. They will carry tagging gear (ARTS, pole, LK-tag and DTAG with necessary accessories), documentation sheets, GPS, camera and communication gear (VHF/GSM). Both tag boats will also be equipped with a mobile AIS system which transfers GPS data to Sverdrup continuously. The tagboats will have a regular crew of 3; a driver, a tagger and someone in charge of photo id/documentation.

Tag boat 1.

Tag boat 2

Sonar source – Socrates

During the controlled exposure experiments the multi purpose towed acoustic source, called Socrates II (Sonar CalibRAtion and TESting), will be used and operated from the Sverdrup. This source is a sophisticated versatile source that is developed by TNO for performing underwater acoustic research. Socrates has two free flooded ring (FFR) transducers, one ring for the frequency band between 0.95 kHz and 2.35 kHz (source level 214 dB re 1 µPa @ 1m), and the other between 3.5 kHz and 8.5 kHz (source level 199 dB re 1 µPa @ 1m). It also contains one hydrophone, depth, pitch, roll, and temperature sensor. All these sensors can be recorded.

Socrates can transmit one list of sounds (defined by wav-files) that can be repeated. For each wav-file the source level is specified. The first transmission can start exactly on the minute (using the GPS time). Changing the transmission scheme can be done (by hand) every minute. During the transmissions, the tow cable length of the Socrates can not be modified (the depth can only change when the speed is modified). During the towing of Socrates the ship has to sail between 3 and 12 knots. The Socrates has to be towed below 40 meters of depth, or maximum source level is limited. During towing of Socrates the ship can turn once at a rate of 15deg pr. min.

During exposure experiment two types of signals will be used: LFAS (1-2 kHz hyperbolic up-sweep at 214 dB re 1µPa @ 1 m source level) and MFAS (6-7 kHz hyperbolic up-sweep at 199 dB re 1µPa @ 1 m source level). Prior to full power transmission a ramp up procedure will be used, starting at 160dB and increasing to full power within 10 min for both LFAS and MFAS transmissions. The signal interval will be 20s during both ramp up and full power transmission.

Acoustic array – Delphinus

During the trial, the TNO developed Delphinus array will also be used. It will be deployed from the Sverdrup to acoustically search for marine mammals. The Delphinus is a single line array (54 metres long) containing 18 hydrophones connected up to 20 kHz (sampled at 48kHz), and three hydrophone up to 160 kHz (sampled at 400kHz). The hydrophone section is 3.7 meters long and has an outer diameter of 65 mm. The middle section contains 16 hydrophones that have a spacing of 6 cm, while the outer two hydrophones are spaced 60 cm from the rest. These two hydrophones are used for classification and localization. The array is also equipped with a depth sensor (also recorded).

The Socrates (left) and Delphinus (right) on board the Sverdrup in 2006.

Socrates and Delphinus can be towed separately or together. When the Delphinus array is towed, the tow speed needs to be between 3 and 12 knots. The Delphinus functions best at a speed between 6 and 9 knots. Dual tow of Socrates and Delphinus is possible up to 10 knots. The tow depth of Delphinus needs to be lower than the Socrates (depth separation). Delphinus needs always be deployed before Socrates and Socrates will be recovered out of the water before Delphinus. When a CTD sensor is used to measure the sound speed profile, Socrates and Delphinus need to be out of the water.

Whale tag - DTAG

The DTAG, is a miniature sound and orientation recording tag developed at WHOI. The tag is attached to the whale using a hand held carbon fibre pole with suction cups, or a pneumatic remote deployment system. At a pre-set time the vacuum is released from the suction cups and the tag floats to the surface. The tag contains a VHF transmitter used to track the tagged whale during deployment and to retrieve the tag after release. All sensor data are stored on board the tag and the tag therefore has to be retrieved in order to obtain the data. DTAGs record sound at the whale as well as depth, 3-dimensional acceleration, and 3-dimensional magnetometer information. DTAG audio will be sampled at 96 kHz and other sensors at 50 Hz, allowing a fine reconstruction of whale behavior before, during, and after sonar transmissions.

DTAG (left), and deployment of the tag to sperm whales using the ARTS system (middle) and a hand held pole (right).

LKTAG

The LKTAG contains a depth sensor and a VHF-transmitter, and an electronic release mechanism (HoTR). The release mechanism will release at any preset time, however transmission of a coded RF signal from the tag boat or mother ships can at any time fire the release and release the tag instantly. The release of the HoTR can also be delayed at any time by transmission of a specific coded signal adding deployment time to the unit. The LK-TAG is launched from the whale tag launcher ARTS and attached in the blubber of the animal by a small anchor (ca 40 mm long). If the electronic release malfunctions, the tag will release itself from the animal using a galvanic time release set to 24 h or 48 h. The advantage of this system is that deployment of LK-TAGS could be done at longer distances from the whales and it is not as weather dependent as during deployments of DTAGs. However, LK-tags collect much less information, though DTAGs are therefore the main instrument during the trial. The LKTAGs will be used as an alternative only after initial tagging attempts with DTAGs, and if the conditions or animals does not allow for further DTAG approches. LK-tag will only be used for the Ramp-Up experiment, not for the regular sonar exposure experiment (LFAS-MFAS-Silence).

ARTS - DTAG

The hand held pole techniques for deployments of DTAGs have been used in many previous field trials, and are therefore an established and robust technique. The limitation is however, that you have to be very close to the animal (within 5-6 m) to tag it, and tagging efficiency is a limiting factor during controlled exposure experiments. FFI and WHOI have therefore developed an alternative technique which involves the use of the ARTS remote launching system and a DTAG carrier for this system. The ARTS-DTAG system will enable the tagger to launch the DTAG on an animal from about 10 m distance. In addition it also enables the tagger to turn towards a new target much faster than with the pole. Thus, potentially this system will increase our tagging efficiency.

The ARTS-DTAG system has been extensively tested under controlled conditions, and it showed potential during field testing in 2008.

The ARTS system is very powerful and potentially dangerous to the tag boat crew. To use this system, weapon experience is required, and the ARTS should be operated as if it is a loaded rifle. In addition, to reduce risk to the animals and the risk of damage or loss of tags, the following limiting rules apply:

Distance to target	**DTAG** *Barrel pressure (Bars)*	**LKTAG** *Barrel pressure (Bars)*
< 5m	7	9
5-10 m	9	11
10-15 m	11	13
15-20 m	Don't shoot!	15

Required barrel pressures at different distances to target when using the ARTS to launch DTAGs or LKTAGS. Numbers are considered to be *<u>"no more, no less, or desist from firing"!</u>*

Crew plan

HU Sverdrup II

Role	Org	May 14-27	May 27 – June 11.
3S Cruise leader /chief scientist FFI	FFI	Petter Kvadsheim	Petter Kvadsheim
Chief scientist TNO/Sonar operator	TNO	Frans Peter Lam	Frans Peter Lam
Chief scientist SMRU/PI BRS	SMRU	Patrick Miller	Patrick Miller
Socrates/Delphinus/Software eng.	TNO	Sander Ijsselmuide	Jeroen Janmaat
Socrates/Delphinus/Hardware eng.	TNO	Mark van Spellen	Adri Gerk
Naval-/Mammal observer	RNLN		René Dekeling
Delphinus operator/MMO	TNO	Bart Voet	
MMO	FFI	Paul Ensor	Tommy Sivertsen Sr
MMO	FFI	Pål Anton Nilsen	
MMO	TNO		Annemieke Podt
D-tag support/MMO	SMRU	Eva Hartvig	Eva Hartvig
Acoustic analysis/MMO	SMRU		Paul Wensveen
Chief tag boat 1, Pole tagger	SMRU	Patrick Miller	Patrick Miller
Tag boat 1 Driver	SMRU	Allan Ligon	Allan Ligon
Tag boat 1 Photo ID	SMRU	Sanna Kuningas	Ricardo Antunes
Chief tag boat 2, ARTS tagger	FFI	Lars Kleivane	Lars Kleivane
Tag boat 2 pole tagger/photo ID	WHOI	Alex Bocconcelli	
Tag boat 2 pole tagger/photo ID	FFI		Pål Anton Nilsen
Tag boat 2 driver	FFI	Thomas Sivertsen Jr	Thomas Sivertsen Jr
TOTAL staff		**14**	**15**

MS Strønstad

Role	Org	May 14-27	May 27 – June 11.
MSS Cruise leader	FFI	Rune Roland Hansen	Rune Roland Hansen
MMO I	SMRU	Ana Catarina Alves	Ana Catarina Alves
MMO II	SMRU	Marijke Olivierse	Marijke Olivierse
MMO / group behavior	TNO	Fleur Visser	Fleur Visser
MMO / boat driver	FFI	Gunnar Rikardsen	Gunnar Rikardsen
MMO	TNO	Annemieke Podt	Rob van Bemmelen
Passive Acoustic/MMO	SMRU	Ricardo Antunes	
Passive Acoustic/MMO	SMRU		Paul White
Passive Acoustic/MMO	SMRU		Mark Hadley
TOTAL staff		**7**	**8**

Total crew

Organization	May 14-27	May 27 – June 11.
FFI	7	7
SMRU	7	9
TNO	6	6
RNLN		1
WHOI	1	
Total staff	**21**	**23**

Responsibilities:

FFI

Personnel: Cruise leadership and permits, VHF-tracking, marine mammal observers, local knowledge, CTD/TL-measurements, tag-boat drivers, ARTS tagging.

Equipment: 2 Research vessels with crew, 2 tag boats, gas for tag boats, 2 CTD's, 1 ATS-VHF-tracking system with antenna, AIS receivers/transmitters for tag boats and MSS, power supply for tag boat, digital video camera, LK-tags, 2 ARTS, DTAG-ARTS carrier and robots, VHF-communication equipment, Acoustic model Lybin, maps, hand-held GPS.

SMRU

Personnel: PI BRS cetaceans, DTAG-technician, DTAG pole tagger, marine mammal observer, visual trackers, photo id/documentation, VHF-tracking, acoustic tracking, acoustic measurements and analysis.

Equipment: Miller towed hydrophone array, vertical array, digital cameras, VHF-tracking antenna, 2 VHF receivers (148-150 MHz), 1 big eye, hand-held GPS, killer whale playback equipment, 1 sperm whale tagging pole, Logger software for both platforms.

WHOI

Personnel: DTAG pole tagger/ DTAG-technician

Equipment: 4 DTAGs with accessories, 2 tagging poles, 2 DTAG robots straight, 1 DTAG robot 90º, 1 ATS VHF direction finder.

TNO

Personnel: Software and hardware operators and technicians for Socrates and Delphinus, marine mammal observers, visual observations,

Equipment: Socrates, Delphinus, wireless network link between HUS and MSS, AIS-receiver, IRMA, handheld GPS, XBT.

Data collection

Controlled exposure experiments on cetaceans

The Sverdrup and Strønstad will search for whales in the specified locations using towed array acoustics and visual observations from both vessels. As soon as whales are located, the tag boat(s) will be launched from the Sverdrup with taggers and photo-id capability. During tagging, the Sverdrup and Strønstad observers should provide visual and acoustic tracking support to the tagboats, or search for new animals depending on the situation. The vessels should work in areas close enough together that the Strønstad can take over tracking the tagged whale and the Sverdrup can approach a tagged whale in order to conduct a CEE. 20nmi separation should be considered a maximum distance during search for target species subjects.

When a target species marine mammal is detected, a decision will be made whether or not to attempt tagging and a CEE. Killer whales, pilot whales and sperm whales are primary target species. However, we may opportunistically also try to tag minke whales and bottlenose whales. A rule whether or not to attempt to tag and do a CEE for each species should be made the day prior by the chief scientists.

Before the tag boats are allowed to approach the animals and start tagging attempts the visual observers on the Strønstad will collect group behavior data for 30 min. If an animal is tagged, we will continue to try to tag more than one whale within the same group. Once a tag is attached, the other tag boat should move to assure that it is working with the same group of animals as the tagged animal. This increases the total number of whales tested (and helps assure that a tag will remain attached for the full experiment duration), but has the cost of taking time attempting to tag. The decision to cease attempting to tag should be made within one hour of initial tag deployment. Any decision to further extend tag attempts should be based on considerations such as the success of the first attachment (in terms of VHF tracking and likelihood of long attachment) and the behavioral state of the animals in the group.

Once a tag is attached, one tag boat will follow the tagged animals to take identification photographs, assess VHF signals, and maintain proximity to the animal – while the other continues attempting to tag a second animal. 2nd tagging should always be on another animal in the same group as the 1st tagged animal. When Strønstad have established good tracking of the first tagged animal, both tag boats will continue to try a second tagging within the same group for about 1 hour.
Once the tracking from the Strønstad is reliable and tagging efforts cease, tag boat team will transfer to Strønstad, except a driver and 1 extra person who will return to Sverdrup with tag boat 2. Care will be needed during the boat recovery not to loose the tagged whale. If possible, the Sverdrup should provide a support role in tracking the whales during personnel transfer to the Strønstad.

Teams on the Strønstad will visually monitor and VHF-track the tagged whale(s) throughout each experiment. The Sverdrup will move into position to start the CEE. The primary goals of the start location are to place the source in a position about 3 nmi from the tagged animal to the side or in front of the whales direction of movement. Source transmissions will start one hour after tagging, once the Sverdrup is in an appropriate location to start sonar exposure. The final decision to start sonar transmission is made by Kvadsheim after consultation with Miller and the Socrates operator. During the 30-minute transmission cycle, the Sverdrup will approach the whales at a speed sufficient to move to ~100m range by the end of the 30 min period, following a 10-minute ramp-up period (7-8 knots).

The first CEE will be planned to occur 2 hours following tag deployment for the first tag deployment on each species. For the subsequent deployments, the CEE will be planned to start 8 hours after deployment in order to collect baseline behavioral data before exposing each tagged animal. The second playback will start one hour following the end of the first playback, once the source vessel is in a new acceptable location. All protocols will be identical for first and second playbacks. After another one-hour period, a final third playback will be conducted after which the Strønstad will continue to track the tagged whale until the tag detaches from the whale. The tag will then be recovered by tag boat 1 as the tag boat team return to Sverdrup from the Strønstad.

During transmissions, visual/VHF observers on Sverdrup will assure that no other whales are so close to the source that they might be exposed to sounds over 200 dB re 1μPa as required by the permit. Playback will also be ceased immediately if any animal shows any signs of pathological effects, disorientation, severe behavioral reactions or if any animals swim too close to the shore or enter confined areas that might limit escape routes. The decision to stop transmission outside the protocol is made by Kvadsheim or by the PI (Miller) observing the whales from the Strønstad. A standard protocol will be established to allow the source to be stopped immediately upon a mitigation request from the Strønstad. The Strønstad will visually monitor and track the tagged whale(s) continuously before, during, and after transmissions and make recordings using towed hydrophone array. The Strønstad will inform the Sverdrup of the whales' location as needed. For efficiency of communication, a VHF radio protocol should be established to allow the Miller and Kvadsheim to speak directly to each other on the radio.

Tags will be programmed to release after 15-18 hours, enabling collection of 2-8 hrs pre-exposure, ~5 hours for the three CEE exposures, and 3-8 hours of post-exposure data. When exposures are completed with more than 3 hrs of tag-attachment time remaining, a playback of killer whale sounds may be attempted. When killer whale playbacks are completed with still more than 3 hrs of expected remaining tag-attachment time, experiments where tagged animals are exposed to LFAS or MFAS down-sweep signals instead of the regular up-sweeps will be conducted using the regular CEE protocol.

Playback schedule:
Three different playback sounds will be transmitted as part of the normal cycle:

1.) LFAS: 1-2 kHz hyperbolic Up-sweep of 1000ms duration with 20s IPI;
2.) MFAS: 6-7 kHz hyperbolic Up-sweep of 1000ms duration with 20s IPI;
3.) SILENT: silent vessel approach with Socrates deployed if feasible.

Killer whale playbacks will be either herring-feeding or mammal-feeding killer whales. Which playback to be used will depend on the target species. For killer and pilot whales herring-feeding sound will be used, but for sperm whales mammal-feeding sounds will be used to test anti-predation hypothesis. Killer whale playbacks and sonar down-sweep exposures will not be done as part of the regular schedule, but opportunistically.

We will strive to achieve as many CEEs as possible during the field effort, up to the permitted limit. Additionally, the schedule for playback might be altered depending on our success at achieving 2nd experiments.

CEE #	**1st Exposure--**	**2nd Exposure--**	**3rd Exposure--**
1	MFAS	LFAS	SILENT
2	LFAS	MFAS	SILENT
3	SILENT	LFAS	MFAS
4	MFAS	SILENT	LFAS
5	LFAS	SILENT	MFAS
6	SILENT	MFAS	LFAS

The schedule above was devised to maximize contrasts with existing experiments from 2006. For cross-species comparison, identical playback schedules should be followed for each species, unless logistic reasons intervene.

Data collected during 3S-08

During the 3S-08 trial the following CEE have already been completed:
Killer whales: CEE no 1
Pilot whales: CEE no 1, 2 and 3
Sperm whals: CEE no 1
Consequently, the first CEE of 3S-09 should be no 2 for killer whales and sperm whales. As for pilot whales, the three pilot whale experiments from 2008 were possibly repeated exposures of the same group, and we have therefore decided that also for pilot whales the first CEE this year should be no 2.

Staffing:

Staffing must be sufficient on the Strønstad to enable VHF and visual tracking of the tagged whale before the tag boats are recovered. For that purpose, 3 observers should be available on the Strønstad when the tag boat is deployed. They should be relieved as soon as possible with staff from the tag boats.

Effectiveness of Naval Sonar Ramp Up to mitigate risk to marine mammals:

As a secondary objective, we will also try to conduct experiments to investigate the effectiveness of Naval Sonar Ramp Up to mitigate risk to marine mammals. The target species for these experiments are killer whales, pilot whales, harbor porpoises, white sided dolphins and white beaked dolphins. Protocol for the execution of these experiments does not require that we successfully deploy a dtag. Decision to try to conduct ramp-up experiments will be taken by the cruise leader based on the following criteria:

-Lack of availability of CEE target species or unfavorable tagging conditions.
-Availability of harbor porpoises, white beaked dolphins or white sided dolphins.
-Availability of killer whales or pilot whales which are un-taggable using dtags.

Once an animal or a group of animals of a target species are sighted Strønstad will start tracking the animals visually. If the sighted species are killer whales or pilot whales, which after repeated attempts have shown to be un-taggable with dtags, attempts will be made to instrument the animals with LK-tag. The LK-tag could be deployed at a longer distance and in less favorable tagging conditions than the dtag. After tagging the animal is closely observed but not disturbed during a post tagging and pre-exposure period of 2 hours. Dolphins and porpoises will not be tagged, but tracked visually from the Strønstad.

In each experiment the experimental group of animals will be their own control. They will be exposed to two different experimental conditions:

1. Ramp up: exposure to LFAS sonar signals gradually increasing in intensity (ramp up).
2. No ramp up control: exposure to high level LFAS sonar signals without preceding ramp up.

The LFAS signal waveform, signal duration and ramp up scheme will be the same as during regular CEE exposure experiments.

During the exposure experiments Sverdrup will approach the animals and move in parallel with the direction of movements of the animals and at the same speed, to keep a constant distance of 100-300m. The observation vessel will continue to track the animals and make behavioral observations and acoustic recordings throughout the experiment. When the geometry of the two ships relative to the animals is considered to be stable, the source ship will turn on the sonar. During the first exposure the transmitted signal will gradually increase in intensity from 160 dBrms (re1µPa @ 1m) to 214 dBrms (re 1µPa @ 1m) within 10 min (RAMP UP).

After 20 min of full power transmission the transmission will be stopped and after an hour of no transmission, transmission will again commence again, this time using the "no ramp up control". This implies that the 215 dBrms (re 1µPa @ 1m)) transmission will be initiated without a preceding ramp up (NO RAMP UP CONTROL). The transmitted signal will again be LFAS transmitted every 20s for 30 min.

During transmission the source ship will not change its course even if the animals do so. This is done to allow the animals to avoid the source. This potential avoidance is one of the things we are studying.

If operational priorities allow for it, the target species will be tracked visually or using the LK-tag signal for 24 hrs, before a second ramp-up experiment is conducted, using the reverse order of ramp-up and no-ramp-up exposure.

Sound speed profiles (CTD) and LYBIN

Sound speed profiles should be taken whenever acoustic transmissions (sonar signals or killer whale playback) have been used in an area. CTD profiles may be taken from both the Sverdrup and the Strønstad, but Sverdrup cannot reduce speed beyond 3 knots when towing Socrates or Delphinus.

After an exposure experiment, Socrates and Delphinus are usually recovered on the Sverdrup, which allows Sverdrup to collect CTD profiles along the exposure path, while Strønstad is still tracking the tagged animals.

CTD profiles should also be collected on a routine basis every day to monitor the acoustic propagation conditions in the operation area. This will enable us to plan the acoustic experiments using transmission loss models (LYBIN).

Daily work plan

The 3S-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 and cruise management. In addition, the crew is divided between 2-4 different platforms (Sverdrup, Strønstad, Tag boat 1 and Tag boat 2), depending on which phase of the operation we are in. The operation goes through 5 different phases which requires very different staffing from the different teams. These phases are; search phase, tagging phase, pre-exposure phase, exposure phase and post exposure phase. Finally, the operation is conducted in an area and at a time where the sun do not set, which enable us to operate 24 around the clock. This is a challenge but also a great opportunity we have to make the most of the time available.

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

Planning meetings

Every morning before breakfast (0700), the chief scientist from the participating partners (FFI, TNO, SMRU) will convene to plan the activities for that day. Search areas and patterns, species priority, logistical constrains, crew dispositions etc will be discussed and implemented in the daily plan. The plan for the day will be announced on a poster in the main operation room of both vessels.

Every evening at 1900, the chief scientist will meet again to make adjustments to the daily plan, and plan activities for the coming night.

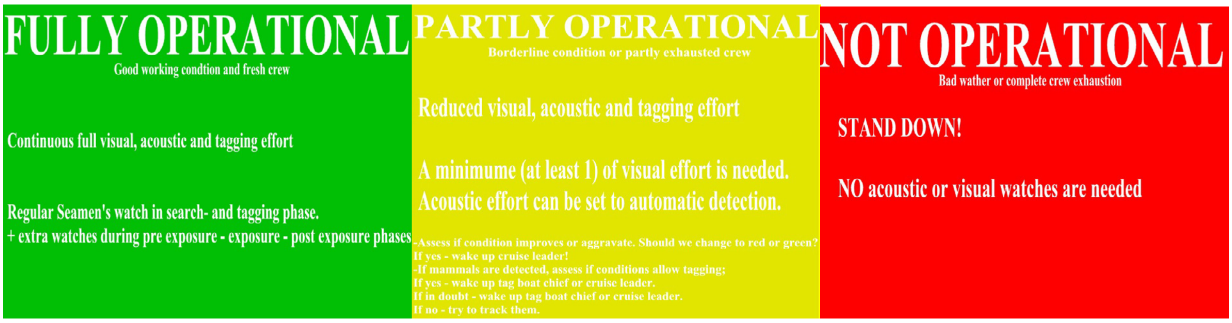
During planned or un-planned port calls, the cruise leader may call for a plenum meeting with the entire scientific crew.

Watch plan

The visual teams and acoustic teams will follow a 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. This will cover the basic staffing requirement during the search phases and tagging phase, but extra manpower is needed as soon as an animal has been tagged and until the tag is recovered (pre-exposure, exposure and post-exposure phase). The tag boat teams will have a more flexible watch plan, to assure that they are rested and ready when their "*service*" is required. However, as soon as a tag is deployed, part of the tag boat team will be transferred to Strønstad to support them in tracking the tagged animal.

Operational status

In extended periods of good weather, and if we are lucky to find animals and tag them, there is a risk that the work load on the team will be too high, and that eventually we will all suffer from collective exhaustion. In these periods, the basic watch plan has to be considered to be normative. It is better to have some level of search effort all the time than periods with no effort at all. On the other hand, increased risk to personnel in some phases of the operation, and increased risk of reduction in the quality of the data collected in other phases are factors which also have to be considered carefully in these periods of intense work load. Thus, the cruise leader may decide to reduce effort during search and tagging phase to rest the crew. Because of this risk of crew exhaustion, the cruise leader may also reduce effort in periods of bad weather. To make sure everyone is aware of the operational status a traffic light system will be implemented. The operational status will be clearly indicated in the main operation room and the bridge of both ships.



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 should rest!

Operational phases

Search phase

Weather forecast and reports from our local network of fishing vessels and research vessels concerning marine mammal presence will determine where we search for whales, visually and acoustically. Since we have 24 hours of daylight, visual and acoustic search for whales should continue on both vessels around the clock. HUS and MSS will coordinate the search to optimize our chances of finding whales. To assure good coordination Sverdrup and Strønstad should stay within VHF radio range of each other.

Tagging

If whales are spotted, depending on species and behavior of the animals, we will launch 1 or 2 tag boats. Before the tag boats start tagging, the observation boat will collect group behavioral data for 30 min (pre-tagging observations). If possible, a CTD profile should be collected when tag boats are deployed so that it can be used to plan possible acoustic transmission, when tags are deployed. During the tagging phase it is important that the mother ships of the tag boats continue to do marine mammal observations to support the tagging team or look for alternative animals. If possible the crew of the Strønstad should try to do behavioral observation of the animals before and during tagging attempts. Once a tag has successfully been deployed on an animal, both HUS and MSS have to start tracking the tagged animal with the VHF direction finder system installed on both vessels. Tagging might continue, attempting to tag more animals.

Pre-exposure phase

When one or two animals have been tagged and the decision is made to stop tagging, both tagging teams will transfer to MSS, except for the driver of tag boat 2 and one extra person who will return to HUS with the tag boat. Tag boat 1 will be towed by the Strønstad. In the pre-exposure phase the focus will be on tracking the animals with the VHF-systems and visually from both vessels. MSS will generally stay closer to the animal and do visual observations of baseline behavior. It is important to document the behavioral context of the exposures, i.e. what type of behavior are the animals involved in prior to exposure. The pre-exposure phase might last 2-8 hours depending on the need for baseline data from the specific species and behavioral context.

Exposure phase

In preparation for the exposure, the Socrates will be deployed and HUS will distance itself from the observation vessel (MSS) and the tagged animals. During the exposure phase 3 different exposure runs will be carried out in a semi randomized sequence (LFAS-MFAS-Control). After a ramp-up, the HUS will approach the position of the tagged animals, as reported from the MSS, head on at 7-8 knots from a distance of 3nmi. The course of the source ship will be adjusted if the animals change position, to continue to approach them head on, until the source ship is 1000m from the animals. After this the course will not be changed to allow the animals to avoid the signals. During the exposure, behavioral changes will be recorded from the MSS, who will stay close to the animals. However, visual observations also from the source ship are an important part of the risk mitigation protocol, because other animals might be in the area. After about 20-25 min the HUS will pass the tagged animals and continue on a straight course still transmitting for another 5 min. The HUS will then re-position for the next exposure. However, there will be a silent period of at least 1 hour between exposures. The exposure phase will last 5 hours.

Post-exposure phase

After termination of the exposure phase, we will go back to VHF and visual tracking of the tagged animals, and observation of observed behavior from the MSS, until the tags releases and can be picked up. CTD profiles should be collected in the exposure area. When all tags have been retrieved, the tag boat teams will transfer back to HUS in tag boat 1 to download and secure the data. Visual and behavioral data will also have to checked, corrected and secured (backed up). Then we return to the search phase. The post-exposure phase might last 2-8 hours. The total duration of tag deployment will usually be set to 15 h before the tag releases.

Ramp Up experiments

Ramp up experiments are not part of the regular experimental protocol. However, during ramp up experiments, MSS will track the animals as if it was a regular exposure. The only difference might be that we do not necessarily have a tag on an animal during ramp up experiments, and thus have to rely on visual tracking alone. Since HUS will be much closer to the animals than during the regular exposure experiments, the mammal observers on the HUS should support the mammal observers on the Strønstad during this tracking. Visual observation from HUS is important also for mitigation purposes.

Management and chain of command

Operational issues

Operational decisions such as decisions on sailing plan, decisions to deploy tag boats/Socrates/ Delphinus, crew dispositions etc are ultimately made by the cruise leader. The cruise leader is also the coordinator and leader of the exposure experiments. However, the cruise leader is obliged to consult with the chief scientist of the 3S-partners on decisions affecting their area of interest or responsibility. The vessel (HUS/MSS) leader is responsible for communication with the crew of their ships. Each tag boat has a chief which makes decisions on tagging strategy etc.

Safety issues

The captain of the ship makes final decisions on safety issues.

Permit issues

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

Sonar operation safety issues

A Risk Management Plan for the operation of Socrates and Delphinus is specified to minimize risk to this very expensive equipment (Appendix 1). Final decisions on issues related to the safety of Socrates and Delphinus are made by the chief scientist at TNO.

Scientific issues

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

Communication plan

In all phases of this trial the crew will be split in different groups (acoustic teams – marine mammal observation teams – tag teams - coordination/management) and vessels (Sverdrup – Strøntad – tag boat 1 – tag boat 2). Coordination and thus clear communication between these units will be crucial, especially in critical phases. To ensure good communications all teams must bring a VHF radio and a cell phone (if within GSM-range).

The radio call signals for the different units will be:

"Sverdrup"	Sverdrup bridge/cruise leader (Kvadsheim)
"Strønstad"	Strønstad bridge/obs deck II/MSS cruise leader
"Tag boat I"	4 stroke outboard engine work boat
"Tag boat II"	Water jet MOB
"Socrates"	Sonar operator on Sverdrup (Socrates and Delphinus)
"PAM"	Patrick's acoustic array on Strønstad
"Obs deck I"	Marine mammal visual observation deck on Sverdrup
"Obs deck II"	Marine mammal visual observation deck on Strønstad

A main working channel (channel A), and an alternative channel (channel C) in case of interference, will be specified. The main working channel could be used between all units.

During the tagging phase, communication to and from the tagging teams must be limited. A dedicated channel (channel B) will be specified for communication between "Sverdrup"-"Tag boat I"-"Tag boatII".
During tagging operations, when tag boats team wants to operate with minimal disturbance, tag boats should stand by on channel B. Only urgent and important messages (such as safety issues) from Sverdrup should be communicated on this channel. Tag boats should call other units on the regular working channel (A). Tag boats must report in to "Sverdrup" to confirm communication lines every our. Other communication to tag boats should be relayed through "Sverdrup".
MSS and both tag boats will be equipped with AIS-transmitters, so that the positions of all units could be monitored from HUS.

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

Main working channel	**Channel A**	**Maritime VHF channel 73**
Tag boat's stand by channel	**Channel B**	**Maritime VHF channel 71**
Alternative channel	**Channel C**	**Maritime VHF channel 67**

Operation area

Our main operation area will be on the continental shelf, along the continental slope and the high sea outside of the slope from 10-16ºE and 67-70 N. The operation area is primarily within Norwegian territorial waters, but also extends into the exclusive economic zone. The Vestfjorden will be a back up area if we experience longer periods of bad weather with Northern and Eastern winds, because it is more sheltered.

Weather and Light

In May-June the air temperature will still be relatively cold at sea: 5-15 ºC. Wind direction and speed vary widely. Note that there will be a midnight sun in the area. This means 24 hours of daylight, and working conditions. This is a big advantage to the operation and our chances of success, because we can work around the clock and don't have to consider retrieving tags before dark. However, make sure you get some sleep! A watch shift plan will be specified.

Port out:
Harstad

Mid sail crew change:
Harstad

Port in:
Bodø

Operation area

Travel and accommodation

Travel

<u>*Port out and Crew shift in Harstad:*</u>

There are direct flights from Oslo to Harstad/Narvik airport (Evenes). There is an airport express bus to/from the airport and downtown Harstad, which takes about 1h. However, the airport serves both the towns of Harstad and Narvik, and they are in opposite directions from the airport. Make sure you enter the right bus at the airport, not to end up in Narvik. The bus terminal is walking distance from the harbor in Harstad.

Alternatively you can fly to Tromsø and take a fastboat down to Harstad (takes 2.5 hrs). When you arrive call cruise leader (Petter) (95138992) to ask where to find the ships.

During the mid-sail crew change the on-going scientific crew can embark the research vessels in Harstad at May 27. The off-going crew needs to arrange with hotel accommodation in Harstad if their return flights are at the 28. or later.

Port in - Bodø:

It is a 15 min taxi drive from the harbor in Bodø to the airport. There are direct flights from Bodø to Oslo, and from Oslo to wherever.

Hotel

If you need hotel accommodation, FFI has arrangements with hotels in both Harstad and Bodø. If you refer to the arrangements with MOD (*Forsvarsavtalen*) when you book hotels you get a discount as our guest in the country. This applies to the following hotels which are all close to the harbor:

Harstad:

Grand Nordic Hotel Harstad, Strandgaten 9. phone +47 77003000. resepsjon.gnh@nordic.no www.nordic.no/

F2 By Nordic Hotel Harstad, Fjordgata 2. phone +47 77003200. f2@nordic.no, www.nordic.no/

Quality Hotel Arcticus, Havnegata 3. phone +47 77040800. q.arcticus@choice.no, www.choicehotels.no

Bodø:

Clarion Collection Hotel Grand, Storgata 3, tlf: +47 75 54 61 00, booking.cc.grand.bodo@choice.no

www.choicehotels.no

Rica Hotel Bodø, Sjøgata 23, tlf: +47 75 54 70 00, rica.hotel.bodoe@rica.no

www.rica.no/

Shipping

Sverdrup will be docked at the local shipyard in Harstad before the start of the cruise and equipment which needs to be shipped in advance should be sent to their address (coordinate with FFI).

Harstad:

FFI RV HU Sverdrup II
Harstad Mekaniske Verksted AS

Samasjøvn. 22
NO 9481 HARSTAD, Norway

For shipment of equipment out of Bodø we recommend to use our local transporter there. They will also collect the goods at the ship and arrange with shipment:

Bodø:

Bring Logistics Bodø
Terminalveien 1
8006 Bodø
Phone: +47 75 58 83 00

Immediately after the trial the Strønstad will leave for their home dock near Harstad. All equipment will have to be off-loaded by 16:00 at June 11. The Sverdrup will however transit towards Horten near Oslo starting from Bodø on June 12. It will make a short stop in Bergen at the 14., and arrive in Horten at the 15. Sverdrup can bring equipment southwards and off-load it in Bergen or Horten for further shipping.

Risk Management and Permits

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

Since the operation includes animal experimentation, we will operate under permits from the Norwegian Animal Research Authority (permit no 2007/61201 and 2009/35289) acquired by Petter Kvadsheim. The permits include tagging (DTAG or LKTAG) and acoustic exposure of minke whales, killer whales, pilot whales, sperm whales, bottlenose whales and humpback whales according to the LFAS-MFAS-Silent-protocol. In addition, permits include acoustic exposure of killer whales, pilot whales, harbor porpoise, white beaked dolphins and white sided dolphins according to the ramp-up-protocol. Killer whales and pilot whales can be tagged as part of the ramp-up experiment, but not porpoises and dolphins. The exposure experiments are permitted under the condition that maximum exposure level does not exceed 200 dB (re 1 μPa), and that project participants are skilled in handling the animals. In addition to Kvadsheim, Patrick Miller and Lars Kleivane will be field operator and will be responsible for permit compliance in the field.

A "Humans diver and environmental risk management plan" is specified for this trial (Appendix 2). The cruise leader is primarily responsible for these risk issues, but other key personnel should also be aware of the risks management plan. A separate risk management plan has also been specified for the handling operation of Socrates and Delphinus (Appendix 1). 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

To ensure good relations and interactions with local stakeholders an information letter about the trial will be issued from FFI to local environmental groups, fishery organizations, the whaling organization and whale watching companies a week before the trial starts. A press release will simultaneously be issued to the local media. During the cruise, all media contact should be referred to the cruise leader who will coordinate with the chief scientist of all partners and FFI's information office. An on-shore PR-contact will be appointed by FFI, and will serve as the POC for all inquires from media.

Contact information – (removed in published version)

Name	e-mail:	office phone	cell phone

Appendix 1:

Deployment / Recovery of Socrates and Delphinus

The SOCRATES source and Delphinus array will be deployed up to and including sea state 4. It will be recovered if sea state is forecast to be higher than 5. The decision to recover will be taken by CO Sverdrup II, the Cruise leader and the chief scientist TNO.
TNO will be responsible for the deployment of the systems. Deploy and recovery time for SOCRATES to/from a depth of 100 m takes approximately 30 minutes and similar for the Delphinus. Stabilisation time of towed body and towed array is about 10 minutes. During deploy and recovery, the tow ship speed is approximately 3 – 4 kts.

Sverdrup II can tow both the SOCRATES source and the Delphinus array simultaneously. The deploying sequence will be first the Delphinus towed array and then the SOCRATES towed source. Consequently the retrieval sequence will be first SOCRATES and then Delphinus.
Because of the dual tow, turns of Sverdrup are preferably carried out to PORT with a maximum turn rate of 12 degrees/minute. For single tow there is a maximum turn rate of 15 degrees/minute either to port or starboard. If the experimental set-up requires a different setting, a look-out from TNO should check the equipment on the aft deck.

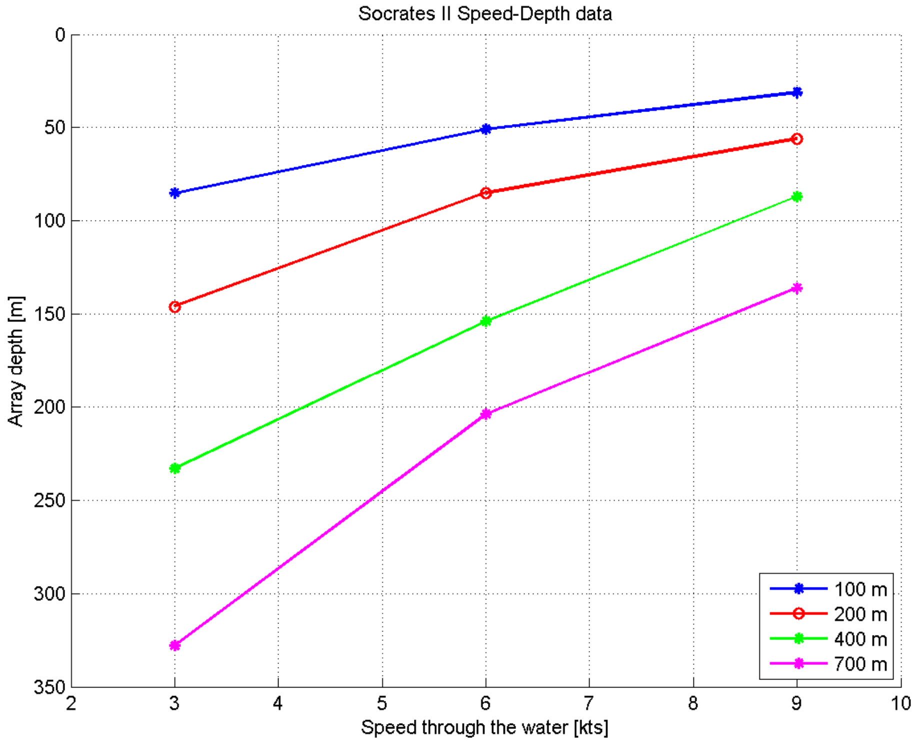
The operational limitations for Sverdrup II while towing are presented below:

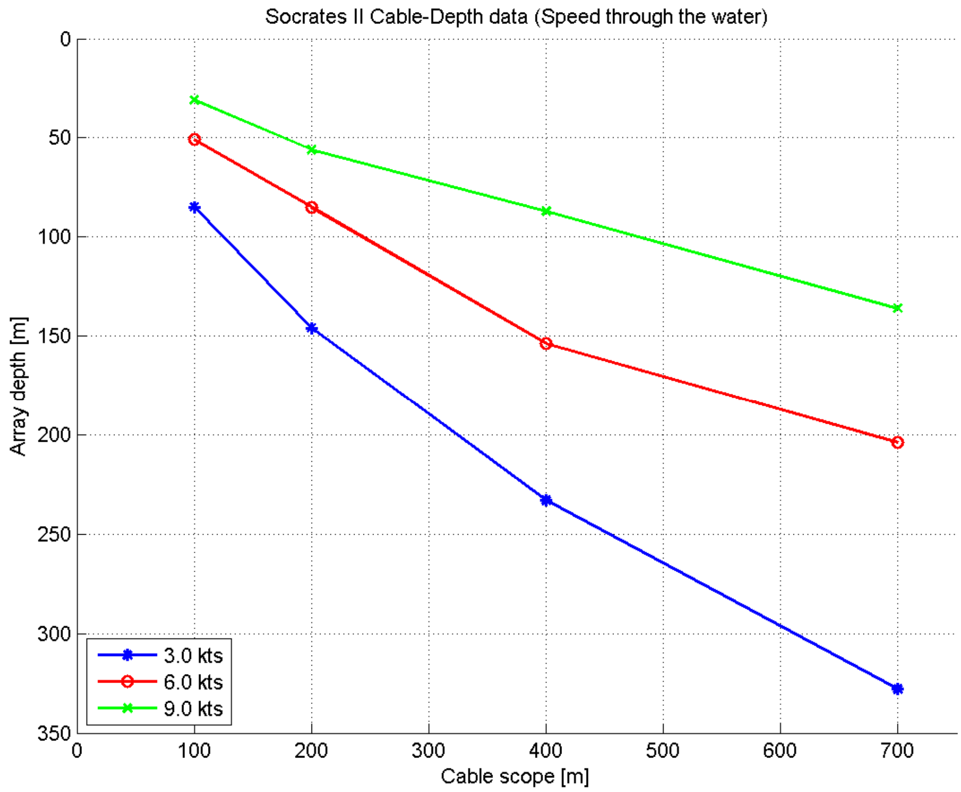
Item	min	max	Remarks
SOCRATES II weight [kg (daN)]	400	700	Weight in water/air
SOCRATES II depth [m]	40	700	Min. depth limitation FFR
SOCRATES II tow length [m]	100	700	
Free depth under SOCRATES [m]	30		Depending on sea-bottom type
Delphinus depth [m]	20	400	
Delphinus tow length [m]		700	
Speed [knots]	3 3 3	12 12 8	SOCRATES II Delphinus SOCRATES II + Delphinus
Survival speed [knots]	-	12	
Sea state	-	5	Up to SS 5 during towing, Up to SS 4 for deploy/recovery

Note1 : For safety reasons array cable scope is always less than the water depth!

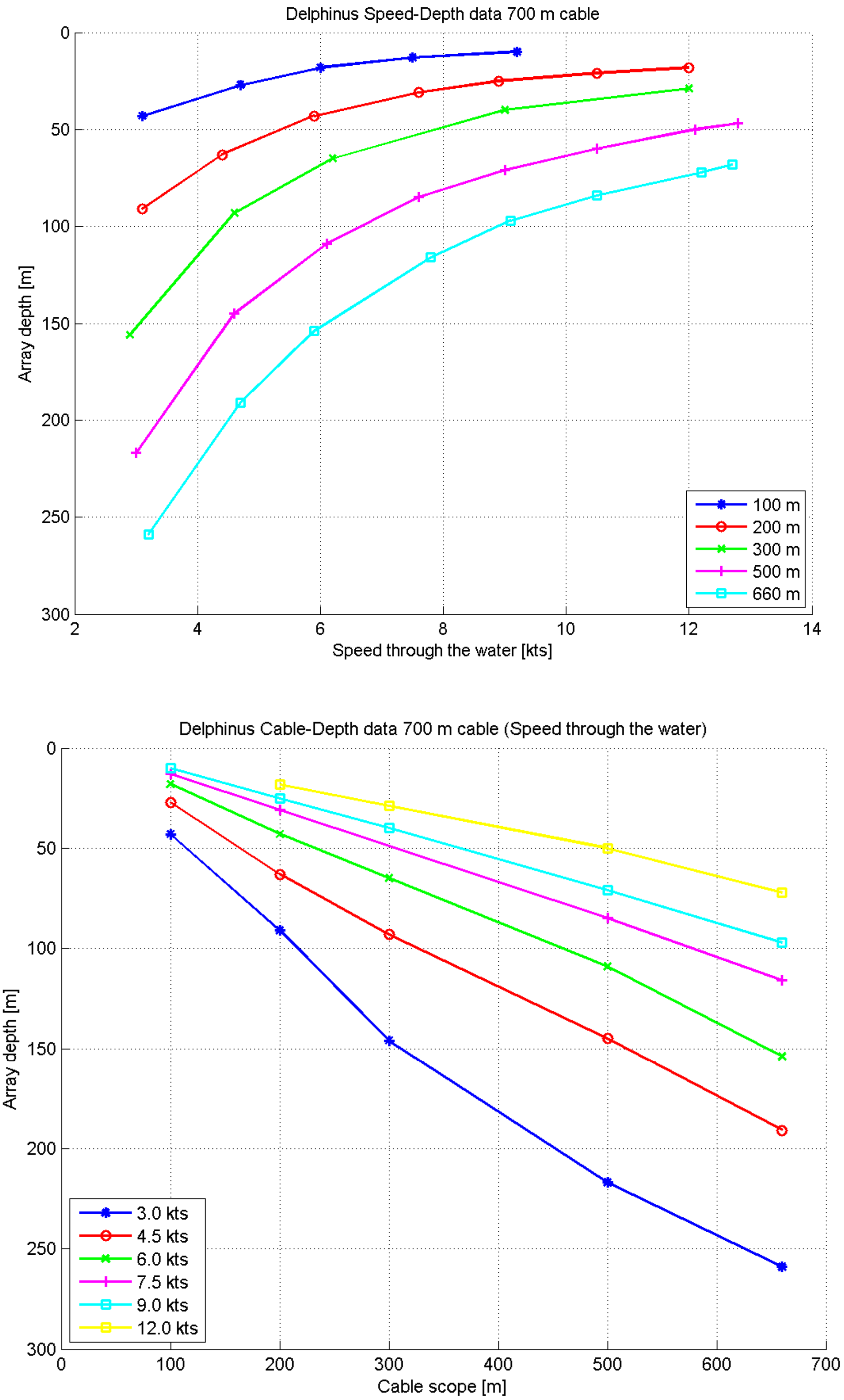
Note 2 : For maximum source level to be transmitted (214 dB), the operation depth for Socrates II should always stay below 40 m. This requires careful communication between sonar operator (source level) and bridge (tow speed).

Note3: For safety reasons, tag boats should not cross the wake of Sverdrup closer than 500 m during towing operations.





Socrates towing depth versus tow speed (through the water) and towing depth versus cable length.



Delphinus towing depth versus tow speed (through the water) and towing depth versus cable length.

Appendix 2:

3S-2009 Human Diver and Environmental Risk Management Plan

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Introduction

In May-June 2009 a multi-national experiment is scheduled in Lofoten-Vesterålen, Norway. The main objective of this experiment will be to tag free ranging whales with sensors recording behavior and acoustic signals, and thereafter expose the tagged animals to naval Low and Mid Frequency Active Sonar (LFAS and MFAS) signals, in order to study behavioral reactions of the animals to such signals.

We have designed this scientific experiment to generate important data for the naval partners to consider in their specification of “safe” sonar operations. The objective of this experiment is thus, to enable navies to use sonars while minimizing the impact of their sonar transmissions on the marine environment. The nature of the experiment makes it necessary to use a high-power sonar source in an ecologically important area. Therefore careful risk mitigation measures during the operation of the sonar source are essential. We do not want to end up with exactly the opposite of our main goal, that the experiment itself leads to unnecessary environmental damage. This risk management plan specifies the risk involved and the steps we will take to minimize the risk of unintended harm to the environment and to human divers.

Participating organizations:
The trial is a joint effort between:

- The Norwegian Defense Research Establishment (FFI), Norway
- The Royal Netherlands Navy (RNLN) and TNO, The Netherlands*
- Sea Mammal Research Unit (SMRU), Scotland
- Woods Hole Oceanographic Institution (WHOI), USA

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* *The Netherlands Organisation for Applied Scientific Research (TNO) is through the NL MOD an indirect participating organization to this experiment. The performance of the tasks of NL MOD to this experiment will be carried out by TNO, as a contractor of NL MOD under the terms and conditions of the agreement with reference number 016.06.5105.02 (30 Oct.2007) (Internationale samenwerking Marine Mammal Protection Fase 2) between TNO and NL MOD.*

Risk inventory

The operation area (fig. 1) will be on the continental shelf, along the continental slope and the high sea outside of the slope from 10-16ºE and 67-70 N. The operation area is primarily within Norwegian territorial waters, but also extends into the exclusive economic zone. The Vestfjorden will be a back up area if we experience longer periods of bad weather with Northern and Eastern winds, because it is more sheltered.

Fig.1. *Expected operation area during the trial*

The trial starts in mid May and ends in mid June. During this time it is expected that large numbers of marine mammals will migrate through or feed in the operation area. In addition, large schools of herring and other species of fish are expected to feed in this area, and thus there will also be substantial fishing activity. Some whale-watching companies are operating in the area, mainly because of the high presence of sperm whales and humpback whales. The area is also densely populated with fish farms, primarily mussels, cod and salmon. During the experiment a high-intensity sound source is going to be used. This sound source is a horizontally omni-directional towed transducer, which will be towed from the FFI research vessel HU Sverdrup II at approximately 40 m depth. The transmitted signals will be in the 1-2 kHz and 6-7 kHz band. The corresponding transmitted sound pressure levels will be 214 dB (re 1µPa @ 1m) and 199 dB, respectively. Hearing curves indicate that both the herring, human divers and marine mammals will hear the transmitted signals at considerable distances (Fig. 2).

The risk inventory includes:

1. Risk of causing injury to human divers.
2. Risk of causing injury to marine mammals
3. Risk of impact on whale safari activity.
4. Risk of impact on the fishery and whaling.
5. Risk to fish farms.

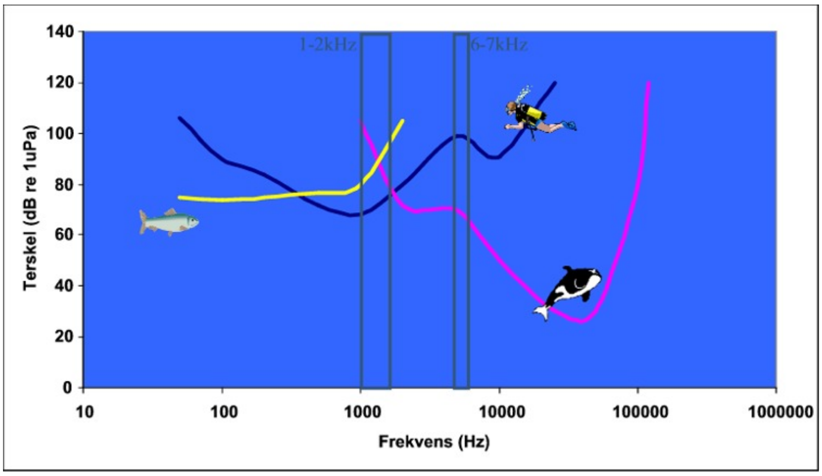

Fig. 2. *Hearing curve of herring, killer whales and divers. The frequency band of the transmitted frequencies are also indicated.*

Risk mitigation

1. Mitigation of risk to human divers

Diving areas
It will be determined in advance of the experiment if diving activity, or possible diving areas, have been identified in the planned operations area. Local diving clubs have reported the most commonly used diving sites within the operation area (Fig. 3).

Maximum received sound pressure levels
The main concern with exposure of divers is that divers might experience a high stress level during the exposure because they are unacquainted with the sound. NATO guidelines therefore differentiate between risk to naval divers and commercial and recreational divers. The guidelines are based on psychological aversion testing, and for commercial and recreational divers a maximum exposure level of 154 dB is established for the relevant frequency band. Based on the source level of 214 dB for LFAS – and 199 dB for MFAS transmission and the maximum received level of 154 dB and expected propagation conditions during the trial, a stand off range of 2000 m for the LFAS signal and 400 m for the MFAS signal will be established to keep received well below the safe limits. The stand-off distance also applies to possible diving areas, unless it is certain that no diving takes place.

Mitigation measures

1. We will stay away from known diving sites.
2. During transmission there will be visual observers on the source boat and on a secondary observation vessel placed on the course line of the source boat. Any observed diving activity should be reported to the cruise leader instantly.
3. If any diver comes within the stand off range, transmission will be stopped.

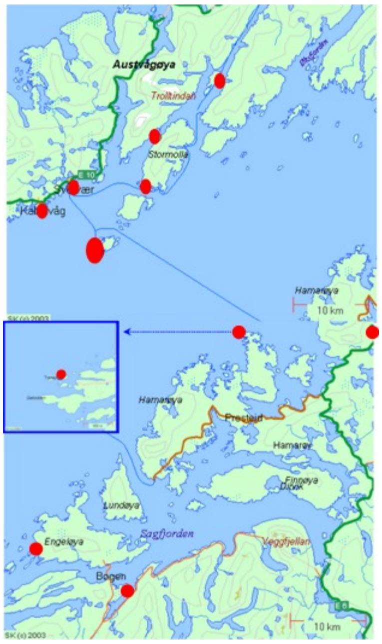

Fig.3. *Recreational diving sites in operation area, based on reports from local diving clubs.*

2. Mitigation of risk to marine mammals

Species:

The study species are the most common in the area. These species includes:

1. Sperm whales (spemhval)
2. Minke whales (vågehval)
3. Pilot whales (grindhval)
4. Bottlenose whales (nebbhval)
5. Humpback whales (knølhval)
6. Killer whales (spekkhogger)
7. Harbor porpoise (nise)
8. White beaked dolphins (kvitnos/springer)
9. White sided dolphins (kvitskjeving/springer)

In addition to the study species, the following marine mammals are also likely to be encountered:

1. Gray seals
2. Harbor seals
3. Fin whales

There are several seal colonies in the area (Fig. 4) and harbor seals will enter their pupping season in June. However, we will not work in shallow areas with water depths less than 100m. This will reduce the risk that shallow water species like harbor porpoises and seals may be exposed unintentionally to high sound pressure levels.

<u>Area</u>

The operation area is specified in fig. 1. We will mainly work in open oceans were embayment of marine mammals is unlikely. However, the operation area also includes narrow fjords and straits, inside the Vestfjorden, but the subject species are usually not found within these fjords at this time of the year. If we do work within fjords, the source ship will start transmission inside the fjord and move towards the outlet of the fjord, never towards the head of the fjord. Before commencing transmission visual observers on the source ship should search for marine mammals further up the Fjord to reduce the risk of animals being trapped within fjords.

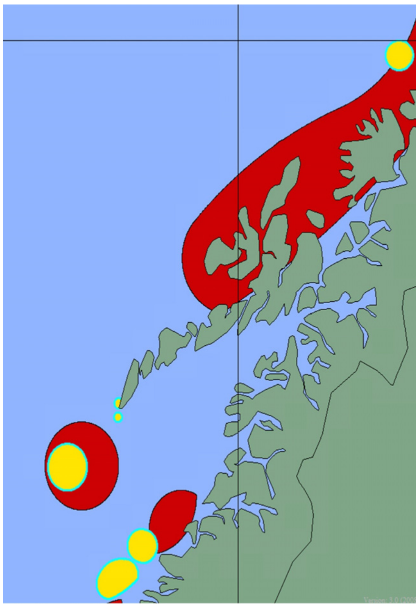

Fig. 4. *Harbour seal (red) and grey seal (yellow) colonies.*

<u>Maximum received sound pressure levels</u>

Maximum exposure levels are determined to avoid physical injury (e.g. hearing injury) to marine mammals. Such injuries are not expected to occur unless an animal comes very close to the transmitting source. According to the permit issued for this trial by The Norwegian Authority for Animal Research, the maximum exposure limit are 200 dB (RMS re 1 μPa). We will operate using a safe stand off range of 50 m when transmitting LFAS at full power, which according to the maximum source level and estimated transmission loss keeps the maximum exposure level well below the 200 dB limit. For transmission using source levels below 200 dB, no stand off range is considered necessary. During transmissions, visual observers on Sverdrup will assure that no marine mammal comes within this safety zone. The objectives of the experiment are to study behavioral reactions of whales to sonar signals. Therefore transmission will not stop based on behavioral reactions of the study subjects unless the reaction puts the animals in direct danger of getting hurt (e.g. stranded). However, transmission will be ceased immediately if any animal shows any signs of pathological effects, disorientation (unusual non-directional swimming), severe behavioral reactions (succession of forceful actions such as breaches, behavior outside species-typical behavior) or if any animals swim too close to the shore or enter confined areas that might limit escape routes. The decision to stop transmission outside the protocol is made by the cruise leader stationed on the source vessel, based on advice from the visual and acoustic monitoring team on Sverdrup and on a separate observation vessel, which will stay close to the tagged animals. After such action, only the cruise leader can order restart of transmissions. The observation vessel will inform the Sverdrup of the whales' location every 5. minutes.

Exposure protocol

The starting point of the source vessel Sverdrup should be 3nm away from the tagged subject animals. That will give a transmission loss of roughly 60-70 dB (using 16-19logR). Usually, we will start with a ramp-up allowing other marine mammals in the area to escape the proximity of the source. The initial source level will be 160 dB, and this will be increased to the maximum source level of 214 dB within 10 min. Towing speed will be constant at 7-8 knots, and initially course set directly towards the animals. If the animals changes position the source ship will change the course correspondingly, but when the source ship is within 1000 m of the animals, course will be maintained constant. This will allow the animals to avoid the signal, if they try to. We will pass the animals after 25-30 minutes. The Sverdrup will maneuver to pass no closer than 100m from the closest whale. At 100m range, the received level should be roughly 170-180 dB. Transmission will continue for another 4-5 min after passing the animals. The received level of the sonar near the whales will be monitored in real time using a towed array from the observation vessel. This information will be passed to the source vessel to assure that the source is operating correctly within the planned acoustic exposure range. The behavior of the tagged whales will be monitored closely from the observation vessel by a team of experienced marine mammal observers. This team will be led by Dr. Patrick Miller who is a highly experienced marine mammal behavioral biologist, whose expertise is whale behavior. Occasionally, we will follow a slightly different protocol to study the effect of ramp up itself. This protocol implies starting transmission at full power, but keep a constant distance to the animals.

Mitigation measures

1. Stay away from shallow areas and sensitive areas like harbor seals colonies.
2. Avoid working in areas where 'embayment' is possible, such as very close to the head of fjords.
3. If transmitting inside a fjord the source ship will move way from the fjord head towards the outlet.
4. During transmission there will be visual observers on the source boat, and on a secondary observation vessel placed close to the tagged animals.
5. A safe stand off range of 50 m will be established for LFAS transmission. If any marine mammal comes within this zone, transmission will be ceased.
6. Transmission will commence using a ramp-up, unless we are conducting control experiments to look at the effect of ramp-up itself.
7. A protocol for termination of exposure experiments if animals are in danger of getting injured is established.

3. Prevention of conflict with whale-watching activities

The main objective of the trial is to obtain information about the behavioral reactions of whales when exposed to sonar signals. This will give us a basis to assess how future naval exercises will affect whale watching activities. Our planned operating area (fig.1) overlaps with the whale watching area as reported to FFI by the whale watching companies (fig. 5).

The primary target species of whale watching in these areas are sperm whales and humpback whales. We will strive to avoid operating close to whale watching activities, particularly for early tests. When we have gained some experience with how the whales react to the sonar signals, we will consider if it is possible to operate closer to the whale watching activities without causing conflicts. The most important mean to prevent conflicts with the whale watching activity will be to establish good collaboration with the whale watching companies. We will try to establish good communication and have continuous dialog with them during the trial. In good time before commencing the experiments written information about the trial will be sent to the whale watching companies.

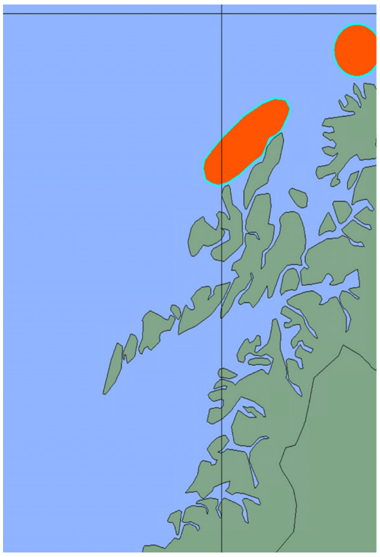

Fig. 5. *Whale watching area as reported by the local whale watching companies*.

4. Prevention of conflict with the fishing - and whaling fleet

The entire operation area is within the coastal catch area for the whaling fleet, and we will conduct the trial in the middle of the catch season. A main objective of the trial is to obtain information about the behavioral reactions of whales, including minke whales, when exposed to sonar signals. This will give us a basis to assess how future naval exercises will affect whaling. As a precautionary measure, we will try to keep a distance of 2000 m from whaling vessel in active pursuit during sonar transmission.

Based on historical catch data from the Directorate of Fisheries it is expected that there will be a moderate to high fishing activity in the operation area (fig. 6). The target species is mainly cod and halibut and the primary fishing gears are trawlers, long-line, nets and jigs. Based on knowledge of hearing curves and previous studies of acoustic sensitivity of different species of fish, it is expected that cod fish, halibut and herring will not be affected by the signals transmitted during the trial. Very little herring fishery is expected to take place during the trial. As a precautionary measure we will keep a 100 m distance from fishing vessels engaged in active fishing during sonar transmission.

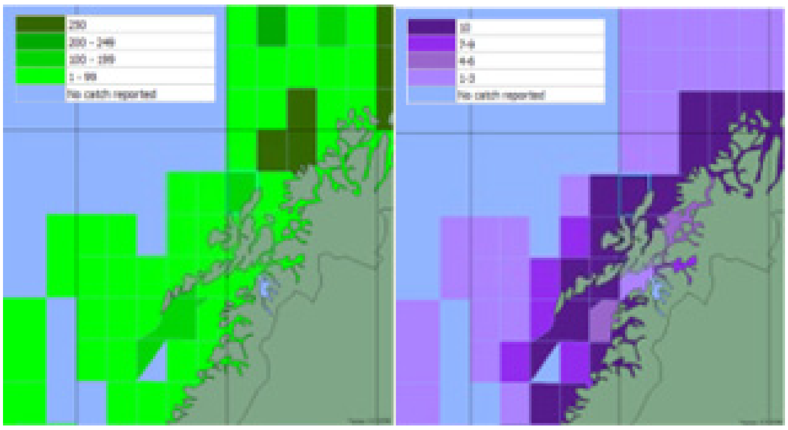

Fig 6. Expected fishery activity based on catch (left) and number of vessels (right) in the area. Maps are based on historical catch data from the last 3 years.

We will have a local fishery adviser on board, and his main task will be to communicate with the fishing and whaling vessels, and keep track of the most intense fishing and whaling areas.

5. Prevention of conflict with fish farms

There are numerous fish farms in the operation area (fig. 7). These are placed in shallow sheltered areas such as narrow straits and bays. This implies that we are unlikely to enter the proximity of any fish farms during transmission. The main concern with farmed fish is physiological stress, which might lead to reduced survival, growth or meat quality. According to the register of the Directorate of Fisheries the fish farms in the area contains cod, salmon and mussels. These species are not considered to be sensitive to acoustic signals in the relevant frequency band. They are not likely to detect the signals unless the source is in the immediate proximity of the farm. A standard 100 m stand off range from any fish farms is considered sufficient.

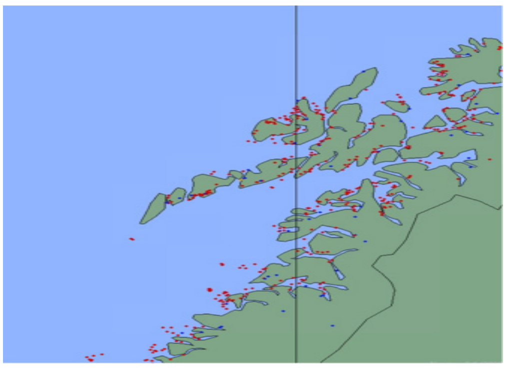

Fig. 7. *Fish farm concessions based on data from the Directorate of Fisheries.*

Incidents

Although we will use extensive safety measures, it is still possible that undesired events will take place. The trial is an animal experiment and as such it has been approved by the Norwegian Authorities for Animal Experimentation. The legal aspects is regulated through the Animal Welfare Act (Dyrevernloven) and the Regulation on Animal Experimentation (Forskrift om Forsøk med Dyr). Should stranded or injured animals be discovered in the operation area, we should seek to react as quickly as possible to identify the location of the animal, to assess whether any link with our sonar transmission is possible.

Marine mammal strandings:
Strandings of dead seals, porpoise and sperm whales are not uncommon in the operation area, while strandings of other large species are uncommon. All strandings should be treated as suspicious. Norway does not have an official stranding network, but if any link with our sonar transmission can not be excluded we should be prepared to assist with the stranding operation, and in the case that animals die, we should assist to get the animal quickly to a facility where good necropsy procedures can be carried out. The appropriate authority to contact is the local animal welfare authority (Mattilsynet/Viltnemd) and the local veterinary authorities (Distriktsveterinær). We have a pre-established contact with expert marine mammal pathologists at the National Veterinary Institute in Tromsø. They will advise us on how to prepare the necropsy, and assist us as soon as possible. All possible means will be applied to try to establish the cause of death

Injured marine mammals:
If any marine mammals are found injured during the trial, we will respond quickly to establish if our sonar transmission could be the cause of the injury. If any causal link between the injured animal and our activity can be irrefutable excluded, the local animal welfare authority (Viltnemd) will be notified, and they will take over responsibility. The responsibility of handling injured animals which are injured or could have been injured as apart of the exposure experiment lies with the permit holder. We have pre-established contact with veterinarians at the National Veterinary Institute in Tromsø, and in such an event they will be consulted. The local animal welfare authority will also be notified. In the highly unlikely event that an animal has to be terminated (put to death) in accordance with the Animal Welfare Act and the Regulation on Animal Experimentation, the decision to do so lies within the permit holder. He will contact a local whaling team and decide how the destruction should be done (large-bore rifle or harpoon canon). In a situation like this all possible means will be applied to try to establish the cause of the injury.

Responsibilities

Damage to third party
FFI will be fully liable for any damage arising out of and/or resulting from the performance of the experiment suffered by any third party.

Permit issues
Petter Kvadsheim (FFI) is the formal permit holder, and he is responsible for any issues related to the welfare of the experimental animal during the execution of the animal experiment. In addition to Kvadsheim, Lars KLeivane (FFI) and Patrick Miller (SMRU) are field operators and will also be responsible for permit compliance in the field.

Marine mammal and diver safety
The cruise leader (Petter Kvadsheim, FFI) is responsible for human diver and marine mammal safety issues.

Communication
The cruise leader (Petter Kvadsheim) has a superior responsibility for communication with

third parties, including relevant authorities, and between the different groups within the trial team. The chief scientists of the participating organisations are responsible for communication with their team members on relevant safety issues.

PR issues:
During the trial the field scientist cannot be expected to handle all public enquires and media contacts at all times. FFI has appointed on-shore point of contacts that will assist in handling these enquiries.

Other relevant documents

For more information on the execution of the experiments, please refer to Petter Kvadsheim (FFI) and the "3S-2009 Cruise Plan" (available at phk@ffi.no)

For more information on the objectives of the study please refer to Patrick Miller (SMRU) and the white paper proposal "Cetaceans and naval sonar: behavioral response as a function of sonar frequency" (available at pm29@st-andrews.ac.uk)

For more information on permits issues please refer to FFI for the permit documents from the Norwegian Authority for Animal Research (Forsøksdyrutvalget) (available at phk@ffi.no).

For more information on legal issues please refer to the Animal Welfare Act (Dyrevernloven) and the Regulation on Animal Experimentation (Forskrift om Forsøk med Dyr) (available at http://www.mattilsynet.no/fdu/regelverk).

For more information on NATO guidelines for sonar operations in the proximity of divers, please refer to NATO-URC "staff instruction 77" (available at http://192.106.197.208/solmar/PDF/77-04%20Marine%20Mammal.PDF).

For more information on the Royal Norwegian Navy's "Regulations for use of active sonar in Norwegian waters", please refer to the Joint Operational Headquarter (FOHK) at http://www.mil.no/fol/start/.

Contact information (removed in published version)

Name	e-mail:	office phone	cell phone

Appendix 3.

Cetaceans and naval sonar: behavior response as a function of sonar frequency

3S-09 Experimental trial

Observer's handbook

For marine mammal observers on observation ship

By Ana Catarina Alves, Patrick Miller, Fleur Visser & René Swift

This handbook supplements the 3S-09 cruise plan. If any instruction in this document is in conflict with the cruise pan, the cruise plan instruction has priority. All observers should <u>read</u> both documents before you come on board. It is very important that you are familiar with all the protocols.

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1 INTRODUCTION

1.1 AIM OF THE PROJECT

You will be participating on the third field trial of the research project to quantify the behavioral reactions of cetaceans to controlled presentations of military sonar signals at 2 different frequencies (1-2 kHz and 6-7 kHz), and relevant control sounds within Norwegian waters. This study will produce quantitative information on how cetaceans react to sonar and relevant control sounds. This information will then be used to establish safe operating procedures for allied Navies. Additionally we may also do some experiments to study the effectiveness of ramp-up procedures during military sonar exercises. The project involves an international team from Sea Mammal Research Unit (SMRU), Woods Hole Oceanographic Institution (WHOI), Norwegian Defence Research Establishment (FFI), and the Netherlands Organization for Applied Scientific Research (TNO). The project is being funded by the Norwegian and Dutch navies and the Office of Naval Research in the USA.

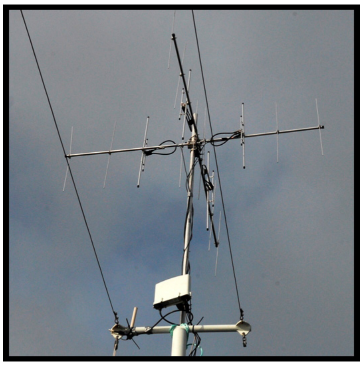
1.2 TARGET SPECIES

The primary target species for 2009 trial will be killer whales (*Orcinus orca*), long-finned pilot whales (*Globicephala melas*) and sperm whales (*Physeter macrocephalus*), since these were the species where more data was collected in the past field trial. It is very important to increase sample size for a more robust data analysis. Experimental trials will also be attempted on other species of interest as minke whales (*Balaenoptera acutorostrata*) and bottlenose whales (*Hyperoodon ampullatus*). We may also work with other species like harbour porpoise (*Phocoena phocoena*), white-sided dolphins (*Lagenorhynchus acutus*) and white beaked dolphins (*Lagenorhynchus albirostris*).

1.3 DATA COLLECTION

A D-Tag will be attached to the whales and record acoustic data, depth and the whale orientation (pitch, roll and heading). It will also transmit a VHF signal that will enable us to follow the whale and record additional data as whale position and behavior. An ADF system (Automatic direction finder) will be connected to the antennas placed on the highest point of the ship that detect the signal from the VHF antenna on the D-tag. The ADL system will give us an indication of where the signal is coming from in relation to the ship. This is particular useful if we loose visual contact with the tagged whale and when we need to recover the D-Tag after it comes off the whale.

All the additional data will be recorded using computer software Logger written for IFAW by Douglas Gillespie. Logger software is a windows application that records automatically the GPS position of the ship as well as other ships instrument data. Other data is recorded manually via a number of forms designated by the user. All data are stored in a Microsoft Access database from which they can be extracted for later offline analysis. Paper forms will be available in case of failure of logger software or the computer being used for data recording. Observers will also have to use appropriate paper forms to log information if a second different tag is deployed: the **LK-tag**.
This is because IFAW does not support the use of invasive techniques for animal studies, meaning that we can not use Logger software.



@Sanna Kuningas *@ Ana Alves*

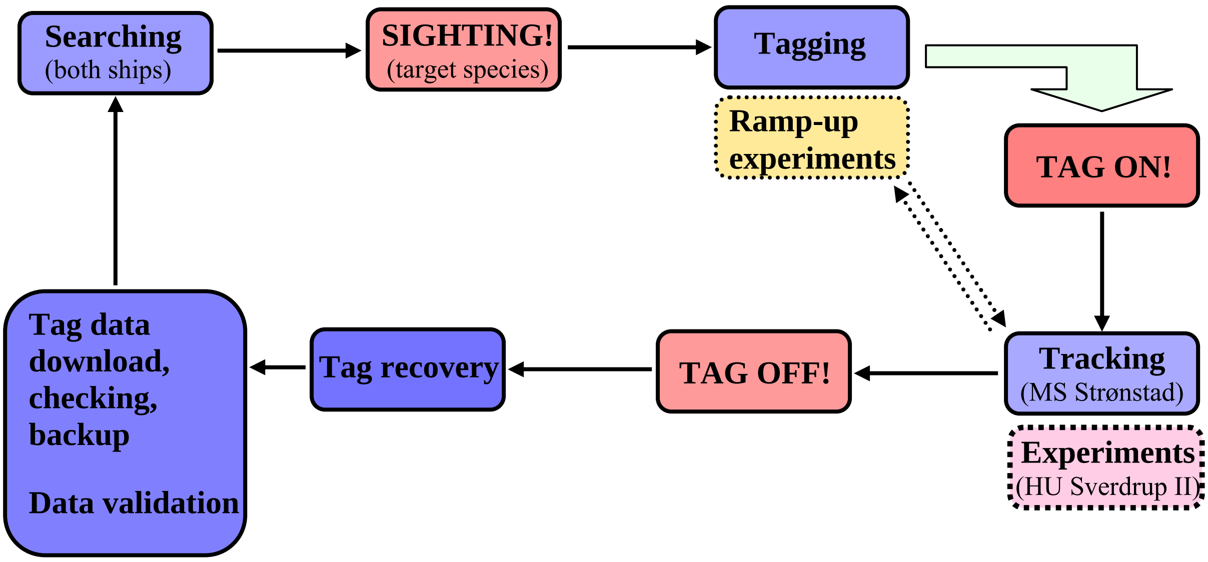
D-tag being deployed on a long-finned pilot whale and MS Strønstad antennas set up for capturing D-tag VHF signals.

2 3S-2009 CRUISE PROCEDURE

2.1 OVERVIEW OF CRUISE PROCEDURE

In this cruise two ships will be used: MS Strønstad, the main observation ship during the experimental trials, and HU Sverdrup II, the sonar source platform and where tag boats and tag teams will be accommodated. Each experimental trial is divided in 7 different phases that will be described below.

The diagram below shows an overview of the cruise procedure.



2.2 SEARCHING

During the searching phase both ships will be looking for the target species, visually with the aid of binoculars and acoustically with the aid of hydrophone arrays. Sightings of any other non-target species should be recorded as a single event. No resightings should be made on non-target species unless more accurate data needs to be added once the animals are closer to the ship. After logging the non-target species sighting, including doing some photographic documentation, the observer should resume its search for target species as soon as possible. The first ship sighting a target species should communicate to the other ship the occurrence and its current GPS position, in case the ships are out of sight of each other.

2.3 TAGGING

After sighting a target species one or two tag boats will be launched from HU Sverdrup II. Each tag boat will have a team using different methods for attaching the D-tag to the whale: pole and ARTS system. The time of deployment of tag boats should be recorded in logger in both ships. Both ships should give support to each of the tag boats in directing them to a group of whales and searching for other potential groups in case the one being worked by the tag boats reveals to be difficult to approach. To study the effects of tagging on the animals, observers from MS Strønstad are expected to, after choosing a group of animals (to where they will direct their tag boat to) track them before tag boats approach the group, during the tagging attempts and after, even if the tag boat team are not successful in tagging an animal of that group. Pre-tagging behavioral observations will not be done for sperm whales, as it is not feasible.

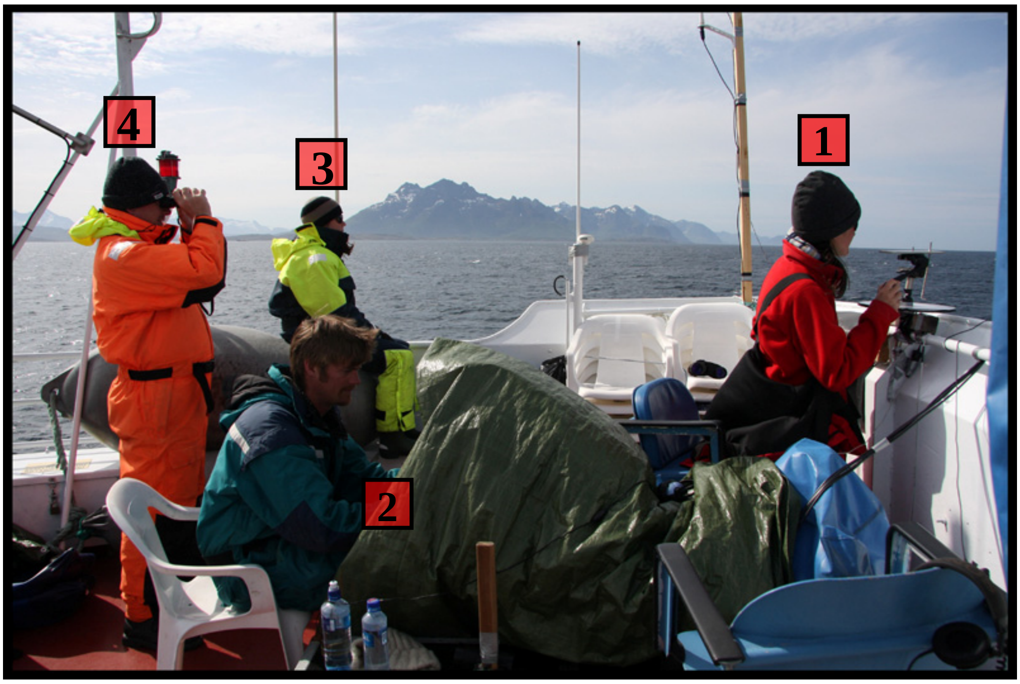
Each tag boat will have at least a team of three people: the ARTS/Pole tagger, the boat driver and someone in charge of photo-identifying whales and documenting all tagging events.

2.4 RAMP-UP EXPERIMENTS

If tagging seems to be impossible, we may switch to a non-tagged ramp-up experiment protocol. In these experiments we will be using the same tracking protocol but instead of a tagged whale we will try to follow a specific non tagged animal within a group of animals (or the group itself) or a solitary non tagged animal for one hour before HU Sverdrup II approaches up to a distance of 300m from the animal/group. At this point HU Sverdrup II will either do a ramp-up exposure or an exposure using maximum level straight away. The observers on the MS Strønstad should be blind to the experimental condition.

2.5 TRACKING

After attaching a tag on the whale, ship MS Strønstad takes the main role of tracking the tagged whale until the tag comes off the whale. The tracking phase is characterized by three different periods concerning the experimental trial: pre-exposure, exposure and post-exposure period. All observers in MS Strønstad will be kept blind to the experiment as long as possible to avoid biasing the behavior data. The general organization of the flying platform where all the tracking work happens can be seen on the image below.

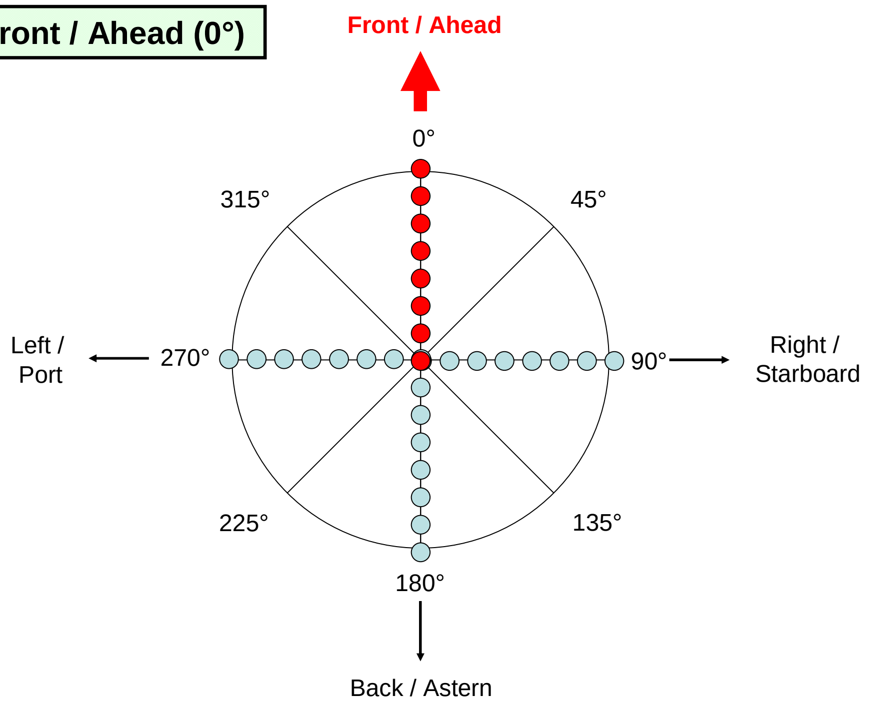


@Allan Ligon

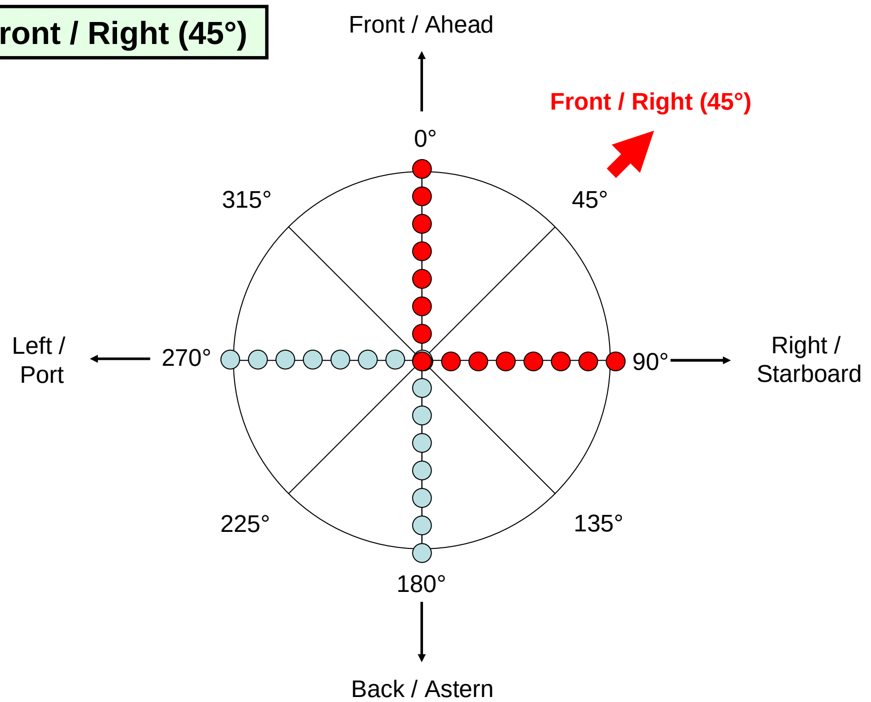
1- Tracker
2- Data recorder
3- Behavior observer
4- VHF/Photo-ID observer

The tracker observer will collect data like **angle**, **distance** and **aspect** to the tagged whale. In case more than one whale is tagged it should also inform the data recorder which tagged whale is being targeted. The data recorder will log all data in logger software, including name of observer's working on the flying platform during the experimental trial, and maintain visual contact with the ADF box offering guidance of where the tag VHF signal is coming from whenever is needed. The images below show how to interpret the information given by the ADF box. Red circles indicate where the red light in the box will show up in case the VHF signal is coming from the direction written on the top left of each image.

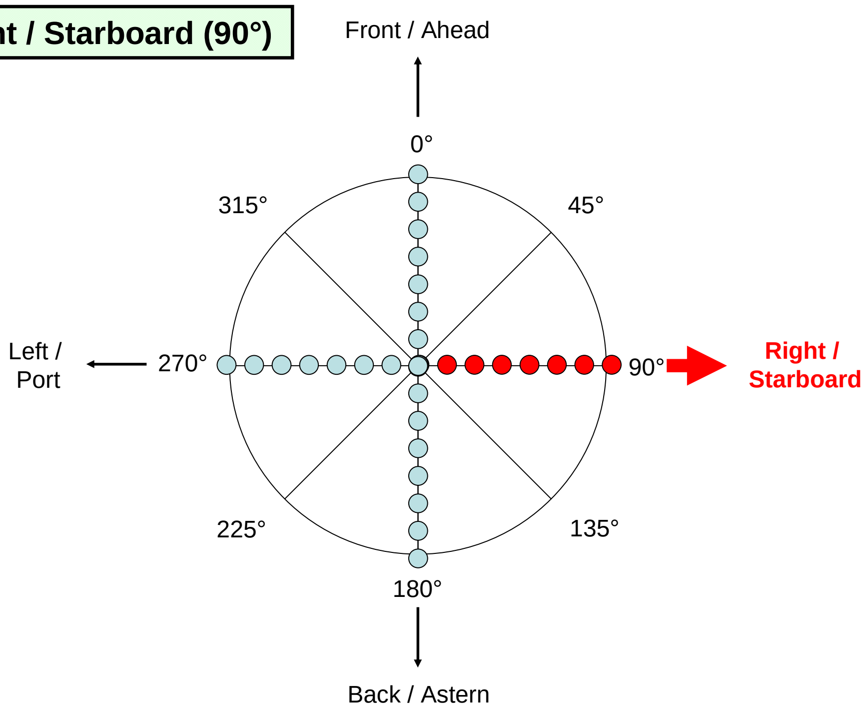
Front / Ahead (0°)



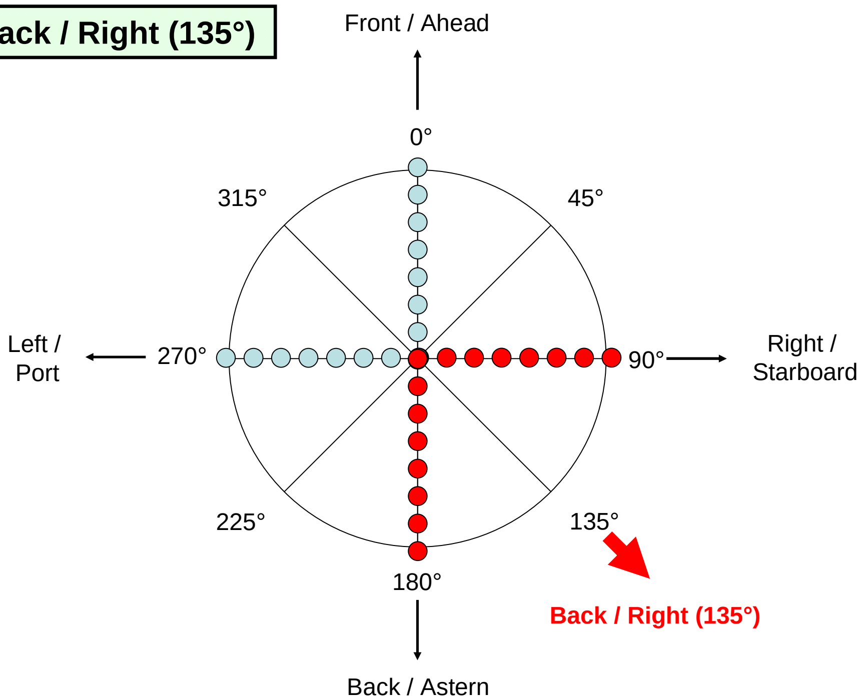
Front / Right (45°)



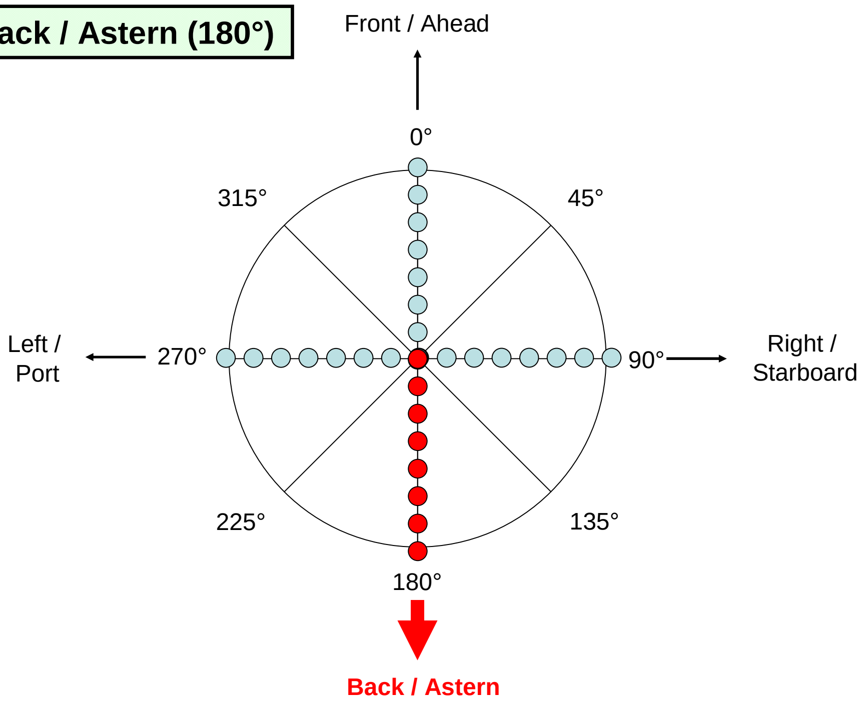
Right / Starboard (90°)



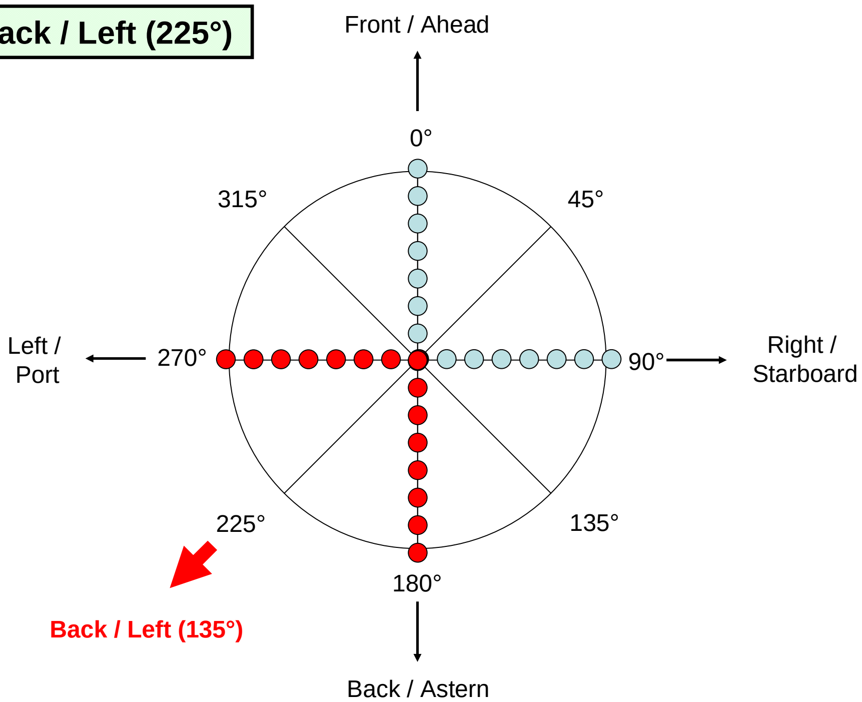
Back / Right (135°)



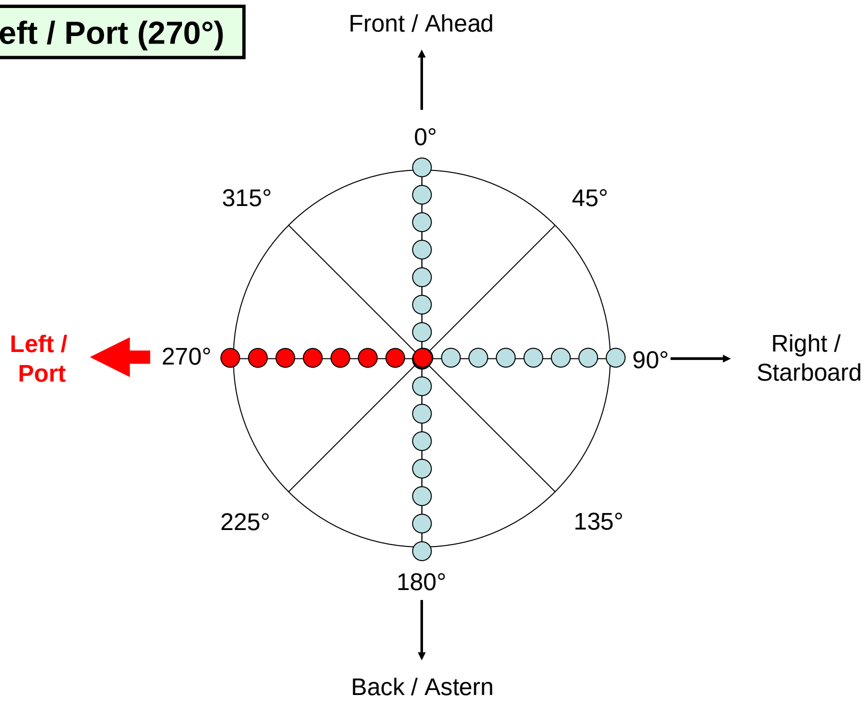
Back / Astern (180°)



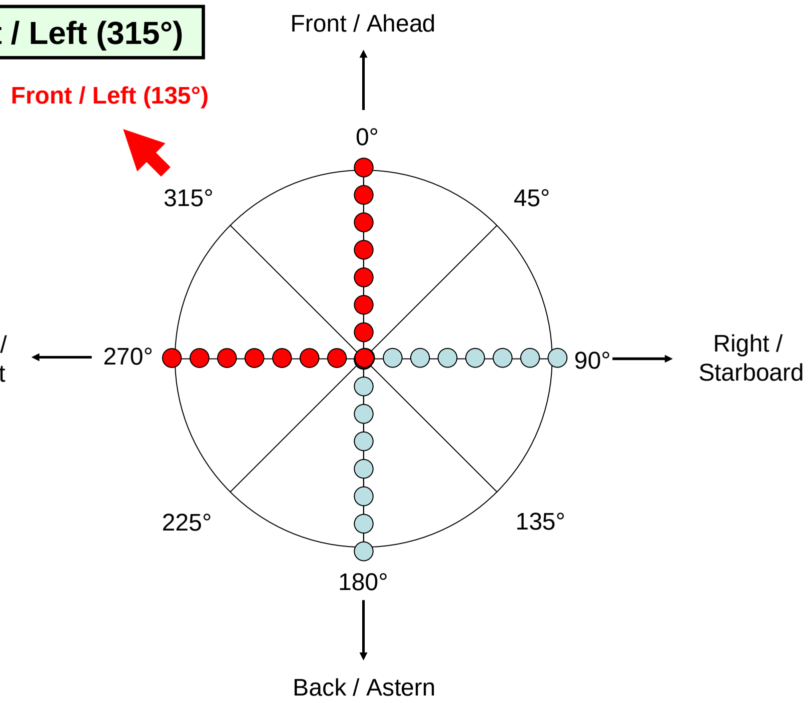
Back / Left (225°)



Left / Port (270°)



Front / Left (315°)



The behavior observer will collect data on the behavior of the sub-group/group where the tagged whale is present. The VHF/Photo-ID observer will keep regular contact with HU Sverdrup II to transmit the position of the tagged whale and give support to the behavior observer. This observer should also be ready to do more photo-identification in case of a close encounter of the ship with the whales.

2.6 VHF TRACKING INFORMATION

During the tracking phase you will need to fine tune the **gain**, **volume** and **dial** settings of the handheld VHF receiver. The gain, volume and dial knobs are found on the top of the VHF receiver.

a) **Gain**
You will need t adjust the gain relative to your distance from the tag.
Adjust the gain down as you approach the tag, and up as you move away from the tag.

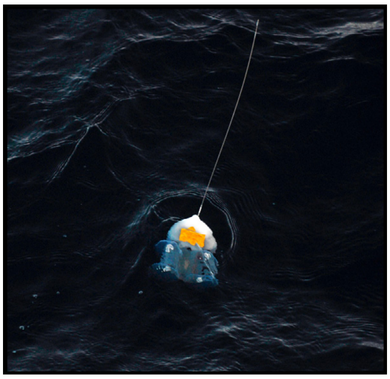
b) **Volume**
Adjust volume up and down to make the beeps more or less audible.

c) **Dial**
Adjusting the dial changes the tuning (frequency) of the VHF receiver very slightly and alters the pitch of the tag signal beeps making them more audible. This can be particularly important when there is a lot of background noise and interference. Adjusting the dial de-tunes the VHF and reduces the signal strength, so re-tune the VHF to the original tag frequency once you have establish/re-establish contact with the VHF.

The duty cycle of the DTag is 1 beep per second, while for the LK-Tags it is 4 beeps per second.

2.7 TAG RECOVERY

When the D-tag comes off the whale it floats on the water with its antenna up. This means that the observers will hear the signal coming from the tag with no interruptions (*e.g.* when whale is underwater the signal ceases). This is what will give the indication of "TAG OFF". All observers in the flying platform of MS Strønstad should help to locate the tag with the aid of the ADF system. In most cases a tag boat with portable antennas will be deployed to retrieve the tag.



@Ana Alves

D-tag floating after detaching from the whale.

2.8 TAG DATA DOWNLOAD, CHECKING AND BACKUP

At the end of each experimental trial data collected by the D-tag will be downloaded, each D-tag chip will be checked for any problems, and all data will be backed up. These tasks will be performed by Patrick Miller, Eva Hartvig, and Ricardo Antunes on HU Sverdrup II.

2.9 DATA VALIDATION

All data introduced into logger during experimental trials, in both ships, must be validated. All forms and entries in the database should be checked for any mistakes or unclear entries. For this reason it is utterly important to record **who was** the data recorder, tracker and behavior observer at **all times**, so we can go back to these observers in case of any unclear data and while all the events are still fresh in their minds.

2.10 DAILY REPORT

The daily report should be done by the two primary observers MMO I and MMO II on the observation ship (observers with fixed 6h shifts). This will give a tremendous help to remember things when we are back in the office and several months after the cruise has happened. Each observer should document events (for instance writing down on a note book they keep close to them) as they happen.

A folder with a word document named as, for *e.g.*, “MS Strønstad daily reports” will be created on the main computer (running logger) for observer’s to write down all their notes. Observer’s should do this as soon as they have the opportunity (for instance during searching periods) and not delay it until the very last day of the cruise. All entries should have **date** and **time** of the occurrence, **description** of it and **name of the observer** logging this information.

2.11 EFFORT/WEATHER REPORT

The two primary observers will be responsible to log information on effort and weather consistently. This should be done once every hour. If effort/weather conditions change within this hour the observers should log the new conditions.

3 3S-2009 CRUISE PROTOCOLS

3.1 COMMUNICATION ISSUES

1- A communication plan is defined in the cruise and this must be followed.

2- Communication to and from the tag boats must be limited as much as possible during active tagging and must be on the conditions of the taggers.

3- A list of all channels and in what circumstances each one is to be used should be displayed on the daily plan issued by the cruise leader.

4- During VHF communications between tag boats and ships the words “ON” and “OFF” should be used very carefully and should be clear the context in which they are being used.

5- Once tag boats have been deployed a second radio check should be performed with every ship when testing relevant tag frequencies (see tagging protocol). For safety reasons and before tag boats start their attempt to tag radio communications should be working properly.

3.2 SEARCHING PROTOCOL

1- As searching phase is weather dependent, there will be a colour code for operational status: green means "good operational status", yellow means "Borderline conditions" and red means "No working conditions". **Cruise leaders** on each ship will **make the decision** of what is the **operational status** following consultation with the primary observers and ultimate approval of the cruise leader on HU Sverdrup II. The cruise leader on the observation vessel will decide on how many observers should be on the flying platform according to the operational status and who is going to be called on duty based on advice from the primary observer on watch. These observers should also stay on duty even when colour code is yellow. This way when weather conditions improve there is someone on duty to report it to their cruise leaders that will then re-evaluate the operational status.

2- When spotting any cetacean you should log the sighting in logger and complete as many fields as you can on the sighting form. **Resightings** on **non-target species** should only be made **if** any relevant data (*e.g.* species identification or multi-species aggregation not seen initially) is identified after closing down the sighting form.

3- The first ship/observers that find a **target species** should **communicate immediately** to the other ship, and continue to follow the animals. This is especially important in the case where ships are out of sight of each other, to minimize the waiting time for one ship to move closer to the other.

4- In case any of the other **species of interest** are found, the animals should be followed. Observers should report it to their cruise leaders that in turn should communicate it to cruise leaders of the other ship and decide whether to attempt to tag those whales or not.

5- During the searching phase if logger has to be closed down for data validation, you should log any sighting information on the paper forms that will be provided. You will also have effort/weather forms, and behavior forms, in paper format.

3.3 TAGGING PROTOCOL

Before tag boats launch

1- Tag boat team should confirm all relevant tag frequencies and communicate them to observers in both ships. Observers should leave a note next to logger computer with information of which tag frequencies are on each tag boat.

2- Observers on each ship should choose a group of animals to track. These will be the group of animals that tag boats are going to be directed with the help of its "mother ship" to attempt to tag.

3- Observers on MS Strønstad should try to find a group with the presence of an individual with conspicuous characteristics to do behavioral observations.

4- Observers on MS Strønstad should track their group of animals or ideally a focal individual they have chosen for at least **30 minutes** prior to the approach by tag boats. The tracking methodology to be followed here is the same as when we have a tagged whale (see tracking protocol below). This is only expected to be done for the very first tagging attempt (first group of animals).

5- Observers should only **stop tracking** the group **30 minutes after** the tag boat team have chosen to move to a different group (when the tagging is unsuccessful). When you stop tracking you should do a last resighting of the group and write on the comments field "TRACKING FINISHED – NO TAG".

After tag boats launched

6- Time of deployment of tag boats must be logged in logger comments form in both ships.

7- Each tag boat should communicate to each of the ships to perform a check of all operational tag frequencies present on its boat and get a report or confirmation of signal strength and directionality (seen on the ADF box).

8- During the tagging phase signal strength and directionality of all tag frequencies should be checked by both ships at least twice every hour. If any problems are found, for *e.g.*, ADF box not working properly or no signal from the tag, these should be reported immediately to the tag boat with the tag in question.

9- Tag boats are expected to communicate to their "mother" ships whenever they want to move to a different group they have already targeted to give time for the ship to manoeuvre to the new group location.

10- The decision of how long tag boats will attempt to tag and when they should stop to rest and leave the whales to rest as well is up to the tag boat teams, via the cruise leader in HU Sverdrup II.

Once a tag has been deployed

11- Once a tag has been deployed ("TAG ON") the successful tag boat should communicate the deployment immediately to all units on the main VHF working channel. The other tag boat, the observers on the MS Strønstad and HU Sverdrup must all confirm having received that message. Information on GPS position, position of the tag on the whale, and any other relevant information of the attachment or characteristics of the tagged whale will be reported by the tag boat and recorded by the observers on the MS Strønstad.

12- The tag boat should stay close to the tagged whale for Photo-Id data collection, assess VHF signal and track the tagged animal until MS Strønstad observers have visual confirmation of the tagged whale and good VHF signal from the tag.

13- If MS Strønstad observers are still tracking a different group of animals (for the tagging effects study) when the tag boat successfully tags one animal, the second tag boat should hold any attempts to tag a second animal until the observers in MS Strønstad are tracking the tagged animal.

14- The second tag boat should attempt to tag another animal of the same sub-group/group. Second-tagging should only start once the MS Strønstad has started tracking the first tagged animal.

3.4 RAMP-UP EXPERIMENTS PROTOCOL

1- If tagging is judged to be impossible the cruise leaders on HU Sverdrup II may decide to go for a ramp-up experiment.

2- In this case we may decide to work with the primary target species that we have been unable to tag, or non-target species, including harbour porpoise, white-sided and white beaked dolphin.

3- The first ship/observer finding any species of interests for this experiment should communicate immediately to the other ship.

4- Upon the decision of proceeding with the experiments by the cruise leaders, MS Strønstad observers should start tracking a group of animals or ideally a focal individual.

5- When you start tracking you should do a new sighting event (new sighting number) and log on the comments field "BEGIN RAMP-UP EXPERIMENT PROTOCOL".

6- You should track the group of animals/focal individual until you hear from HU Sverdrup II that the experiment is over.

7- For ramp-up experiments you should follow the same tracking protocol as for a tagged whale (see tracking protocol below).

3.5 TRACKING PROTOCOL

1- As soon as you get a confirmation of a tagging success by the tag boat team, write down immediately on the comments form in logger "TAG ON" and all the information the tag boat team give you (tagging GPS position, tag position on whale, etc.). Please <u>DO NOT</u> write the words "TAG ON" in any other time on any other logger form <u>after</u> this event.

2- If observers in MS Strønstad are still tracking a different group for the tagging effects study, they should add to the comments form when logging the "TAG ON" the next sighting number in logger and that the initial tracking data will be done by the tag boat team on a paper form.

3- Tracker observer should do a fix (get info to be logged on logger) either on the tagged whale if you can see it, or on the tag boat that should be next to the tagged whale. The first fix on the tagged whale (or tag boat if close to the tagged whale) should **always** be a **new sighting event** (with a new sighting number), even if you have been tracking the group where the tagged whale was before.

4- You should however mention on the new sighting event (on comments field) if the tagged whale was on the group or the focal individual that was being tracked with the sighting number X, so that we know this group was being tracked for later analysis on the tagging effect.

5- When the tracker sees the tagged whale, he/she should shout "MARK" and get all the data required. The data recorder should press the button that opens a resighting form immediately after hearing the word MARK. The observers should always communicate the data to the recorder in the exact same order.

6- As soon as you spot the tagged whale and have a good fix on it inform the tag boat team so that they can leave the whales or attempt a second tagging.

7- At least 3 people should be at the flying platform to start tracking properly the tagged whale. If they are not it is the responsibility of the cruise leader on MS Strønstad to call to duty the necessary observers based on advice from the primary observers.

8- You should do a fix every 2 minutes as much as possible; meaning that after 1.5 minute from last fix you should do another one on next possible surfacing.

9- Data recorder should stay close to the computer ALL times to be always ready to log a fix. Data recorder and tracker observers should rotate at least every 1 hour.

10- If more than a whale is tagged take note on a paper which sighting number represents each tag frequency. Be clear on your notes and leave them visible next to the computer.

11- Also in the case of having more than one tagged animal, one tag will be the priority tag where we will track as frequently as it is stated on the protocol. The other tags will be tracked less frequently and in an opportunistically way.

12- ALL observers should stop working and be substituted at least after 6 hours of work. The only exception will be for the behavior observers that will follow a different shift rotation.

13- When observers rotate, especially the data recorder, they should handover all important information for the next observers, *e.g* any problems with equipment, any decisions made related to the tracking of the whale, clarification of sighting numbers and tag frequencies, etc.

14- If close proximity to the whales happens at any point, and if there is enough observers on the flying platform, one observer should try to get more photo-ID documentation. If possible from a lower level than the flying platform.

15- When the tag comes off the whale, the data recorder should log in the comments form “TAG OFF”. If more than a whale is tagged it should also report the tag frequency and resighting number.

16- After tag is off, and whenever we go back to search mode or off-effort mode, the observer with fixed shifts on duty should proceed to validate logger data. This is **very important** and should be done as soon as the opportunity arises.

3.6 BEHAVIOR RECORDING PROTOCOL

1- Determine the focal group and the focal subgroup: communicate with other observers and decide together.

2- Groups are defined as a set of individuals that interacts and/or shows coordinated activity in its behavior.

3- A subgroup is defined as a subset of individuals which form a denser, more closely organized formation within the whole group, forming a discrete unit (spacing from rest of group).

4- If there are subgroups present: always follow one subgroup, and not the complete group.

5- Focal group characteristics are recorded in the **sighting** form, as size and composition.

6- Take a note upon which characteristics the (sub) group was defined. This will be entered as a comment on the first **resighting** entry for that subgroup.

7- Only subgroup information is recorded in the **resighting** forms.
8- If group information needs to be amended, this should be entered in the **comment** field.

9- At the first sample of the (sub)group (on the first **resighting** form), call the values for all selected parameters;

10- From the second sample onwards, call the values for all parameters, except the all-event sampled surface displays. For those, only call the behavior and the number observed. If there are none, the behavior observer should say ´no events´.

11- The data recorder will enter the number of events in the correct category. When there are no events, the recorder will enter a zero in the BR1 category only. All blank cells mean that no data was collected, so a value should always be entered when sampling is occurring. If a behavior is deemed to be non-observable, this should be entered in the comments, and using the drop down menu if available.

3.7 ACOUSTIC RECORDING AND TRACKING PROTOCOL

1- The hydrophone array may be useful for searching, but it depends on the performance of the array at the desired search speed. Use during search is optional, and should be done by passing the acoustic signal to headphones on the flying bridge so a visual observer can listen for animal sounds.

2- The acoustic observer should work with the Strønstad crew to determine the engine speeds and propeller pitch angle that minimize underwater noise from the ship.

3- The array should be deployed, and recording started, immediately once the decision is made to attempt to tag an animal. Recording should continue continuously until the end of all work with that encounter.

4- A new "song" should be started on the Alesis recorder every hour. This assures that the data is preserved, and is **VERY** important. It is also important to start a new song just before each sonar transmission cycle, and to stop it just after the final "ping" is transmitted.

5- Whenever a song is started, the "0" time of the song to the nearest second should be recorded in the excel spreadsheet. This is done by carefully synchronizing the seconds shown on the recorder with a GPS or GPS-synchronized watch.

6- The acoustic observer should periodically check the real-time spectrogram and listen to the signal to assure that all is working well with the system.

When we decide to work with sperm whales

7- The acoustic observer will track sperm whales underwater using Pamguard software. This system provides bearing angles to click sounds, and requires specific training by the primary acoustic observer Ricardo Antunes. The acoustic observer should attempt to estimate the whales' underwater location every 10 minutes during tracking. That information should be stored as a PamGuard comment, and may be passed to the acoustic team on Sverdrup by VHF radio.

8- When tracking sperm whales, the driving of the ship is directed by visual observers when the target whale is visible at the surface, but is directed by the acoustic observer once the animal dives. Turns may be necessary to resolve the left-right ambiguity of the linear array.

9- When the animal flukes, the visual observers should immediately inform the acoustic observer at what relative bearing the animal fluked, and at what distance.

10- If the acoustic tracker is able to follow the animal through an entire dive cycle, he/she should inform the visual observers once it stops clicking. The acoustic tracker should inform the visual observers at what angle it stopped clicking, and estimate the distance to the animal.

3.8 DATA VALIDATION PROTOCOL

1- To validate logger data, you will have to stop running logger on the computer. This will only be possible to be done during the searching phase or when off-effort.

2- You should verify all logger forms: sighting, resighting, VHF, comments and if you still have time effort/weather, but this one is not the priority.

3- Within each form you should check all fields (columns and rows) for any mistakes.

4- You should open all the 3 main tables (sighting, resighting and comments) simultaneously. This way is easier to go through each record, since one or other record might be related to other entries in other tables (*e.g.* one comment entry can be related to a sighting, and of course the resightings will always be related to a specific sighting).

5- Here is a list of the most common problems in the past cruise:

   a. Resightings of non-existing sightings number
   b. Resightings of wrong sighting number
   c. Tag status missing
   d. Confusing comments

6- Resightings of non-existing sightings: it can either happen when the data recorder enters the wrong sighting number or records a sighting as a resighting without noticing. In the first case you can look at distance, angle and aspect of the resighting and compare with the values for the previous sightings and judge which sighting number makes more sense for the resighting values. The second case is more difficult, you can again compare with the last record for sighting/resighting and this time check also the GPS time for both occurrences. It is worth checking the comments as well.

7- Resightings of wrong sighting number: see above for when resightings of non-existing sightings happen due to entering the wrong sighting number.

8- Tag status missing: This happens whenever the data recorder forgets to tick the "Tag" box. In this case you should not change anything, unless there is strong evidence on the comments that we saw the tag on the whale.

9- Confusing comments: As an example it has happened that the data recorder instead of ticking the "Tag" box wrote on the comments "TAG ON". Again to confirm that is only a misunderstanding and that the whale was not tagged on that moment, you should check the previous records.

4 COMPLETING DATA FORMS

Data will primarily be recorded by the data recorder in logger software. Data recorder should fill out every field on every data form (including effort form), except when a sighting/resighting form was open by mistake. Even when some data is repetitive between resightings you should fill in all fields. When data is missing there is no way for us to know later whether that was because data recorder forgot to fill in or if it means is the same as in the previous record.

Paper forms will be used in case of logger software and/or computer failure, or if an LK tag is deployed on the focal animal. The data recorder will be responsible for logging on paper all data except for behavior, whose observer will have its own paper form, although they will be recording data at the same time with the same GPS coordinates. This means that tracker, data recorder and behavior observer need to be more focused and coordinated to get all the data at the same time.

Paper forms will have more fields than in logger (the computer records automatically some of the fields). For that reason during tracking phase the regularity of fixes may be adjusted accordingly to the time required by data recorder and behavior observer to record data on paper.

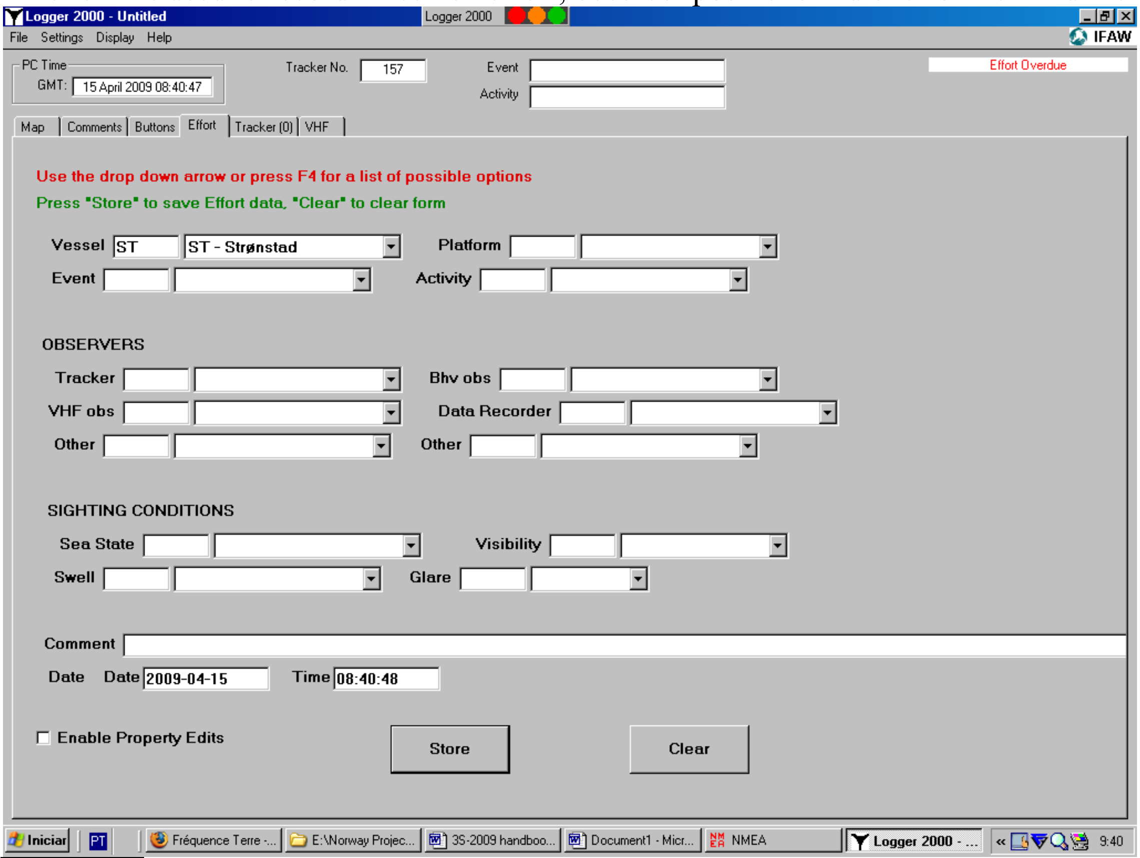
When filling in paper forms, write with soft pencil. An eraser should never be used. Make one line through the incorrect entry (do not obliterate the incorrect entry) and then clearly write the correct entry on the comment field.

Write NEATLY. Someone will have to read your handwriting. If necessary copy your entries onto a new data form to make them legible. Do this as soon as possible and not more than one day after the entry. Do not dispose the old form – attach it to the new form with a staple.

4.1 LOGGER FORMS

EFFORT/WEATHER FORM

This form is used to record all search effort, observer positions and environmental data.



Vessel Enter ship's code. This may already be filled in.

ST - Strønstad
SV - Sverdrup II

Platform Record the platform where the work is being carried on, using the following codes:

FLY - Flying bridge
BRI - Bridge
OT - Other (see comments)

Event Record the event using the following codes:

1 - Start search phase
2 - Tag boats launched
3 - Focal follow
4 - Start tracking
5 - End tracking
6 - Observer rotation
7 - Change platform
8 - End effort
9 - CTD/Plankton sampling
10 - Tag boat support

Activity Record the general activity using the following codes:

SP - Searching
PT - Pre-tagging
TAG - Tagging
TRA - Tracking
RUE - Ramp-up experiment
CT - CTD Stop
WB - Bad weather
OF - Off effort
TR - Transit

Observers Record the codes of the observers on watch.
During search phase fill in the observer codes in "Other" and "Data recorder".

Sea State Record the sea state on the scale 0-5, using code 5 for sea state >5.
The scale is as follows:

SCALE	DESCRIPTION	SEA STATE
0	Calm	Sea like mirror, surface only glassy.
0.5	Calm	A mix of glassy patches and patches with ripples.
1	Very light	No glassy patches, ripples with the appearance of scales, no wavelets.
2	Light breeze	Small wavelets.
2.5	Light breeze, well established	More pronounced wavelets. Crest well defined, but do not break. Rare white caps.
3	Gentle breeze	Large wavelets, crests begin to break. Always 1 to 5 white caps in one sector of view.
4	Moderate breeze	Small waves becoming longer, more frequent white caps.
5	Fresh breeze	Moderate waves of pronounced long form. Many white caps, some spray. STOP EFFORT.

Swell Record the swell height as described using the scale 0-6 or 9.

SCALE	SWELL	WAVELENGTH	HEIGHT
0	No swell		
1	Low swell	Short or average	<1 meter
2	Low swell	Long	<1 meter
3	Moderate swell	Short or average	<2 meters
4	Moderate swell	Long	<2 meters
5	Big swell	Short or average	2 – 4 meters
6	Big swell	Long	2 – 4 meters
9	Confused Swell	Pronounced swells from two or more direction.	

NOTE: Swell waves and sea waves are not the same, although both are produced by wind. Sea waves are generated by the local prevailing wind and vary in size according to the length of time a particular wind has been blowing, the fetch (distance the wind has blown over the sea) and the water depth. Swell waves are the regular longer period waves generated by distant weather systems and have their own direction away from the disturbance that produced them.

Glare Record the intensity of the glare according to the scale given below.

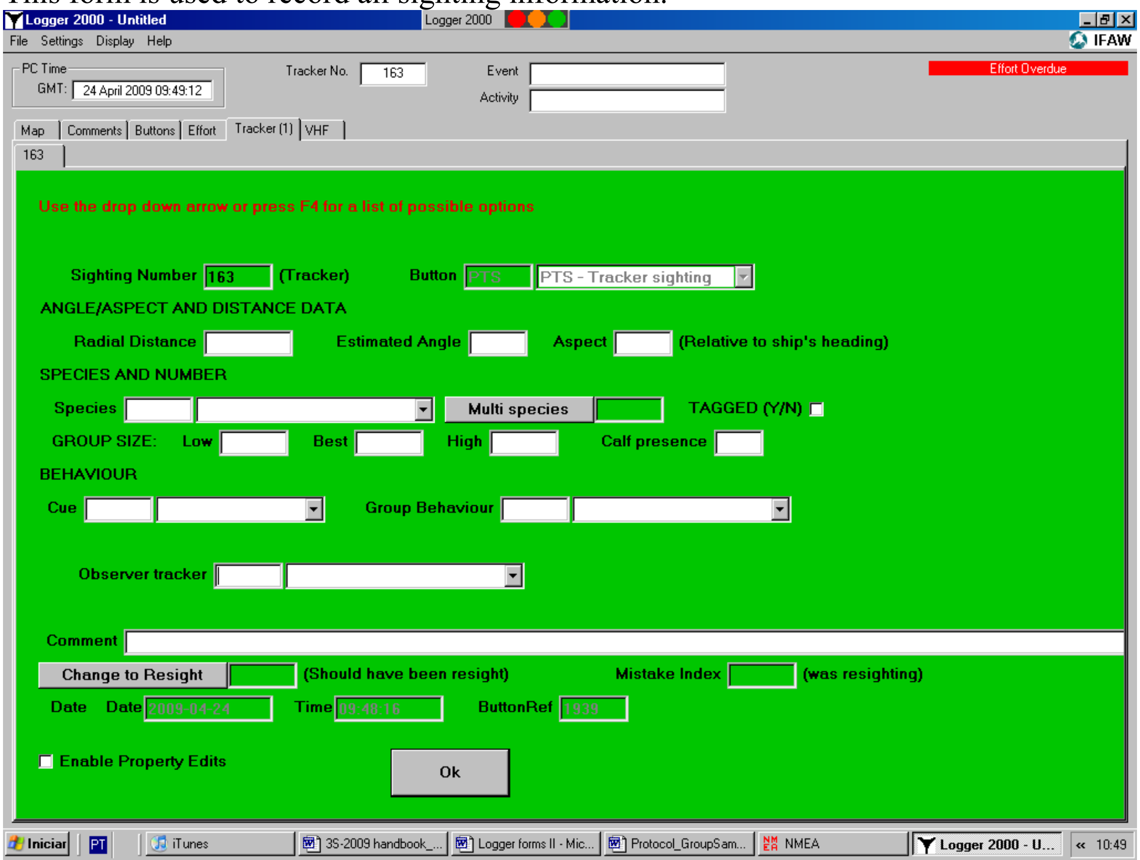
0 - No glare
1 - Mild, glare present but with minimal impact on sightability
2 - Moderate, glare present with some impact on sightability
3 - Severe, substantial or total affect on sightability

Visibility Record an estimate of how far you can see large objects at a distance using the following scale:

0 - Good	>5nm or >9km
1 - Moderate	2-5 nm or 4-9km
2 - Poor	1-2nm or 2-4km
3 - Fog	fog within <1nm or <2km

TRACKER SIGTHINGS FORM

This form is used to record all sighting information.



Sighting number This is the number of each sighting. It is assigned automatically when you open a sighting form.

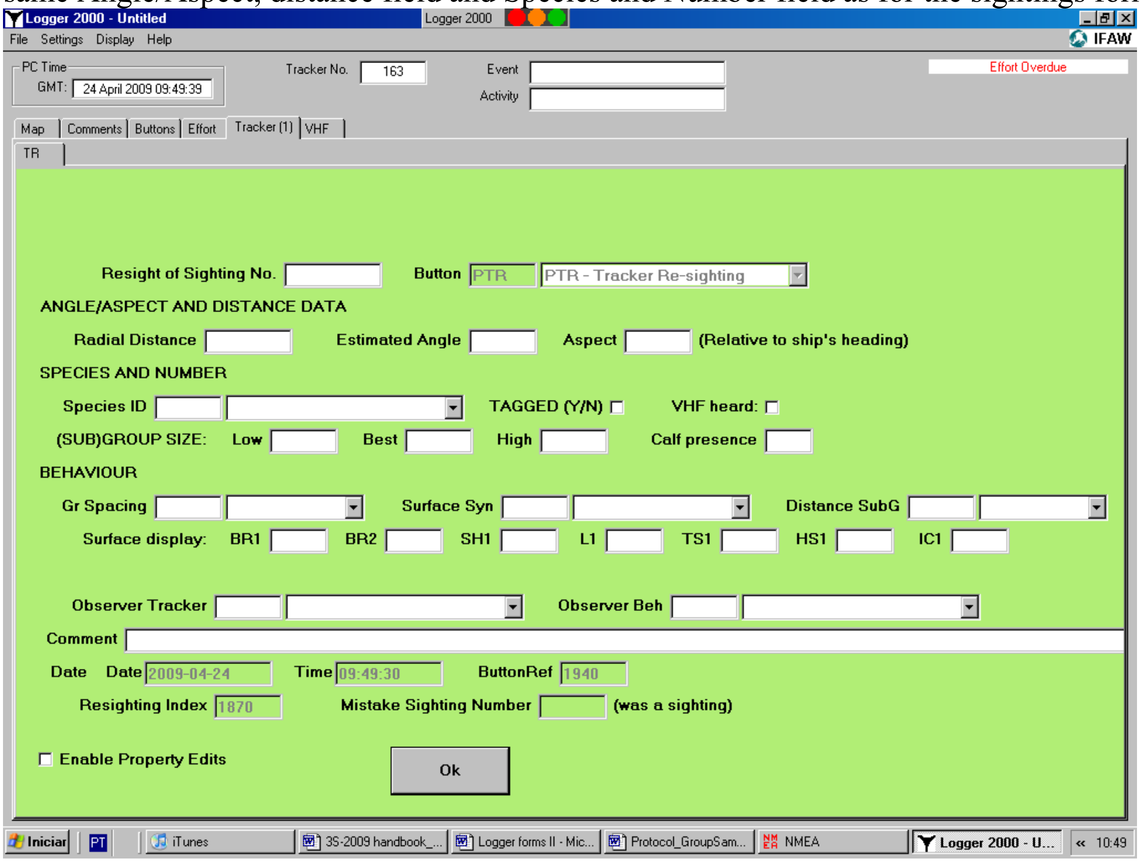
Radial distance	The estimate of radial distance, in meters, from the ship to the sighting at the time the sighting was made. Do not round the number.
Estimated angle	This is the estimated angle (to the nearest degree) from the bow of the ship to the sighting at the time the sighting was made. Use the angle board to record the angle. Do not round the number.
Aspect	Movement of the animal in relation to the ship. The aspect heading is recorded as an angle relative to the ship using the angle board, where: 0º - animal is moving directly away from the ship 90º - animal is moving left to right 180º - animal is moving directly towards the ship 270º - animal is moving right to left
Species	Record the species code. Record the species in the comment field if you can not find it in the code list. Inform also the primary observer.
Tagged	If the animal you are recording the sighting is tagged and tracker has seen the tagged tick the box.
Group size	Record the lowest, best and highest estimates of group size, including calves. In mixed species groups enter the number of each species. The best estimate is not necessarily the average of the lowest and highest estimates.
Calf presence	Record the the presence or absence of calves in the group, using size and behavior to recognize them. Enter 1 if there is any calves present and 0 if there is no calves present. Leave blank for no data, if sampling has not been done. If the number of calves can be counted reliably, record the number of calves present in the comments field, AND record '1' for calf presence.
Cue	Record the indicator, or cue, which led to the sighting. Record using the following codes: BY Body BL Blow JU Breach/Jump SP Splash SL Slick, "footprint" or ring FL Flash SB Sea birds AW Other associated wildlife (e.g. Fish) SD Sound

Behavior	Record the most dominant behavior observer within the group using the following codes:

SW Normal Swimming
MI Milling
BO Bow riding
AT Attracted to ship
AV Avoiding ship
BR Breaching
SS Slow Swim
FE Feeding
SO Socialising
PO Porpoising/Fast Swimming
LO Logging/Resting
OT Other

TRACKER RESIGHTINGS RECORD

This form is used to record all resighting information. The tracker resightings form has the same Angle/Aspect, distance field and Species and Number field as for the sightings form.



The specific fields for the resighting form are:

Resighting of sighting No	Type in the original sighting number of the resighting. This is important so that resightings can be matched to sightings.

VHF heard	Tick the box if you have heard the VHF signal. This is especially important when we hear the VHF but have not seen the tag on the animal or vice versa.

Group spacing	Record the category of group spacing for the focal group. Look at the spacing of the individuals in the group as a whole, and determine the average number of bodylengths which separate individuals in the group using the following codes:

GS1	Very tight	<1 Bodylength between individuals
GS2	Tight	1 to 3 Bodylengths between individuals
GS3	Loose	1 to 15 Bodylengths between individuals
GS4	Very loose	>15 Bodylengths between individuals
GS5	Subgroups	patchy, divided in subgroups
GS0	no data	can not be determined

Surface Syn	Record the category of synchrony for the focal group. Synchrony is determined by the percentage of group members displaying simultaneous surfacing, the same heading, speed, swimming mode and level of activity. Use the following codes:

Syn1	Highly synchronous activity at surface
Syn2	Moderate synchrony at surface
Syn3	Low OR no degree of synchrony
Syn0	No data, can not be determined

Distance SubG	Record the category for distance to the nearest other subgroup. Only take into account subgroups which are no more than 200 m from the focal group, as presence of groups at larger distances can not always be determined with certainty. Use the following codes:

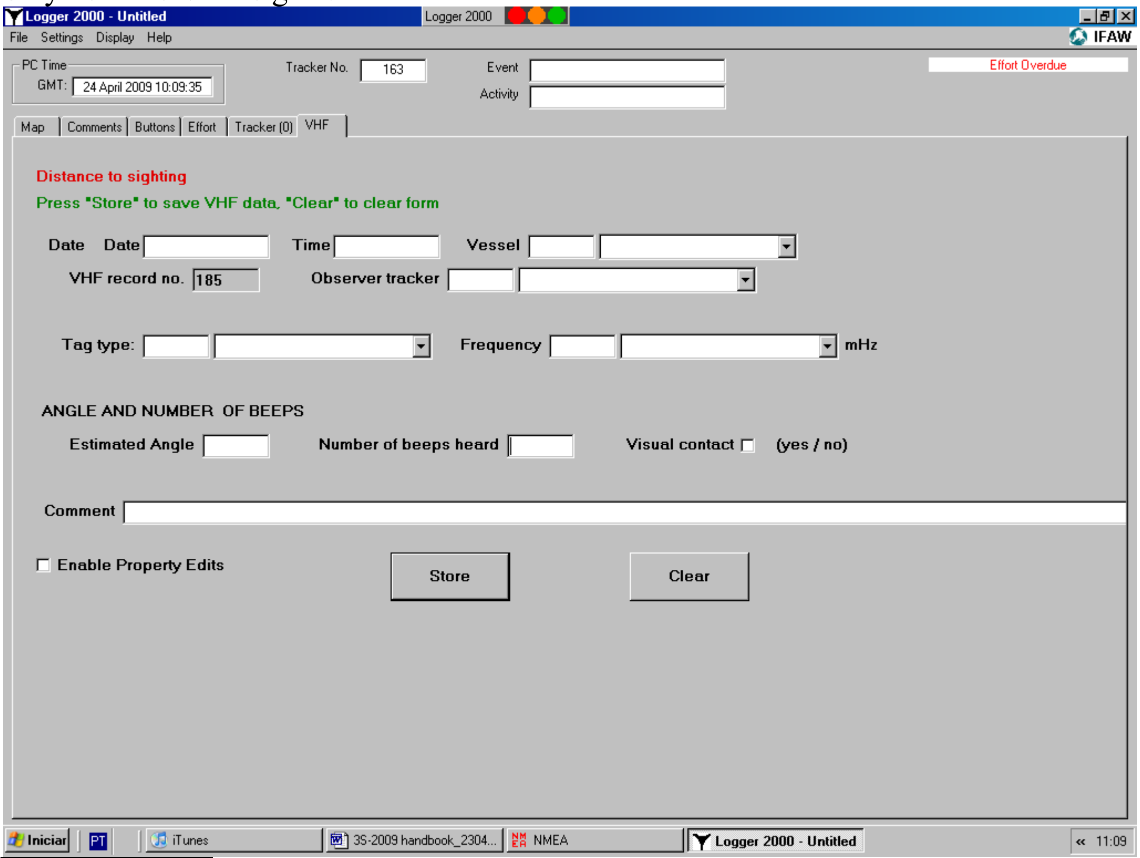
Dsg1	<10m	
Dsg2	10 - 50m	
Dsg3	50 - 100m	
Dsg4	>100m	
Dsg5	>>200m	No group within 200m from focal group
Dsg0	no data	Can not be determined

Surface display	Record the occurrence of event types, and the number of occurrences per event type. For 3S-2009 we will record:

BR1	Total Breach
BR2	Half breach (50% of body leaves water)
SH1	Spyhop
L1	Log
TS1	Tailslap
HS1	Headstand
IC1	Interaction (dramatic social interaction between ind. at surface)

VHF FORM

This form is used to record VHF signal information. It is important when observers loose the whale or sighting conditions are poor and we are unable to see the whale. In this case we can only hear the VHF signal.



Date & Time	Press F1 to update time and date automatically.
Vessel	Enter ship's code. This may already be filled in. ST - Strønstad SV - Sverdrup II
Observers	Record the codes of the observer.
Tag type	Record the tag type using the following codes: D - Dtag L - LK-tag S - Dummy Dtag
Frequency	Record the tag frequencies using the codes that will be provided at the beginning of the cruise.
Estimated angle	Record the estimated angle given by the interpretation of the ADF box red lights.

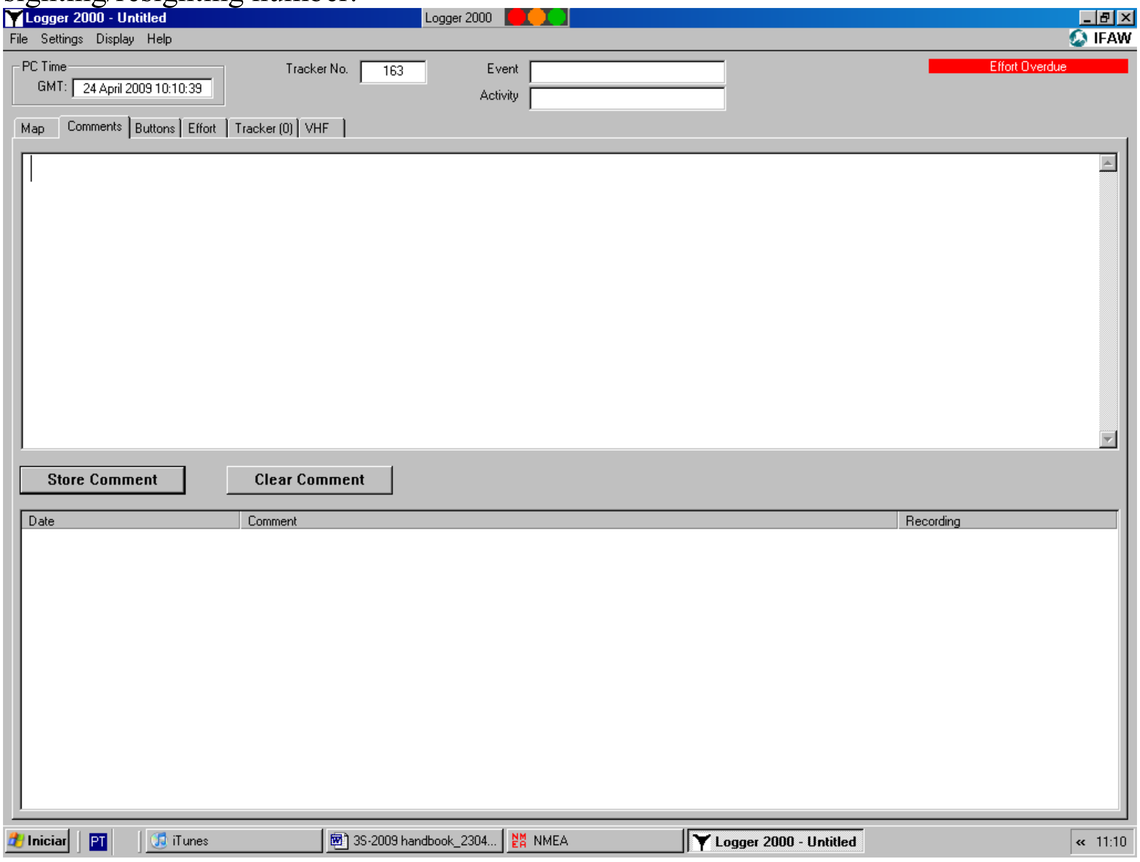
No# beeps heard — Record the number of beeps heard.

Visual contact — Record if any observer has seen the tag on the whale.

COMMENTS FORM

Use the comments form to log all the information requested on the protocols.

NOTE: Comments form is different from comments field. Every logger form has a comments field where you should record any relevant information concerning that specific sighting/resighting number.



4.2 PAPER FORMS

SIGHING/RESIGHTING PAPER FORMS

The sighting/resighting paper forms will have the same fields as in logger, with only some extra information that is usually recorded automatically by logger:

Vessel — Record the ship's code or name.

Date — Record the date as day, month and year, entering each as a two digit code. See example shown.

Date		
Day	Month	Year
01	05	2009

Time	Enter time as GMT. Record to the nearest second.

Latitute	Record latitude of the ship in degrees, minutes. Record the minutes to two decimal places. See the exemple shown.

Deg	Min
56	12.34

Longitude	Record Longitude of the ship in degrees, minutes. Record the minutes to two decimal places. Use E or W to denote East or West longitude. See the exemple shown.

Deg	Min	
10	30.45	
W		E/W

Resighting #	Record the number of times the animal/subgroup has been resighted by the tracker. After a new sighting the first time the animal/subgroup is seen again, the resighting number will be 1, the second time, 2 etc.

4.3 BEHAVIOR PAPER FORMS

Group Behavioral Sampling 3S-2009					Date:			Sighting #:	Tag-Freq:		
Resight #	TIME	SPECIES	SPAC	DIST	SURF-SYN	DISPLAY	#	VESSEL	BEH	DIVE	COMMENTS

The behavior paper form will have the same fields as in logger resighting form, and some of the extra information that is usually recorded automatically by logger, as date and time (see sighting/resighting paper forms).

The extra data fields for the behavior paper form are:

Sighting #	Record the original sighting number of the resightings recorded on this form.
Tag-Freq.	Record the Tag - frequency belonging to the tagged animal whose behavior is being recorded.
Resight #	Same number as for the resighting paper form.
Vessel	Record the number of vessels close to the focal animal/subgroup and the type (e.g. Tag boats).

4.4 LK-TAG PAPER FORM

On the LK-tag paper forms you will have to record all sighting/resighting and behavior information as you would do for a D-tag.

5 GENERAL GUIDELINES FOR OBSERVERS

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

Weather conditions will be the most limiting factor during the cruise. The project Cruise Leader (Petter Kvadsheim) and Principal Investigator (Patrick Miller) 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, and unless they last for several days, you will only have long hours of rest when weather conditions deteriorate.

Cruise methods and procedures have been fixed in advance, and need to be kept standardized with previous cruises. There is very little that can be changed without affecting the data being collected. If you can think of improvements, discuss them with the project 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. You will have several opportunities when not on duty to enjoy the wildlife.

Arrive at the working platform a few minutes before your shift begins. You are responsible for awakening in time for your shift (bring an alarm clock!) unless otherwise arranged.

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 leaders directly and openly as soon as possible. A delay may make matters worse or cause ill feeling between work colleagues.

It is good idea, especially for the non- Norwegian observers staying for the whole trial period (1 month), to bring you favourite food goodies (*e.g.* tea, coffee, chocolate, cookies, etc.), as you might not find the same thing/brand in Norway (especially in Northern Norway).

For observers staying in MS Strønstad, there won't be an internet connection. For both ships mobile phone network might be limited when inside fiord areas or inexistent for several days in row when in offshore areas.

Be prepared!

Good luck!